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Appendices

Regulatory Regime Changes Under Federalism: Do States Matter More?

Wayne B. Gray[1] and Ronald J. Shadbegian[2]
[1]Clark University, Worcester, MA; [2]University of Massachusetts-Dartmouth, North Dartmouth, MA

Our overall project examines factors affecting environmental performance, both compliance status and emissions for air, water, and toxic pollutants, as measured with plant-level data for paper mills, oil refineries, steel mills, and electric utilities. We combine data on traditional regulatory activity (inspections and other enforcement actions) with information on community pressures and political pressures faced by the plant at both the state and local levels. We also examine spatial aspects of regulation, by looking at the impact of enforcement activity directed toward one manufacturing plant on the environmental performance of other plants nearby, and the spatial distribution of the health benefits from sulfur allowance trading.

This research project examines the impact of the U.S. Environmental Protection Agency's (EPA) Cluster Rule on the paper industry, using data from 1996-2005 for 150 pulp and paper mills. This was a pathbreaking rule for EPA in its multimedia approach, as it sought reductions in both air- and water-toxic releases from affected plants, and also anticipated reductions in conventional pollutants. We use two approaches when looking to measure the impact of the Cluster Rule. We know the date when the rule became effective for the plant, so we test for changes in toxic releases around the effective date. The Cluster Rule also imposes different requirements for different plants, depending on their production technology, and we test for bigger changes occurring at plants that faced more stringent requirements. Our analysis also includes controls for other plant and firm characteristics. Besides testing for an impact of the Cluster Rule on air- and water-toxic releases, we examine conventional air and water pollutants to see if they exhibit reductions at about the same time. Finally, the paper also examines the possibility that location matters, testing whether differences across states in regulatory stringency before the adoption of the Cluster Rule affect either the level of toxic releases or reductions in those releases around the rule change.

Our analyses yield mixed results in terms of reductions in air and water toxics, the goal of the Cluster Rule. We observed significant reductions in releases of air toxics and total toxics around the rule's effective date, but not water toxics. In addition, those reductions do not seem to be larger at the plants expected to face greater stringency under the Cluster Rule. There also is little evidence of dramatic reductions in conventional air and water pollutants. However, we do find significant evidence for the importance of plant location, driven by state-level differences in regulatory stringency as measured by Congressional pro-environment voting in the state. Plants located in states with greater stringency had significantly lower toxic releases before the rule took effect, but a smaller reduction in toxic releases, which suggests that some of the reductions required by the Cluster Rule had already been accomplished in those high-stringency states. This emphasizes the importance of considering the "federal" structure of U.S. regulatory policy, with differences in stringency across states having implications for the impact of changes in regulatory policy at the national level.

The Persistence of Economic Factors in Shaping Regulation and Environmental Performance: The Limits of Regulation and Social License Pressures

Dorothy Thornton[1], Robert A. Kagan[1], and Neil Gunningham[2]
[1]University of California, Berkeley, CA; [2]Australian National University, Canberra, Australian Capital Territory, Australia

Many students of regulation, ourselves among them, have questioned models of regulation and business behavior that emphasize economic motives alone, and find instead that social pressures and social norms (relating to environmentalism and law-abidingness) play an important role in inducing businesses to comply with regulations and to go beyond compliance. This research project explores the limits of such “social license” pressures. Whereas our previous research focused on highly visible, closely regulated industries and on larger corporations, this project explores the limits of “social license” pressures by examining regulation of dangerous particulate and NO_x emissions from smaller heavy-duty diesel trucking companies that operate in highly competitive, minimally profitable markets and find it extremely difficult to afford or pass on the cost of best-available emission control technologies. We find that economic variables—most prominently the high cost of new, low-polluting vehicles—have: (1) limited the coerciveness of direct regulation of vehicle owners and operators (who have not been compelled or induced to retire older, higher polluting trucks); (2) dwarfed the reach and effectiveness of the governmental programs that subsidize the purchase of new vehicles; and (3) elevated the importance of each company’s “economic license”—as opposed to its “social license”—in shaping its environmental performance.

Company-level variation in environmental performance was assessed via in-depth field interviews of 16 small- and medium-sized trucking firms, 8 in Texas, and 8 in California. Social license pressures played virtually no role in shaping the firms’ choices that affect emissions (e.g., average age of fleet, maintenance practices, controls on operating speeds and idling). We find that intercompany variation on those dimensions are shaped primarily by: (1) the firm’s particular market niche—the kinds of goods being hauled, and how far they are being hauled; and (2) the firms’ financial state.

Oregon Business Decisions for Environmental Management

David E. Ervin[1], Patricia Koss[1], Madhu Khanna[2], and JunJie Wu[3]
[1]Portland State University, Portland, OR; [2]University of Illinois, Urbana-Champaign, IL; [3]Oregon State University, Corvallis, OR

We surveyed 1964 Oregon facilities in 2004-2005 regarding their business environmental management (BEM) actions, environmental performance levels, and other characteristics. The sample included construction, electronics, food and wood products manufacturing, transport, and accommodations—Oregon's major industrial sectors. The mail survey queried facilities about their motivations and barriers for environmental management, environmental policies, practices, performance data, and general characteristics. A response rate of 35 percent was achieved. Tests reveal that self-selection bias is not present.

Three analyses were conducted. In the first, we analyzed the motivations for facilities to participate in voluntary environmental programs (VEPs), and to adopt environmental management practices (EMPs). We used observed facility characteristics to proxy for the effects of external factors such as regulatory, consumer, and investor pressures, and internal factors such as technical and resource capacity on voluntary environmental behavior. Second, we examined the incentives that affect the intensity with which facilities implement EMPs and pollution prevention (P2) practices. This analysis tested the roles of internal drivers, including managerial attitudes toward the environment; external factors, such as regulation; perceived subjective pressures, such as investors; and objective factors captured by facility characteristics, such as ownership status. Third, we tested a new model of facility environmental management in which decisions on EMPs, P2 practices, and environmental performance (EP) are interlinked. This model hypothesizes that facility managers maximize their utility by considering the effects of BEM actions on profit and the values that they receive from environmental stewardship.

The results of all three approaches are generally consistent in showing the importance of regulatory pressures as well as managerial attitudes and perceptions that environmental issues are a significant concern in motivating participation in VEPs, adoption of EMPs, and use of P2 practices. We also found that larger facilities are more likely to participate in more VEPs, but are likely to adopt more EMPs only if they perceived environmental issues to be of significant concern. Facilities with this perception also were more likely to be influenced by competitive pressures to adopt more EMPs and P2 practices. Consumer and interest group pressures are found to play insignificant or weakly significant roles in voluntary environmental decisions. For the interlinked model, investor pressure also was found to positively influence EMP adoption. EMP intensity significantly increases P2 actions; however, EMP or P2 actions do not show significant effect on EP. EP, measured as the change in emissions and wastes in 2004, was positively influenced by 2003 BEM expenditures, parent company ownership, and mid-sized operations, but negatively affected by 2004 BEM expenditures and environmental penalties.

We conclude that environmental regulations are a complement to voluntary BEM, not a substitute. The findings also demonstrate the powerful role of management attitudes toward the environment in BEM decisions. These two factors, along with selected market forces and facility characteristics, significantly and differentially affect VEP, EMP, or P2 decisions. The findings suggest that effective policies must identify the most influential factors for the policy target, VEP participation, EMP adoption or EP, and the synergistic relationships between BEM decisions.

Future work will refine the interlinked model, improve measures of environmental performance, and explore the factors that shape management values toward the environment.

Pollution Prevention Practices: Determinants of Adoption and Effectiveness in Reducing Toxic Releases

Madhu Khanna[1], George Deltas[1], Satish Joshi[2], and Donna Harrington[3]
[1]University of Illinois, Urbana-Champaign, IL; [2]Michigan State University, East Lansing, MI; [3]University of Vermont, Burlington, VT

Many firms are undertaking environmentally friendly organizational change by applying the philosophy of Total Quality Environment Management (TQEM) with its emphasis on reducing waste and increasing efficiency. They also are voluntarily adopting technologies to prevent pollution at the source. The purpose of this research project is to examine whether and to what extent the adoption of TQEM is fostering pollution prevention (P2) activities and how the effect of TQEM differs across different types of innovations. We also examined the implications of P2 activities for the toxic release performance of firms.

These issues were investigated using a detailed panel dataset on P2 practices adopted by a sample of S&P 500 firms that report to the Toxics Release Inventory. We used two different approaches to examine the effect of TQEM on P2 practices adopted by firms. Under the first approach, we used a treatment effects model to examine the effects of TQEM, while controlling for a variety of other regulatory and market pressures that might be driving the adoption of such practices. Under the second approach, we classified the effects of TQEM based on five attributes regarding whether they involve: (1) a physical change in equipment; (2) a change in materials used; (3) a change in operating procedures; and whether they are (4) visible to consumers; and (5) enhance efficiency. We used fixed effects models to examine how the count of P2 activities are affected by TQEM adoption, and we took into account the differences in the nature of pollution prevention activities and that their response to TQEM adoption may vary, depending on their attributes. In examining the effect of P2 activities on toxic releases, we used panel data at the facility level to examine the effects of current and lagged P2 activities on toxic releases while controlling for inertia in the extent to which firms can improve environmental performance.

We found that TQEM leads firms to adopt P2 techniques even after we control for the effects of various types of regulatory pressures and firm-specific characteristics. Moreover, we found that the presence of "complementary assets," in the form of technical capability of the firm, is important for creating an internal capacity to undertake P2 adoption. However, we discovered that the effect of TQEM on P2 is nonuniform and provides stronger support for the adoption of practices that involve procedural changes or have unclassified/customized attributes. Visibility to consumers or efficiency enhancement does not incrementally contribute to the effect of TQEM on P2 adoption. Because the P2 activities most strongly affected by TQEM are generally more prevalent in the petroleum refining and chemical manufacturing sectors, our simulations showed that these sectors experience the largest impact from the adoption of TQEM on the rate of P2 innovation. Our analysis indicated that firms do experience diminishing returns to P2. Finally, we found that the effect of P2 on toxic release is rather weak and transitory. P2 activities adopted a year ago have a significant negative impact on current toxic releases, but P2 adoption in earlier years has a weakly positive or insignificant impact on current toxic releases. These findings suggest that although there exist some "low hanging fruit" for P2, the extent of voluntary adoption of P2 practices and their impact on toxic releases is likely to diminish over time in the absence of any regulatory stimulus.

Institutions for Removing Information Asymmetries in the Market for Corporate Environmental Performance

Ann Terlaak
University of Wisconsin, Madison, WI

The goal of this research project is to assess the conditions under which certification of environmental management practices removes information asymmetries between firms and stakeholders by credibly signaling about superior environmental performance. Issues that may limit the signaling ability of certification schemes include firm strategic behaviors that dilute the standard's value and design problems within management standards that cause "unwanted" firms to select into certification.

This project involves both conceptual and empirical analyses, with the empirical analyses using longitudinal datasets that contain information on certification with the ISO 14001 Environmental Management Standard as well as facility toxic releases.

Conceptual analyses suggest that the two unique elements of certified environmental management standards—codification and certification of practices—simultaneously enable and restrict the ability of standards like ISO 14001 to signal about superior environmental performance and guide socially desired firm behaviors. Although codification and certification are enabling because they allow a certified standard to shape firm behaviors in settings where other soft-law institutions are ineffective, they also are limiting because they induce a mix of both low- and high-performing firms to participate, thereby weakening decentralized enforcement processes and reducing the standard's signaling value.

Empirical analyses suggest that additional problems arise due to multi-plant firms engaging in strategic adoption behaviors. The issue is that standards like ISO 14001 may be designed to not only signal about existing performance levels but also improve on these levels. As a result of this improvement aspect, stakeholders may especially pressure poor performing firms to seek certification of ISO 14001, and adopting the standard may become a means for firms to assuage stakeholder demands. However, because of difficulties associated with fully internalizing the benefits of green firm practices, actual certification rewards are uncertain. Multi-plant firms may respond to this uncertainty by minimizing adoption costs through certifying their better performing plants, rather than their poorer performing ones. This selection is obviously not in the interests of stakeholders who would like the lowest performers to adopt and certify best environmental practices. The resulting situation may be described as multi-plant firms using ISO 14001 to engage in "satisficing adoption" that allows harvesting stakeholder approval with only minimal organizational changes.

To date, findings suggest that ISO 14001 has not been as effective as hoped for in that it neither is a reliable signal of superior environmental performance nor an improvement tool that substantially improves the performance of poor performing firms. Because these issues seem to be at least partially the consequence of the standard's design, solutions may require not only "patches" that ameliorate unwanted effects once they occur, but also standard redesigns.

Future work will focus on validating some of these insights by performing comparative analyses with the ISO 9000 quality management standard as well as broadening and triangulating measures of environment performance by using permit compliance data.

Evaluating Voluntary Climate Programs in the United States

Richard Morgenstern, William A. Pizer, and Jhih-Shyang Shih
Resources for the Future, Washington, DC

Voluntary programs are playing an increasingly important role in environmental management. Despite their growing importance, however, they have been subject to limited evaluation. As is well known, program evaluation in the absence of randomized experiments is difficult because the decision to participate may not be random and, in particular, may be correlated with the outcomes. The present research is designed to overcome these problems by measuring the environmental effectiveness of two voluntary climate change programs—the U.S. Environmental Protection Agency's (EPA) Climate Wise Program, and U.S. Department of Energy's Voluntary Reporting of Greenhouse Gases Program, 1605(b)—with particular attention to the participation decision and how various assumptions affect estimates of program effects. For both programs, the analysis focuses on manufacturing firms and uses confidential U.S. Census data to create a comparison group as well as measure outcomes (expenditures on fuel and electricity).

Overall, we found that the effects from Climate Wise and 1605(b) on fuel and electricity expenditures are no more than 10 percent and likely less than 5 percent. There is virtually no evidence of a statistically significant effect of either Climate Wise or 1605(b) on fuel costs. There is some statistically significant evidence that participation in Climate Wise led to a slight (3-5%) increase in electricity costs that vanishes after 2 years. There also is some statistically significant evidence that participation in 1605(b) led to a slight (4-8%) decrease in electricity costs that persists for at least 3 years.

Voluntary Agreements To Improve Environmental Quality: Are Late Joiners the Free Riders?

Magali Delmas and Maria J. Montes-Sancho
University of California, Santa Barbara, CA

Within the context of environmental voluntary agreements (VAs), this research project analyzes how free riding affects the effectiveness of collective corporate political strategies that aim at shaping government policy. We demonstrate that substantive cooperative strategies are more likely to be pursued by firms that enter a VA at its initiation, whereas free riding or symbolic cooperation is more likely to be adopted by late joiners. We also demonstrate that late joiners and early joiners within VAs adopt different cooperative strategies because they face different institutional pressures. We find that late joiners that cooperate only symbolically may endanger the overall effectiveness of a VA. Our analysis is based on the strategies of firms participating in the Climate Challenge Program established in 1995 by the U.S. Department of Energy and the representatives of the national electric utilities to reduce greenhouse gas emissions.

What Drives Participation in State Voluntary Cleanup Programs? Evidence From Oregon

Allen Blackman[1], Thomas Lyon[2], and Kris Wernstedt[3]
[1]Resources for the Future, Washington, DC; [2]University of Michigan, Ann Arbor, MI; [3]Virginia Tech, Blacksburg, VA

Over a quarter of a century after the passage of federal Superfund legislation, hundreds of thousands of properties contaminated with hazardous substances have yet to be remediated. To reduce this backlog, all but a handful of states have created Voluntary Cleanup Programs (VCPs) that offer liability relief, subsidies, and other incentives for responsible parties to voluntarily clean up contaminated properties. Today, thousands of sites are participating in these programs. Nevertheless, we still know little about the factors that drive enrollment, and information is needed to enhance the programs' efficiency and effectiveness.

This research project examines the factors that influence the decisions of both private firms and public organizations to participate in VCPs. The research has five components: (1) case studies of selected state VCPs; (2) a game theoretic model of a private actor's decision about whether to enroll in a VCP; (3) structured interviews of VCP program officials in each state; (4) a survey of VCP participants; and (5) econometric analyses of VCP participation in Oregon. We concentrated on the last component in this presentation.

Our econometric analysis focuses on Oregon because it has a program with sizable enrollment and is one of a small number of states that maintains a database of known contaminated sites that are not participating in its voluntary or mandatory cleanup programs. We employed a duration model that explicitly accounts for the timing of regulatory activities. In contrast to previous econometric research on VCPs, our results suggest that Oregon's program does not mainly attract sites with little or no contamination seeking a regulatory "clean bill of health." Furthermore, regulatory pressure—in particular, Oregon's practice of compiling a public list of sites with confirmed contamination—has a statistically significant association with VCP participation. Together, these findings imply that Oregon has been able to spur voluntary remediation by disclosing information on contamination. Our results comport with key themes in the literature on voluntary environmental programs—the threat of mandatory regulation spurs participation in such programs, and disclosure of environmental performance information is an efficient policy tool for promoting abatement and remediation.

The Consequences of Self-Policing

Sarah L. Stafford
College of William and Mary, Williamsburg, VA

Over the last decade, both the U.S. Environmental Protection Agency (EPA) and the states have placed increased emphasis on environmental auditing and self-policing as a means for achieving better environmental compliance. In particular, EPA's Audit Policy encourages facilities to self-police by offering significant penalty reductions for facilities that meet certain conditions. EPA's Web Site also notes that when facilities self-police, it can render "formal EPA investigations and enforcement actions unnecessary." This statement implies that EPA's Audit Policy may provide additional incentives in the form of reduced future enforcement. The goal of this study is to determine what the future consequences of self-policing are to be able to better understand how the Audit Policy or similar self-policing policies can affect facility compliance behavior. In addition, the analysis provides insight into other factors that motivate self-policing. A more complete understanding of the factors that drive facilities to self-police also will help to assess the effectiveness of the current policy and potentially can be used to fine-tune the program to increase its effectiveness.

To inform the empirical analysis, a theoretical model of self-policing was constructed in a targeted enforcement regime. The model suggests that facilities with a high probability of enforcement are more likely to disclose than facilities with a low probability of enforcement, *ceteris paribus*. The model also implies that disclosures in the recent past should decrease the probability of future inspections, and that the effect of disclosures on future inspections should depend on the facility's compliance history (i.e., whether or not they are in a target group).

The empirical analysis includes approximately 631,000 regulated hazardous waste facilities in the United States. The analysis examines the effect a disclosure in 2001 has on the probability that a facility is inspected in 2002. The analysis also examines what factors drive facilities to disclose. The most important finding is that facilities that self-disclose are rewarded with a significantly lower probability of inspection in the near future. There also is some evidence that the reward for disclosure is smaller for facilities with relatively good compliance records. This lends support to the concern that facilities could use the disclosure of minor violations strategically to discourage future inspections. The analysis also shows that facilities that have not been inspected over the past 5 years are less likely to disclose, whereas facilities that are inspected frequently are more likely to disclose, in part because they have more to gain from decreasing future enforcement efforts. Large- and small-quantity generators are more likely to disclose, as are facilities that are regulated under more than one media program. However, hazardous waste treatment, storage, and disposal facilities are less likely to disclose. Finally, facilities in states with environmental audit immunity or self-policing policies are more likely to disclose as such policies provide additional incentives for disclosure. Although the results of the analysis are obviously most relevant for EPA's Audit Policy, they also will provide important lessons on the use of self-policing as a regulatory tool in other policy arenas.

Green Production Through Competitive Testing

Erica L. Plambeck[1] and Terry A. Taylor[2]
[1]Stanford University, Palo Alto, CA; [2]University of California, Berkeley, CA

Electronics waste is damaging to the environment and human health, especially in developing countries. New regulations in the European Union, California, and China prohibit the sale of electronics containing certain hazardous substances. However, because testing for these substances is expensive and destructive of the product, regulators cannot test all or even a significant fraction of the electronics sold.

To the extent that regulators block the sale of products that they discover are noncompliant, electronics manufacturers have an incentive to test competitors' products and reveal violations to the regulator. A manufacturer benefits by blocking its competitor(s) from the market, because this makes the manufacturer's products more attractive to consumers, allowing the manufacturer to command a higher price in the end-market.

We found that in many cases, regulators need not test products directly, but instead can rely on electronics manufacturers to do all the testing. There are several reasons why relying on competitive testing can be attractive. First, manufacturers may have a better understanding than the regulator of how violations occur, and hence may be able to uncover violations with less testing expense than the regulator. Second, firms may have a better understanding of the cost of compliance. Consequently, the less well-informed regulator may devote a level of testing investment that may be too high or too low relative to what is socially optimal. In contrast, under competitive testing, testing and compliance expenditures will reflect what the firms understand to be the true costs of compliance, which may improve social welfare.

Relying on competitive testing is most effective in markets dominated by a few firms (e.g., video-gaming consoles) because these firms have the strongest incentives to test their competitors. Conversely, it is least effective in highly competitive markets (e.g., commodity-type consumer electronics) composed of many small firms.

The preceding discussion applies when the structure of the industry (i.e., the number of firms and their capacities) is fixed. The impact of competitive testing is more nuanced when long-run decisions such as entry are taken into account. Reliance on competitive testing causes entry and expanded production by manufacturers with low quality, weak brands and, consequently, low compliance. Thus, in industries where the barrier to entry for low-end firms is low, regulators should be cautious about relying on competitive testing.

The phenomenon of competitive testing has the potential to play out in any competitive market governed by product-based environmental, health, or safety standards, and our insights apply more broadly to these settings.

Disclosure as a Regulatory Instrument for the Environment: A Study of the Toxic Release Inventory in the Printed Circuit Board Industry

Linda T.M. Bui[1] ***and Jennifer Helgeson***[2]
[1]***Brandeis University, Boston, MA;*** [2]***University of Oxford, Oxford, England***

The objective of this research is to develop evidence of the impact on toxic releases of public disclosure of polluting behavior through the Toxic Release Inventory (TRI). We focused our attention on the printed circuit board (PCB) industry. PCB production is one of the largest contributors to pollution in the microelectronic industry, an industry that is rapidly changing in both market structure and technology. One interesting aspect of the industry is that the changes in market structure that have occurred—decreasing concentration and an increasing number of foreign producers competing on cost—would tend to make it less likely for the informal regulatory approach of the TRI to be successful. Yet reported toxic releases in the PCB industry have fallen by more than 96 percent between 1988 and 2003. Why? There are a number of factors that contribute to the explanation for the reduction in releases. In part, plant exit by the dirtiest plants over time has helped reduce the overall level of releases by the industry. However, this is not the only explanation. We found that non-attainment status for the criteria air pollutants also has an important effect. In particular, plants located in non-attainment counties have significantly lower TRI releases, which suggests that regulations for the criteria for air pollutants may have beneficial effects on toxic releases as well. We estimate that in the absence of non-attainment regulations, current TRI levels could be between 125 and 245 percent higher than they are currently. Formal regulations for hazardous air pollutants and pollutants falling under the Clean Water Act also appear to have had beneficial effects on TRI releases. However, we also find that facilities located in attainment counties eventually "catch up" with their non-attainment counterparts. Over time, the dirtier facilities located in attainment counties reduce their toxic releases until they are as clean as the facilities located in non-attainment counties. We interpret this as evidence that TRI reporting does have an effect on firm response. Furthermore, we found that state-level TRI programs that have target reduction goals for toxic releases induce significant reductions in TRI releases even without having noncompliance penalties. In the case of states that only have outreach programs to help TRI polluters learn about pollution prevention programs (e.g., for air releases), these programs also have a beneficial effect on release levels. These latter results are important as they provide policymakers with ways in which they can enhance the likelihood of a successful mandatory disclosure program for pollution abatement. First, by providing a credible threat of more formal regulation, firms respond by "voluntarily" cleaning up. Second, by disseminating information on pollution prevention and abatement, we also may see additional reductions in releases.

The Effectiveness of Information Disclosure: An Examination of the TRI

Madeleine Baker, Lori Snyder Bennear, and Michael Lenox
Duke University, Durham, NC

Controlling toxic chemicals is one of the most challenging tasks faced by environmental regulators due to the range of industries, number of chemicals, and variation in toxicity and exposure. These factors can make traditional approaches to regulation such as technology standards, performance standards, and market-based instruments (e.g., tradable permit systems) less attractive for toxic chemicals than for other pollutants. Information disclosure programs, such as the Toxics Release Inventory (TRI), are potentially innovative alternative regulatory instruments. To be considered a viable regulatory tool (as opposed to a general policy tool), the information disclosure program must result in improvements in environmental performance. In the case of the TRI, this means decreases in toxic chemical releases, toxicity of releases, and other similar measures. This research project seeks to determine the degree to which information disclosure itself results in improvements in environmental performance.

Analysis of the effect of the TRI in reducing releases of toxic chemicals has been hindered by the absence of a clear control group that can identify what would have happened to toxic releases in the absence of TRI reporting requirements. In typical analyses of regulatory efficacy, average outcomes for facilities that are subject to the regulation are compared with average outcomes for facilities that are not subject to the regulations. With the TRI, the difficulty lies in isolating a control group because the researcher only observes data on toxic releases for facilities that are subject to the regulatory reporting requirements, and only in years in which reporting has been in effect. Are observed decreases in toxic releases due to the disclosure requirements or due to other factors such as general changes in the industry or overall economy?

This research project tries to isolate the effect of information disclosure. We used changes in the TRI reporting requirements to help isolate the causal effect of disclosure from other potential explanations of changes in environmental performance. The TRI program has undergone several different changes in reporting requirements including: (1) requiring additional categories of facilities to report; (2) requiring reports for additional chemicals; and (3) lowering reporting thresholds for particular chemicals. In all three cases, one can think of “treatment” as being newly subject to the TRI requirements (e.g., a facility required to report for the first time or a facility reporting on a chemical for the first time). The “control” group then represents facilities that have reported previously.

At this workshop, we will present preliminary results from analyses of adding new chemicals and lowering reporting thresholds. We found no evidence that facilities newly reporting for a chemical have greater proportional decreases in total releases. Future work will examine whether these firms have different proportional decreases in onsite releases, have different proportional decreases in releases weighted by toxicity, or engage in more source reduction activities.

Regulation With Competing Objectives, Self-Reporting, and Imperfect Monitoring

Mary F. Evans, Scott M. Gilpatric, and Lirong Liu
University of Tennessee, Knoxville, TN

Our project entails a broad study of incentives for compliance with environmental information disclosure programs (e.g., the Toxic Release Inventory [TRI]), as well as consequent incentives to emit pollutants. We plan to address the optimal design of such programs with a focus on the incentives generated by alternative enforcement regimes.

Regulatory agencies, including the U.S. Environmental Protection Agency (EPA), commonly cite two categories of benefits associated with information disclosure programs. The first, an indirect benefit, arises from the internalization of the social costs of emissions (and consequent reductions in emissions) due to market responses to disclosures or regulatory instruments such as taxes on disclosed emissions. The second, a direct benefit, results from the disclosure of previously private information. Referring to information disclosure programs in a recent report that describes the U.S. experience with various environmental policies, EPA states, "The environmental information embodied in these approaches has economic value...even in the absence of any changes in emissions by firms." Timely information about emissions may enable potential damages to be avoided or mitigated both by affected parties and public agencies. For example, disclosure may reduce consumption of contaminated water by alerting individuals of the need for avoidance or proper treatment. Disclosure also may decrease the environmental impacts of a toxic release by accelerating cleanup efforts.

Our initial theoretical work models a firm's choice of emissions level and of disclosure (i.e., what share of actual emissions to report) as a function of a particular regulatory enforcement context. Firms are assessed a per-unit tax on disclosed emissions and a per-unit penalty on any undisclosed emissions that are subsequently detected by an audit. The audit is imperfect in that it reveals a percentage of actual emissions. After solving for optimal firm behavior as a function of the model's parameters, we examined the optimal choice of tax and audit probability by a regulator (taking other parameters as exogenously determined). When auditing firm behavior is costly, a policymaker must account for three factors when designing regulatory policy: (1) the benefit of reduced emissions arising from internalizing social costs; (2) the direct social benefit of disclosure of emissions that do occur; and (3) enforcement costs. Because disclosure of emissions is directly beneficial but actual emissions are imperfectly observable, policymakers face a trade-off between inducing truthful self-reporting and deterring emissions. Internalizing the social costs of emissions, such as through a tax, will deter emissions, but it also may reduce incentives for firms to truthfully disclose their emissions.

The next step in this research project involves incorporating the possibility of financial insolvency into the above model of firm compliance. Such a model will allow us to explore the potential for developing an endogenous audit process that depends on a firm's financial status. We will test the behavioral hypotheses from this model using experimental methods and secondary data analysis.

Competing Environmental Labels

Carolyn Fischer[1] and Thomas P. Lyon[2]
[1]Resources for the Future, Washington, DC; [2]University of Michigan, Ann Arbor, MI

We study markets in which consumers prefer environmentally friendly products but cannot determine the environmental quality of any given firm's product on their own. A nongovernmental organization (NGO) can establish a voluntary standard and label the products of firms whose products comply with the standard. Alternatively, industry can create its own standard and label. We compare the stringency of these two labels and analyze how they interact when both voluntary programs are available.

Consumer Labeling and Motivation Crowding-Out

Christopher D. Clark,[1] Kimberly L. Jensen,[1] Steven Yen,[1] Clifford S. Russell,[2] and Michael Hanemann[3]
[1]University of Tennessee, Knoxville, TN; [2]Vanderbilt University, Nashville, TN;
[3]University of California, Berkeley, CA

The primary objective of this research project is to explore consumer reactions to environmental product labels on market goods. This exploration will focus on two particular aspects of these reactions. First, consumer willingness to pay for the reduction of greenhouse gas emissions associated with the production of energy through the choice of either energy-saving products or the use of green energy and production processes will be estimated. Second, the effect that a product label based on an environmental attribute with both public and private benefits (e.g., emissions reductions and cost savings associated with more energy-efficient appliances) has on consumers will be contrasted with that of a label based on an attribute with purely public benefits (e.g., reduced emissions associated with a more energy-efficient production process and the use of renewable energy in such production). Research suggests that the inclusion of relatively small extrinsic rewards (such as cost savings from an energy-efficient appliance) can actually decrease the effect of existing intrinsic rewards (such as the internal motivation for consuming an environmentally friendly product). This effect, commonly referred to as motivation crowding-out, has important implications for the selection, design, and marketing of environmental attributes or labels.

The exploration of consumer responses will involve the use of conjoint analysis (contingent choice) surveys in which subsamples of respondents reveal their preferences in a series of comparisons between varieties of an energy-using home appliance. The appliance varieties will be distinguished by different levels of privately relevant attributes, including price, and also by whether or not they have obtained an environmental “seal-of-approval” label. The benefits associated with the label will vary across subsamples. In two subsamples, both private and public benefits (e.g., energy cost savings and emissions reductions) will be associated with the label, whereas only public benefits will be featured in the other two. The magnitude of the benefits will vary between a low and a high value and generate four separate subsamples.

We expect to find that: (1) respondent willingness to pay is, on average, increased by the existence of public benefits; (2) this increase is tied to demographic and attitudinal variables; and (3) this effect is increased by the addition of substantial private benefits, but reduced by the addition of a modest private benefit. The results of these experiments have the potential to influence both the design and marketing of a variety of information disclosure programs and to evaluate the potential of these programs for altering individual behavior.

To date, our efforts have focused on a comprehensive review of the literature and on survey instrument design. A large number of recent additions to the literature have caused us to think more critically about some of the principles underlying our analysis. The next step in this research project is to finalize the survey instrument through focus group analyses.

Voluntary Information Programs and Environmental Regulation: Evidence From "Spare the Air"

W. Bowman Cutter[1] and Matthew Neidell[2]
[1]University of California, Riverside, CA; [2]Columbia University. New York, NY

The primary goal of this research project is to assess whether individuals change their transportation choices in response to "Spare the Air" (STA) advisories, a public voluntary information program in the San Francisco Bay Area that elicits reductions in automobile trips on days when ground-level ozone is predicted to exceed Air Quality Standards (AQS). Because some of the emissions from automobiles are a direct precursor to ozone formation, this program intends to lower ozone levels and improve the chances of attaining AQS in order to avoid costly regulations.

The secondary goal of this project is to assess whether ozone levels are affected by any STA-induced changes in transportation decisions. STAs may be a more efficient mechanism than traditional regulations for lowering ozone levels because it allows policymakers to focus regulatory effort only on those days when the effort is needed to avoid exceeding ozone standards. Given that numerous areas throughout the country have since implemented similar voluntary programs, evaluating their impact is necessary to determine how these programs can best be incorporated into state and local efforts to meet AQS.

To assess the impact of STAs, we used administrative data on highway traffic volumes, public transit ridership, and observed ozone levels in the Bay Area. Because STAs are issued when ozone levels are predicted to exceed a particular threshold, we used a regression discontinuity design to identify the effect of STAs by comparing outcomes on days just above the threshold to outcomes on days just below the threshold. This design controls for confounding factors to the extent that they are similar around the threshold. Therefore, any difference in transportation outcomes can be directly attributed to the STA advisory. We also used traffic conditions in Southern California, an area without STAs, to estimate difference-in-differences models.

Our preliminary results suggest that STAs reduce total daily traffic by 2.5-3.5 percent, with the largest effect during and just after the morning commuting periods. STAs have no statistically significant effect on total daily public transit use, but they do have borderline statistically significant effects during peak commuting periods. STAs, however, do not have a statistically significant effect on ozone levels.

Our results cast doubt on the effectiveness of the STA program and, because the program has the best chance of working in an environmentally friendly area with several public transit alternatives, we suspect that comparable traffic programs elsewhere in the United States are unlikely to significantly improve air quality. The fact that individuals respond to STAs suggests that such voluntary information programs have a potential role in regulatory policy, but such programs alone do not appear sufficient for detecting improvements in air quality; additional incentives appear necessary.

National-Scale Activity Survey

Zachary Pekar[1], Carol Mansfield[2], and Susan Lyon Stone[1]
[1]Office of Air Quality Planning and Standards, Office of Air and Radiation, U.S. Environmental Protection Agency, Research Triangle Park, NC; [2]Research Triangle Institute, Research Triangle Park, NC

The National-Scale Activity Survey (N-SAS) will collect a variety of data related to the Air Quality Index (AQI) and the public's awareness of and response to air pollution in general, focusing initially on ozone with the potential for future waves focusing on particle pollution. N-SAS consists of two complementary surveys. The first is a cross-sectional survey measuring awareness, knowledge, and stated responses to air quality warnings. The second survey will collect activity diary data on a smaller sample of individuals in a specific area or areas to measure actual behavioral changes on high ozone days. The data collected through N-SAS will support outreach programs and policy analysis at EPA. The results of the survey will be useful for accountability initiatives and will enhance the design of informational-outreach programs such as the AQI, improving exposure modeling and benefits analysis.

Appendices

U.S. Environmental Protection Agency (EPA)
National Center for Environmental Research (NCER)
Environmental Behavior and Decision-Making: Corporate Environmental Behavior and Benefits of Environmental Information Disclosure

EPA Region 2 Offices
27th Floor, Conference Room A
290 Broadway Avenue
New York, NY

January 14–15, 2008

AGENDA

January 14, 2008, Corporate Environmental Behavior

8:00 a.m. – 8:30 a.m. **Registration**

8:30 a.m. – 8:45 a.m. **Introductory Remarks**
Kathy Callahan, Deputy Regional Administrator, EPA Region 2
Chris Saint, NCER, Office of Research and Development (ORD), EPA

Session I: Factors Influencing Corporate Compliance Behavior

Session Moderator: Joseph Siegel, EPA Region 2

8:45 a.m. – 9:10 a.m. **Regulatory Regime Changes Under Federalism: Do States Matter More?**
Wayne B. Gray, Clark University

9:10 a.m. – 9:35 a.m. **The Persistence of Economic Factors in Shaping Regulation and Environmental Performance: The Limits of Regulation and Social License Pressures**
Robert A. Kagan, University of California–Berkeley

9:35 a.m. – 9:45 a.m. **Discussant: Walter Mugdan, EPA Region 2**

9:45 a.m. – 9:55 a.m. **Discussant: Knute Jensen, New Jersey Department of Environmental Protection**

9:55 a.m. – 10:25 a.m. **Questions and Discussion**

10:25 a.m. – 10:40 a.m. **Break**

Session II: Environmental Management Systems (EMS)

Session Moderator: Nicoletta DiForte, EPA Region 2

10:40 a.m. – 11:05 a.m.	**Oregon Business Decisions for Environmental Management** *David E. Ervin, Portland State University; Madhu Khanna, University of Illinois at Urbana–Champaign*
11:05 a.m. – 11:30 a.m.	**Pollution Prevention Practices: Determinants of Adoption and Effectiveness in Reducing Toxic Releases** *Madhu Khanna, University of Illinois at Urbana–Champaign (Presented by David E. Ervin, Portland State University)*
11:30 a.m. – 11:55 a.m.	**Institutions for Removing Information Asymmetries in the Market for Corporate Environmental Performance** *Ann Terlaak, University of Wisconsin–Madison*
11:55 a.m. – 12:05 p.m.	**Discussant: Kathleen Malone, EPA Region 2**
12:05 p.m. – 12:15 p.m.	**Discussant: David Gunnarson, Lockheed Martin**
12:15 p.m. – 12:45 p.m.	**Questions and Discussion**
12:45 p.m. – 2:10 p.m.	**Lunch** (on your own)

Session III: Voluntary Climate Change Programs

Session Moderator: Irene Boland, EPA Region 2

2:10 p.m. – 2:35 p.m.	**Evaluating Voluntary Climate Programs in the United States** *Richard Morgenstern, William A. Pizer, Resources for the Future*
2:35 p.m. – 3:00 p.m.	**Voluntary Agreements To Improve Environmental Quality: Are Late Joiners the Free Riders?** *Magali Delmas, University of California–Santa Barbara*
3:00 p.m. – 3:15 p.m.	**Break**
3:15 p.m. – 3:25 p.m.	**Discussant: Joseph Siegel, EPA Region 2**
3:25 p.m. – 3:35 p.m.	**Discussant: John Cusack, Gifford Park Associates**
3:35 p.m. – 4:05 p.m.	**Questions and Discussion**

January 15, 2008, More on Corporate Behavior and Benefits of Environmental Information Disclosure

8:00 a.m. – 8:30 a.m.	**Registration**

Session IV: Hazardous Waste Management

Session Moderator: Barry Tornick, EPA Region 2

8:30 a.m. – 8:55 a.m.	**What Drives Participation in State Voluntary Cleanup Programs? Evidence From Oregon** *Allen Blackman, Resources for the Future; Kris Wernstedt, Virginia Tech*
8:55 a.m. – 9:20 a.m.	**The Consequences of Self-Policing** *Sarah L. Stafford, College of William and Mary*
9:20 a.m. – 9:45 a.m.	**Green Production Through Competitive Testing** *Terry Taylor, University of California–Berkeley*
9:45 a.m. – 9:55 a.m.	**Discussant: Carl Plossl, EPA Region 2**
9:55 a.m. – 10:05 a.m.	**Discussant: Larry Schnapf, Schulte Roth & Zabel, LLP**
10:05 a.m. – 10:35 a.m.	**Questions and Discussion**
10:35 a.m. – 10:50 a.m.	**Break**

Session V: Information Disclosure: The TRI

Session Moderator: Nora Lopez, EPA Region 2

10:50 a.m. – 11:15 a.m.	**Disclosure as a Regulatory Instrument for the Environment: A Study of the Toxic Release Inventory in the Printed Circuit Board Industry** *Linda T.M. Bui, Brandeis University*
11:15 a.m. – 11:40 a.m.	**The Effectiveness of Information Disclosure: An Examination of the TRI** *Lori Snyder Bennear, Duke University*
11:40 a.m. – 12:05 p.m.	**Regulation With Competing Objectives, Self-Reporting, and Imperfect Monitoring** *Scott Gilpatric, University of Tennessee–Knoxville*
12:05 p.m. – 12:15 p.m.	**Discussant: Dinah Koehler, NCER, ORD, EPA**
12:15 p.m. – 12:25 p.m.	**Discussant: Howard Apsan, The City University of New York**
12:25 p.m. – 12:55 p.m.	**Questions and Discussion**
12:55 p.m. – 2:15 p.m.	**Lunch** (on your own)

January 15, 2008, More on Corporate Behavior and Benefits of Environmental Information Disclosure (continued)

Session VI: Information Disclosure: Eco-Labeling

Session Moderator: John Filippelli, EPA Region 2

2:15 p.m. – 2:40 p.m.	**Competing Environmental Labels** *Carolyn Fischer, Resources for the Future*
2:40 p.m. – 3:05 p.m.	**Consumer Labeling and Motivation Crowding-Out** *Christopher D. Clark, University of Tennessee–Knoxville*
3:05 p.m. – 3:15 p.m.	**Discussant: Rabi Kieber, EPA Region 2**
3:15 p.m. – 3:25 p.m.	**Discussant: Marsha Walton, New York State Energy Research and Development Authority**
3:25 p.m. – 3:55 p.m.	**Questions and Discussion**
3:55 p.m. – 4:10 p.m.	**Break**

Session VII: Information Disclosure: Air Quality Information

Session Moderator: Joann Brennan-McKee, EPA Region 2

4:10 p.m. – 4:35 p.m.	**Voluntary Information Programs and Environmental Regulation: Evidence From "Spare the Air"** *Matthew Neidell, Columbia University*
4:35 p.m. – 5:00 p.m.	**National-Scale Activity Survey (N-SAS)** *Zachary Pekar, Office of Air Quality Planning and Standards, EPA; Carol Mansfield, RTI International*
5:00 p.m. – 5:10 p.m.	**Discussant: Bill Baker, EPA Region 2**
5:10 p.m. – 5:20 p.m.	**Discussant: Andy Darrell, Environmental Defense**
5:20 p.m. – 5:50 p.m.	**Questions and Discussion**
5:50 p.m. – 6:05 p.m.	**Final Remarks** *Dinah Koehler, NCER, ORD, EPA* *Chris Saint, NCER, ORD, EPA*
6:05 p.m.	**Adjournment**

U.S. Environmental Protection Agency
National Center for Environmental Research
Environmental Behavior and Decision-Making: Corporate Environmental Behavior and Benefits of Environmental Information Disclosure

EPA Region 2 Offices
27th Floor, Conference Room A
290 Broadway
New York, NY

January 14-15, 2008

POST-PARTICIPANTS LIST

Nancy Anderson
The Sallan Foundation

Howard Apsan
The City University of New York

Winifred Armstrong

Madeleine Baker
Duke University

William Baker
U.S. Environmental Protection Agency

David Bend
U.S. Environmental Protection Agency

Lori Bennear
Duke University

Joseph Bergstein
U.S. Environmental Protection Agency

Natasha Besch-Turner
U.S. Environmental Protection Agency

Allen Blackman
Resources for the Future

Irene Boland
U.S. Environmental Protection Agency

Peter Brandt
U.S. Environmental Protection Agency

Joann Brennan-McKee
U.S. Environmental Protection Agency

Robert Buettner
U.S. Environmental Protection Agency

Linda Bui
Brandeis University

Kathy Callahan
U.S. Environmental Protection Agency

Chantalline Carpentier
United Nations

Dan Ciobanu
U.S. Environmental Protection Agency

Chris Clark
University of Tennessee, Knoxville

Marjorie Clarke
City College of New York

John Cusack
Gifford Park Associates

Andy Darrell
Environmental Defense

Fabio de Castro
Springer

Magali Delmas
University of California, Santa Barbara

Rachel Deming
Scarola Ellis LLP

Nicoletta DiForte
U.S. Environmental Protection Agency

Christine Ervin
Christine Ervin Company and Greener World Media

David Ervin
Portland State University

Mary Evans
University of Tennessee, Knoxville

Carmela Federico

John Filippelli
U.S. Environmental Protection Agency

Carolyn Fischer
Resources for the Future

Maya Fischhoff
Michigan State University

Linda Forbes
Franklin and Marshall College

Scott Gilpatric
University of Tennessee, Knoxville

Lorraine Graves
U.S. Environmental Protection Agency

Wayne Gray
Clark University

David Gunnarson
Lockheed Martin

Jan Hagiwara
U.S. Environmental Protection Agency

Chris Haun
New Jersey Board of Public Utilities

Charles Hernick
The Cadmus Group

Jane Hwang
Social Accountability International

Robert Kagan
University of California, Berkeley

Matthew Keene
U.S. Environmental Protection Agency

Chuck Kent
U.S. Environmental Protection Agency

Rabi Kieber
U.S. Environmental Protection Agency

Yehuda Klein
City University of New York Graduate Center

Lingard Knutson
U.S. Environmental Protection Agency

Dinah Koehler
U.S. Environmental Protection Agency

Mary Ann Kowalski
U.S. Environmental Protection Agency

Daniel Kraft
U.S. Environmental Protection Agency

Richard Krauser
U.S. Environmental Protection Agency

Cho-Yi Kwan
U.S. Environmental Protection Agency

Anthony Lacey
Inside Washington Publishers

Nora Lopez
U.S. Environmental Protection Agency

Joseph Malki
U.S. Environmental Protection Agency

Kathleen Malone
U.S. Environmental Protection Agency

Karl Mangels
U.S. Environmental Protection Agency

Carol Mansfield
RTI International

Sabine Marx
Columbia University

Maureen McGuigan
Virginia Tech

Peter Meyer
University of Louisville

Rachel Miller
RiskMetrics Group

Michael Moltzen
U.S. Environmental Protection Agency

LaTeisha Moore
Return on Good

Richard Morgenstern
Resources for the Future

Walter Mugdan
U.S. Environmental Protection Agency

Matthew Neidell
Columbia University

Andrew Park
U.S. Environmental Protection Agency

Angie Park

Barbara Pastalove
U.S. Environmental Protection Agency

Mel Peffers
Environmental Defense

Zachary Pekar
U.S. Environmental Protection Agency

William Pizer
Resources for the Future

Carl Plossl
U.S. Environmental Protection Agency

Matt Polsky

Irene Purdy
U.S. Environmental Protection Agency

Zeyuan Qiu
New Jersey Institute of Technology

Venkata Rao
U.S. Environmental Protection Agency

Danielle Ravich

Elias Rodriguez
U.S. Environmental Protection Agency

Eirik Romstad
Norwegian University of Life Sciences

Fernando Rosado
U.S. Environmental Protection Agency

Sandra Rousseau
Center for Economic Studies

Chris Saint
U.S. Environmental Protection Agency

Lynn Sanguedolce
ExxonMobil

Lawrence Schnapf
Schulte Roth & Zabel, LLP

Walter Schoepf
U.S. Environmental Protection Agency

Frank Scotto
U.S. Environmental Protection Agency

Joseph Siegel
U.S. Environmental Protection Agency

Jon Silberman
U.S. Environmental Protection Agency

Timothy Smith
University of Minnesota

Sarah Stafford
College of William and Mary

Carol Stein
U.S. Environmental Protection Agency

James Sullivan
U.S. Environmental Protection Agency

Stephan Sylvan
U.S. Environmental Protection Agency

Terry Taylor
University of California, Berkeley

Ann Terlaak
University of Wisconsin, Madison

Jennifer Thatcher
U.S. Environmental Protection Agency

Barry Tornick
U.S. Environmental Protection Agency

David Vidal
The Conference Board

Steven Wallander
Yale University

Marsha Walton
New York State Energy Research and
Development Authority

Kris Wernstedt
Virginia Tech

Janice Whitney
U.S. Environmental Protection Agency

Eric Xu
Innovest Strategic Value Advisors

Nicole Yoskowitz
Columbia University

Rae Zimmerman
New York University

<u>Contractor Support</u>

Maria Smith
The Scientific Consultin Group, Inc.

Mary Spock
The Scientific Consultin Group, Inc.

Day 1 Presentations

EPA United States Environmental Protection Agency

The Science to Achieve Results (STAR) Research Program in Economics & Decision Sciences

Chris Saint, PhD

Acting Director,
Environmental Engineering Research Division
National Center for Environmental Research
Office of Research & Development

Office of Research and Development

EPA United States Environmental Protection Agency

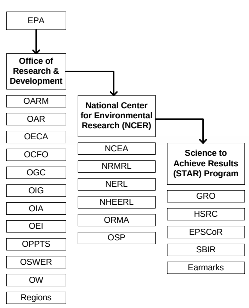
OUTLINE

- ➢What is the STAR Program?
- ➢Why the interest in EDS?
- ➢What research has STAR supported?

Office of Research and Development

EPA United States Environmental Protection Agency

Science to Achieve Results (STAR) Program



- **Mission:** include universities and non-profits in EPA's research program to ensure that the highest quality science supports sound decision-making
- **Awards about $66 - 100 million dollars annually**
- **Manages about 1000 active research grants and fellowships**
- **Each year:** receives 3000-3500 grant applications; make about 300 new STAR awards
- **Established** in 1995 as part of the overall reorganization of ORD

Office of Research and Development

EPA United States Environmental Protection Agency

EPA Interest in Economics and Decision Sciences

- What are the motivations for environmental behavior and decisions?
- How do people value environmental and health benefits?
- What are the typical responses of different entities to government interventions?
- What are the relationships between socioeconomics and long-term environmental issues?

Office of Research and Development

EPA United States Environmental Protection Agency

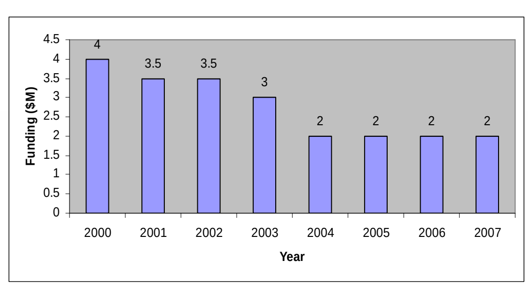
STAR Research: Specific Areas of Interest

- Valuation of ecological and health benefits.
- Corporate environmental behavior.
- Effectiveness of government interventions.
- Market mechanisms and incentives.
- Value and use of environmental information.

Office of Research and Development

EPA United States Environmental Protection Agency

STAR EDS Research Budget History



Office of Research and Development

Regulatory Regime Changes Under Federalism: Do States Matter More?

Wayne B. Gray,
Clark University & NBER
and
Ronald J. Shadbegian,
UMass-Dartmouth & NCEE

(preliminary – not for citation – January 2008)

The opinions and conclusions expressed are those of the authors and not the EPA.

Federal System

U.S. Environmental Policymaking
- EPA promulgates regulations and sets stringency
- States implement and enforce regulations
- States have considerable discretion
  - writing air and water permits
  - inspecting plants
  - some state-specific rules and laws

State discretion – Pros and Cons

Pros:

- States have flexibility in regulating => opportunities for innovative policies (50 experiments)

- Increase net benefits from regulation
  - set MB = MC in different locations

State discretion – Pros and Cons (cont)

Cons:

- States free ride off neighbor's cleanup, allow border plants to pollute (MC<MB)
  - Sigman (2005)
  - Helland and Whitford (2003)
  - Gray and Shadbegian (2004)
  - "Race to the Bottom" – be lax, get jobs
  - "Race to the Top" – local harm, NIMBY

Environmental Federalism

States differ in implementation and enforcement
- Do stricter national regulations reduce state differences in effective regulatory stringency?

  Stricter national regulations could:

  - "raise the bar" forcing less stringent states to become more stringent
  - give greater power to state regulators, enabling greater increases in stringency at more stringent states

Paper Industry Background

Geographically diverse industry (21 states)

Technology differences: pulping type, non-pulping

Major source of water pollution (un-boatable rivers)

Air pollution - PM, SO_2, NO_x - power & recovery boilers

Toxics - dioxin (kraft pulping + chlorine bleaching)

Cluster Rule

First Integrated, Multimedia Regulation

- **Targets reductions in toxic air and water releases from pulp and paper mills**
- **Announced March 8, 1996**
- **Promulgated April 18, 1998**
- **Effective April 2001**
- **Integrated to reduce regulatory burden**

Cluster Rule (cont)

- **Air Regulations**

Two MACT (Maximum Achievable Control Technology) Standards:

490 pulp and paper mills affected

1) more stringent for 155 mills using chemical pulping techniques

2) Less stringent for 335 mills using mechanical pulping techniques or purchased pulp

Cluster Rule (cont)

Goals for AIR Reductions:

59% - Hazardous Air Pollutants
47% - Sulfur
49% - VOCs
37% - PM

Cluster Rule (cont)

- **Water Regulations**

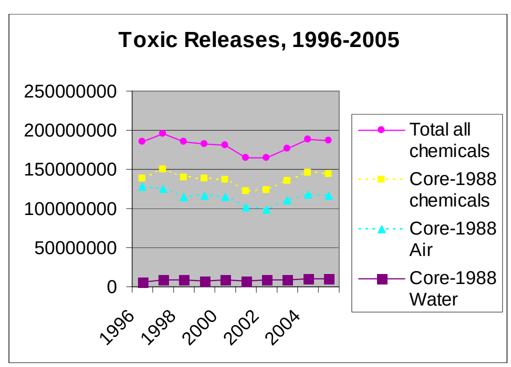
BAT (Best Available Technology Economically Achievable) Standard for reducing dioxin, furan, chloroform

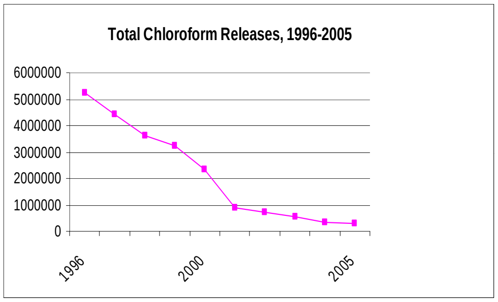
- Impacts 96 of the 155 chemical pulping plants

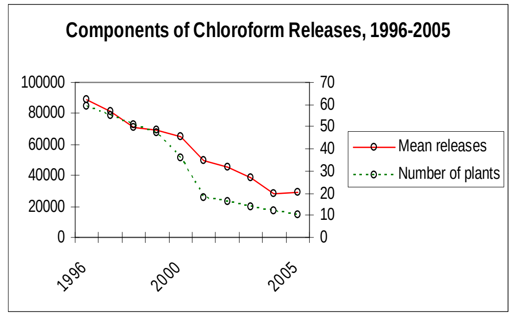
Cluster Rule (cont)

Goals for WATER Reductions

96% - Dioxin and Furan
99% - Chloroform







Literature Review

Environmental performance of polluting plants:

- **Conventional Air and Water pollutants:**
  - **Magat and Viscusi (1990)**
  - **Gray and Deily (1996)**
  - **Laplante and Rilstone (1996)**
  - **Nadeau (1997)**
  - **Shadbegian and Gray (2003, 2006)**
  - **Earnhart (2004a, 2004b)**
  - **Shimshack and Ward (2005)**
  - **Gray and Shadbegian (2005, 2007)**

Literature Review (cont)

- **Toxic Pollutants**
  - **Khanna and Damon (1999)**
  - **Bui (2005)**
  - **Arora and Cason (1999)**
  - **Wolverton (2002)**

Environmental Performance

$Z_{pkt} = f_k(CLUSTER_{pkt}, STATE_{jt}, CLUSTER_{pkt}*STATE_{jt}, X_{pt}, X_{ft}, YEAR_t, u_{pkt})$

Z_{pkt} ≡ environmental performance of plant p at time t for pollutant k (toxic and conventional air and water emissions)
higher Z = poorer performance

$CLUSTER_{pkt}$ ≡ Cluster Rule stringency (MACT, BAT) at plant p at time t along dimension k

$STATE_{jt}$ ≡ index of state regulatory stringency

CLUSTER*STATE – test whether stricter states are differentially affected by the Cluster Rule

DATA

150 paper mills, 1996-2005 (105 MACT, 65 BAT)

TRI – Toxic - Total Releases, Air, Water, Chloroform
IDEA – Water – BOD and TSS
NEI (1996, 1999, 2002) – Air - PM10, SO2, VOCs

State Level Stringency – Green Vote
Lockwood Directory - Plant age, pulp & paper capacity
Technology – Kraft Pulping
Firm data – Compustat – Employment, Profits
Border Plant, Nonattainment, Poor, College Graduates

RESULTS
BASIC TRI MODEL

Ordinary Least Squares Regression

Log(Releases) = f(plant, firm, location, regulation, years)

Regulation – overall stringency – GREEN VOTE

Year Dummies – changes around time of cluster rule
possible anticipation, lagged effect

BASIC TRI MODEL
(base year = 1996 = 0.000)

	AIR	WATER	Chloroform	TOTAL
1997	-0.035	0.412	-0.190	0.109
1998	-0.060	0.803*	-0.340	0.084
1999	-0.067	0.775*	-0.698	0.048
2000	-0.200	0.630	-1.419*	-0.027
2001	-0.424	0.722	-2.578*	-0.240
2002	-0.464	0.815*	-2.835*	-0.275
2003	-0.502*	0.996*	-2.982*	-0.303
2004	-0.419	1.103*	-3.139*	-0.223
2005	-0.488*	1.015*	-3.287*	-0.280

BASIC TRI MODEL

Probability of equality across years

	AIR	WATER	Chloroform	TOTAL
1996-2000	(.93)	(.22)	(.02)	(.94)
2001-2005	(.99)	(.86)	(.58)	(.99)
1996-2005	(.11)	(.20)	(.00)	(.09)
GREEN VOTE	-0.015*	-0.009	-0.024*	-0.010*
R-square	0.387	0.327	0.203	0.452

EXTENDED TRI MODEL

Same Plant, Firm, Location variables

Regulation – overall regulatory stringency – GREEN VOTE
Year Dummies – identify changes around time of cluster rule
(measures effects for least-stringent group)

MACT – 105 plants (subject to stricter air regulation)
BAT – 65 plants (subject to stricter water regulation)

Effective dates:
MACT - all 2001
BAT – some variation (water permit timing)

EXTENDED TRI MODEL

	AIR	WATER	Chloroform	TOTAL
MACT	1.585*		-0.632	1.334*
EFF-MACT	0.365		-0.596	0.350*
BAT		1.192*	3.823*	-0.016
EFF-BAT		-0.327	-3.390*	-0.097
GREEN VOTE	-0.009*	-0.008	-0.024*	-0.005

5-YEAR-CHANGE TRI MODEL

5-year growth: $\text{Log(TRI)}_t - \text{Log(TRI)}_{t-5}$
Comparing 2001-2005 with 1996-2000 (year by year)

Same Plant, Firm, Location variables
Year Dummies – changes within post-Cluster Rule period

Regulation variables
GREEN VOTE – state stringency
Effective MACT – plants subject to stricter air regulation
Effective BAT – plants subject to stricter water regulation

5-YEAR-CHANGE TRI MODELS

	AIR	WATER	Chloroform	TOTAL
EFF-MACT	0.376*		1.086*	0.213
EFF-BAT		-0.353	-4.510*	-0.040
GREEN VOTE	0.012*	0.001	0.011	0.010*

CONVENTIONAL POLLUTANTS

Provides comparison with TRI releases

Possible substitutes (within media or across media)

Possible complements (closed-loop process)

Regulation:
overall regulatory stringency – GREEN VOTE
Year Dummies – changes over time
MACT, BAT – Air, Water toxics stringency

EXTENDED CONVENTIONAL MODEL

	PM10	S02	VOCs	BOD	TSS
MACT	0.775*	0.202	0.656*		
EFF-MACT	-0.481	0.132	-0.520		
BAT				0.176	0.228*
EFF-BAT				0.139	0.098
GREEN VOTE	-0.018*	-0.023*	-0.020*	-0.016*	-0.011*

5-YEAR-CHANGE – CONVENTIONAL

	PM10	S02	VOCs	BOD	TSS
EFF-MACT	0.051	1.332*	0.056		
EFF-BAT				0.161	0.208
GREEN VOTE	0.010	0.031*	0.020	-0.001	-0.002

CONCLUSIONS

- **Control variables have (mostly) expected effects**
  - **Big, pulping plants emit more**
  - **More profitable emit less**
  - **Border plants emit more**
  - **Plants in poor neighborhoods emit more**
  - **Plants in college-educated neighborhoods emit less**
- **Regulatory stringency matters**
  - **Non-attainment – less air toxics, less particulates**
  - **GREEN VOTE – less air, water, chloroform, conventional**

CONCLUSIONS

- **Some Cluster Rule effects found**
  - **Reductions in air toxics around 2001**
  - **Very large reductions in chloroform, starting earlier**
  - **Effective-BAT plants (weakly) reduce water toxics**
  - **Effective-MACT plants (weakly) emit less PM10,VOC**
- **But…**
  - **Increases in water toxics overall**
  - **MACT plants increase air toxics around effective date**

CONCLUSIONS

- Impact of state stringency
  - Plants in stringent states have <u>smaller</u> reductions
  - Answers question of paper: Do States Matter More?
  - No, States Matter <u>Less</u>

Application to Decision-Making

- Regulatory design, impact of stricter rules
- Focus on "federal" aspect of regulation
- Decision-maker = federal regulator
- Considering new rule to increase stringency
  - How much will plants reduce pollution?
  - How will impacts differ across plants?
  - What spillovers on other pollutants?

Application to Decision-Making

- Expect some pollution reduction?
  - Yes, at least for some pollutants
- Impacts differing across plants?
  - Yes, depending on prior stringency
  - Less impact on plants in stricter states
  - Not closely connected to regulation-specific stringency
- Spillovers to other pollutants?
  - Not much observed here for conventional pollutants

Application to Decision-Making

- Key points:
  - State regulatory stringency matters
  - Some plants already have low emissions
- Caveats
  - Results from single industry
  - Negative publicity = additional incentive

The Persistence of Economic Factors in Shaping Regulation and Environmental Performance: The Limits of Social License Pressures

Dorothy Thornton
Robert A. Kagan
Neil Gunningham

Presented at the EPA workshop on Environmental Behavior and Decision-Making Research January 14 - 15, 2008

Regulation of dangerous emissions from heavy-duty trucks: two puzzles

- Explaining design of regulatory programs in the United States
- Explaining variation in environmental behavior of trucking firms

Economic Model of Regulatory Design

- Regulatory policies shaped by concentrated economic interests/dominant firms
- Diffuse, unorganized interests will bear costs of regulation

Political Science View of Regulatory Design

- More variables
- Policy entrepreneurs and diffuse interests
- Mobilization after disaster, scandals, scary research findings

Economic Model of Firm Environmental Behavior

- Compliance driven entirely by risk of detection and punishment
- Implies: No firms go ‘beyond compliance’

Sociolegal View of Firm Environmental Behavior

- Compliance is the norm, even when enforcement risk is relatively remote
- Many firms systematically take “beyond compliance” actions
- Firm behavior shaped by norms, social pressures, and environmental reputation

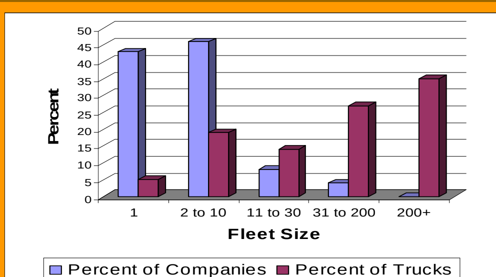
The limits of social license pressures?

- *Are social license pressures meaningful in regulatory fields with many small firms, less closely watched, with fewer economic resources?*

Why Trucks?

- In aggregate, LARGE environmental impact
- Large numbers of small firms: a special regulatory challenge
- Do our theories of regulation and firm behavior still hold when applied to such sectors?

Texas Fleet Size Distribution, 2005



Research Design

- Study evolution of federal and state regulatory programs
- State level policy-tracing – focus on Texas & California
- Policy consequences: intensive case-studies of 16 small/medium firms, 8 each in TX and CA.

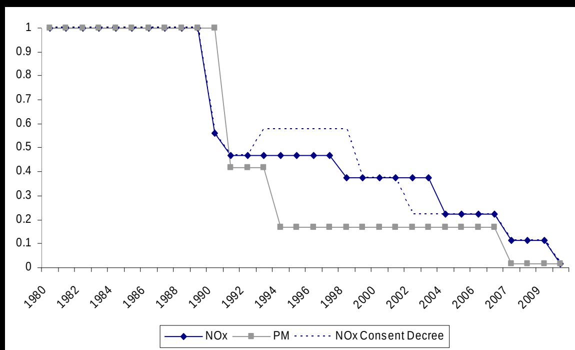
Many Trucks, Intense Competition

- 3 million heavy duty inter-state trucks + many more intra-state
- Engines can last 30 to 40 years
- New truck costs ~$150,000; Used truck ~$20,000
- Result: intense price competition

Health and Environmental Impacts of Diesel Emissions

- Particulates (PM), Nitrous oxides (NOx), and Carbon (CO2)
- California Air Resources Board (CARB) estimates 2,880 premature deaths in CA per year due to diesel emissions

Federal Regulation of Diesel Truck Emissions -- Technology Forcing for Engine Manufacturers



No Direct Federal Regulation of Truck Owners and Operators

- No requirement for owner/ operators to buy new, lower polluting models
- no "best available control technology (BAT)" requirement
- i.e, older, dirtier trucks "grandfathered in"

Explaining the Federal Regulatory Gap I: the Economic Problem

- Traditional "polluter pays" theory assumes regulatory compliance costs will be passed on to product/service users
- Not in trucking: a market with many small, precariously-capitalized companies, perfect competition

Explaining the Regulatory Gap II: The Political Problem

- BAT requirement → political risk of driving many thousands of small firms out of business, driving up costs of all goods and services
- Where were the large trucking companies? Immobilized by conflicting interests

The Federal Govt's Choice: Push States to Get Old Trucks Off the Road

- Tighten NAAQSs for Ozone (NOx) and PM
- State Implementation Plans (SIPs) must meet NAAQS
- Tie federal highway funds to meeting SIP requirements and 'transportation conformity'
- Offer federal funds for state/local subsidy programs

State Actions: TX

- TX: few non-attainment areas
- No SIP requirements that apply directly to trucking companies
- Subsidy program

CA Regulations

- 2000: Diesel Risk Reduction Plan, based on CA toxics law:
- Fleet emissions reduction requirements for: (1) transit buses, (2) garbage trucks, (3) public truck fleets, (4) drayage fleet, then (5) remaining private truck fleets
- Subsidies – esp. urban bus fleets

The limited reach of subsidy programs: economics again

- Texas subsidies dispersed through 2005: $57 Million
- Old trucks replaced=1,300. Cost per truck $44,000
- 2005 Texas trucks with 1990 or earlier MY =40,000
- Cost to replace 38,000 trucks @ 44k/trk = $1.7 Billion

Regulatory Policy Bottom Line: Economics Again

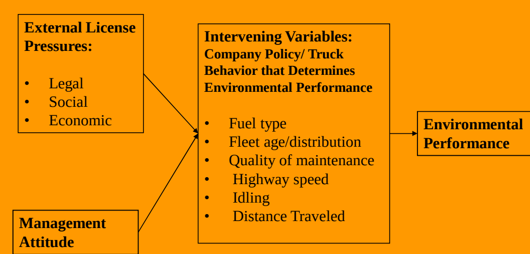
- Slow motion retirement of dirty trucks
- Subsidy programs → minor impact
- Why? mandatory BAT →

  enormous compliance costs →

  many firms out of business, higher shipping costs →

  high political risk

Intervening Variables in the Relationship Between External License Pressures, Management Attitude and Environmental Performance



Firm-Level Environmental Performance: Sampling Companies

- 16 firms, sample stratified by state, location, fleet size (small or very small), estimated environmental performance
- In-depth interviews + technical fleet analysis

Environmental License Requirements for Truck Companies

- Regulatory License Pressures: minimal
- Social license Pressures: minimal
- Economic License Pressures: drive environmental performance

In Summary: There are three Levels of Economic License Pressures

- (1) *Market conditions:* state of economy, price of labor, price of fuel.
- (2) *Profitability* (self-described as 'strained' to 'excellent')
- (3) *Economic Niche* - e.g. long haul vs port drayage

The Impact of Economic License Pressures on Company-Level Fleet Characteristics that Determine Truck Fleet Emissions

Economic Factors		Effect of Economic Factors on the Determinants of Environmental Performance: Better Emissions	Worse Emissions
General Economy	Expanding Economy → higher revenues, More capital*	• Younger fleet (more capital) within niche limits*	• More miles***
	More Expensive Diesel Fuel → Incentive for fuel cost controls** Less capital**	• Less idling • Better maintenance • Better logistics (fewer miles for same deliveries) • Lower highway speed	• Older fleet (higher costs, less capital)
	More Expensive Labor, Workers' Compensation, etc. → Less available capital*, more incentive for fuel cost controls**	Fuel cost controls viz.: • Less idling • Better maintenance • Better logistics (fewer miles for same deliveries) • Lower highway speed	• Older fleet
Market Niche	Long Trips → need for more reliable trucks**	• Younger fleet • Better maintenance	• More idling • More miles
	Sensitive goods More reliable trucks**	• Younger fleet • Better maintenance	
	Customers demand speedy delivery More reliable trucks**	• Newer fleet • Better maintenance	• Faster highway speeds
Company Financial Condition	Company doing well (more capital)**	• Better maintenance • Newer fleet within niche limits • Able to install idling-control equipment	

The Impact of Economic License Pressures on Company-Level Fleet Characteristics that Determine Environmental Performance

- Each economic factor has both negative and positive effects on emissions.
- The net effect is unpredictable and depends on the specific market conditions and management attitude of a particular firm.

Measuring Environmental Performance

- Est. emissions: CA (EMFAC) model
- Used average rank of 5 different measures of environmental performance
  - average grams/mile for NOx and PM.
  - total grams/truck emissions NOx and PM
  - fuel economy

Firm-Level Study: Conclusion I

- In a highly competitive market with little direct regulation or surveillance:
- *Environmental behavior* of small firms is driven by *economic pressures*. Better environmental performance is unintended consequence of economically-motivated behavior.
- *Economic pressures* play out on three different levels: (a) the general market, (b) the economic niche, and (c) company-level financial condition.
- policies must take this economic reality into account.

Firm-Level Study: Conclusion II.

- *Social license* has no direct impact on small companies unless communities (like those adjacent to the Los Angeles or Oakland ports) can exert economic pressures that result in regulatory action.

Oregon Business Decisions for Environmental Management

Findings from U.S. EPA Funded Project on Corporate Environmental Behavior and Effectiveness of Government Intervention

January 14, 2008

1

Project Team

- David Ervin, PI, Portland State U.
- Madhu Khanna, PI, U. Illinois
- Patricia Koss, PI, Portland State U.
- Junjie Wu, PI, Oregon State U.
- Cody Jones, GRA, Portland State U.
- Cameron Speir, GRA, U. Illinois
- Terry Wirkkala, GRA, Oregon State U.

2

Objectives

1. Collect primary data on env mgmt practices (EMPs), voluntary env program participation (VEPs), pollution prevention actions (P2) and env performance (EP) for Oregon businesses.
2. Test the influences of market, regulatory and other factors on the adoption of EMPs, VEPs, P2 and EP.
3. Infer the market and policy conditions that promote effective ‘voluntary’ environmental management programs.

3

Survey Coverage

Building Construction (236)	19.6%
Food Manufacturing (311)	15.4%
Wood Products Mfg (321)	17.3%
Computer & Electronics Mfg (334)	7.4%
Truck Transport(484)	18.9%
Accommodation (721)	20.5%

Sent to 1964 facilities in Oregon in 2005

35% response rate

Non-response bias not detected in employment, geographic location or responses across mailing waves

5 point Likert scale

4

Respondents

Mean facility revenue (mil $)	16.8
Retail	44.7%
Some R&D capacity	13.0%
Publicly traded	10.4%
Multinational status	12.7%
Revenue spent on env mgmt	2.4%
> 0 reg inspection in 2004	42.0%
> 0 env penalty, etc.in 2004	2.0%

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Survey

- Designed questions based on literature and industry interviews. (Appendix A)
- Sections
  1. Business environmental mgmt (BEM) motivations
  2. Environmental policies and practices - EMPs, VEPs, and P2
  3. Environmental performance (EP)
  4. General information, e.g. annual revenues, management age

6

Three Analyses

I. Discern observable facility characteristics associated with voluntary environmental program participation (VEPs) and EMP adoption.

II. Examine the strength of various observed and perceived incentives to adopt EMPs and take P2 actions.

III. Test a new model of BEM in which EMPs link to P2, and EMP and P2 link to EP.

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I. Observed Facility Characteristics Explaining the Count of VEP Participation and EMP Adoption

- VEPs include Climate Savers, Energy Star, ISO 14001, green building programs, etc.
- Factors affecting both VEP and EMP adoption
  - Regulatory pressures (particularly related to solid waste)
  - Perception that environmental issues a significant concern for the facility
- Factors affecting only EMP adoption
  - Innovativeness of facility particularly if ISSUE =1
- Factors affecting only VEP participation
  - Size (number of employees), MNC status and fewer competitors (particularly if ISSUE=1)

8

Implications of Count Analysis

- VEP participation is more costly; provides visible signals to enable product differentiation.
- EMP adoption requires more managerial creativity.
- Regulatory pressures are important but impact differs across regulations and type of voluntary activity.

9

II. Incentives for EMP Adoption and P2 Activities

- Scaled responses to survey questions used to create latent constructs representing extent of EMP and P2 adoption and strength of perceived motivations for adoption from consumers, investors, regulators and other interest groups

➢ **Key Findings**

- Determinants of extent of EMP implementation
  - Managerial Attitudes, Regulatory Pressures (particularly if ISSUE=0), Investor Pressure, Barriers to Implementation
- Determinants of P2 Adoption
  - Managerial Attitudes, Regulatory Pressures, EMP Adoption
- Competitive Pressures significant in motivating EMP and P2 adoption if ISSUE=1
- Consumer and Interest group pressures not significant

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III. Model linking EMP, P2 & EP

- Utility maximization (profit and EM)
- Estimate three equations using principal component indices for EMPs, P2, EP, etc.
  1. EMP intensity = Motivations + Selected Facility Characteristics
  2. P2 use = EMP intensity + EP + Selected Facility Characteristics
  3. EP = EMP intensity + P2 use + Selected Facility Characteristics

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Linked Model Findings

- Good fit: R Square = .55
- Significant variables have hypothesized signs, with two exceptions for EP.
- Management values toward environment have largest positive effect on EMPs.
- Competitiveness, regulatory & investor pressures have positive effects on EMPs.
- Index of barriers negatively affects EMPs.
- EMP intensity and reg. inspections affect P2

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Linked Model Findings cont'd

- Only facility characteristics affected 2004 change in environmental performance (EP)
  - % Revenue spent on EM in 2003 – positive
  - % Revenue spent on EM in 2004 – negative
  - Parent company ownership – positive
  - Environmental penalty in 2004 – negative
  - Mid-sized facility – positive (suggests a non-linear relationship for facility size)

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Conclusions and Implications

- Diverse motivational and market pressures and facility characteristics affect EMP, P2, & EP – Silver bullet approaches will not work.
- BEM decisions depend on more than profit.
- Managerial values and attitudes that environmental issues are important are strong motivators for EMPs, VEPs and P2 actions.

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Conclusions and Implications

- Regulatory system is an essential complement to voluntary BEM.
- Key market forces also significantly influence EMP and P2 decisions.
- Information based voluntary environmental management programs must be supported by complementary regulatory and market forces.

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Future Work

- Improve environmental performance measures and data.
- Delve into the origins of upper management attitudes on the environment.
- Improve BEM theory and modeling to reflect interdependent decision stages, e.g., VEPs, EMPs, P2, and EP.

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Publications and Reports

- Website http://obep.research.pdx.edu/
- Project Summary Report
- Hall, Teresa, "Business Decisions for Voluntary Environmental Management: Motivations, Actions and Outcomes," M.S. Thesis, Oregon State University, 2006.
- Jones, Cody, "Voluntary Environmental Program Participation in Oregon: Summary Statistics," MEM report, Portland State University, 2007.
- "Motivations for Voluntary Environmental Management," Policy Studies Journal (forthcoming)
- "Toward a Fuller Understanding of Business Environmental Management" in review

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Appendix A

Selected Survey Content and Responses

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BEM Motivations

- Consumer interest and willingness to pay for env friendly products/services
- Investor pressure
- Competitiveness concerns
- Interest group pressure
- Regulatory pressures
- Barriers, e.g., upfront costs, time, lack of expertise

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Sample Likert Scale Question

Please indicate the extent each of the following factors has influenced environmental management at your facility in the last 5 years. *(Please check only ONE box for each factor.)*

No Influence				Great Influence	Do Not Know
▼	▼	▼	▼	▼	▼

a. Customer desire for environmentally friendly products and services
☐1 ☐2 ☐3 ☐4 ☐5 ☐D

b. Customer willingness to pay higher prices for environmentally friendly products/services.
☐1 ☐2 ☐3 ☐4 ☐5 ☐D

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EMPs	**Mean Values***	**Description 1 = Yes, 0 = No**
Count	2.09	Count of EMPs implemented at the facility, range 0 to 10
Practices Included	0.41	Environmental training for employees
	0.37	Internal environmental standards
	0.25	Documented environmental policy
	0.25	Well-defined environmental goals
	0.23	Environmental audits at regular intervals
	0.17	Green purchasing policy
	0.17	Environmental cost accounting
	0.14	Environmental standards for suppliers
	0.10	Periodic public publishing of environmental information
	0.02	Employee compensation for contributions to environmental performance

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VEPs	**Mean**	**Description 1 = Yes, 0 = No**
Count	0.39	Count of VEPs the facility participates in, range 0 to 6
Voluntary Programs included	0.07	Facility participated in ENERGY STAR
	0.04	Facility participated in another energy program
	0.04	Facility participated in LEED
	0.03	Facility participated in Earth Advantage green building prog.
	0.01	Facility participated in other green building programs
	0.03	Facility participated in a recycling program
	0.05	Facility had obtained ISO 14001 certification
	0.01	Facility participated in a greenhouse gas reduction prog.
	0.02	Facility participated in a program designed to reduce multiple impacts, such as the Oregon Natural Step Network
	0.02	Facility participated in an industry specific program, such as Smartway Transport
	0.05	Facility participated in another type of program such as water conservation, stormwater management, etc.

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P2 Actions

- Mean = 3.8, SD = 1.1 (Scale:1 low –5 high)
  1. Reduction of spills and leaks is emphasized.
  2. Recycling has increased and landfilling has been reduced.
  3. Pollution prevention is emphasized to improve environmental performance.
  4. Production systems have been modified to reduce waste.
  5. Products have been modified to reduce environmental impacts.
  6. Raw materials are chosen to reduce impacts.

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Environmental Performance

- 2004 Impacts
  - Wastewater and dewatering discharge
  - Solid waste and recycling
  - Hazardous or toxic wastes
  - Carbon dioxide (CO_2) emissions
  - Hazardous air emissions
  - Electricity and natural gas (selected)
  - Green building/energy efficiency (construction)
  - Diesel and biodiesel use (transport)
- Measures: outcomes, compliance, changes

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Facility characteristics

- Publicly traded v. privately owned
- Owned by parent company
- Annual revenue
- Multinational operations
- Environmental official and staff
- % revenue spent on environmental mgmt
- R&D capacity
- Operate in retail market
- Number of close competitors
- Age of upper management

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Pollution Prevention Practices: Determinants of Adoption and Effectiveness in Reducing Toxic Releases

Madhu Khanna
Department of Agricultural and Consumer Economics
University of Illinois at Urbana-Champaign
with
George Deltas, Satish Joshi and Donna Harrington

Total Quality Environmental Management

- Application of quality management principles to environmental management
  - Continuous improvement
  - Defect/waste prevention, quality improvement, cost-reduction
- Meet/exceed consumer expectations for quality improvements and low costs
- 40-60% adoption rates among corporations by mid 1990's

Implementation of TQEM

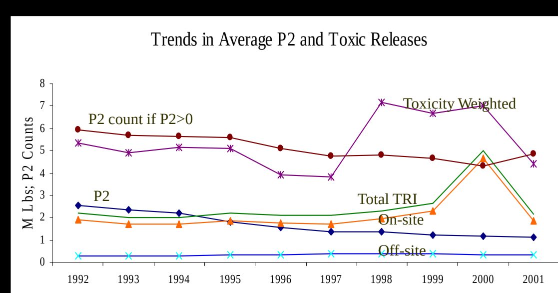
- Systems approach to underlying cause of problem
  - Defect prevention instead of detection
  - Pollution a form of defect/inefficiency
- Creation and utilization of firm-specific knowledge
  - Cross functional teams identify practices, use of flow-charts, life-cycle analysis, full cost accounting
  - Learning from other organizations
  - Involvement of front-line employees in searching for improved and simplified work practices to improve quality
  - Communication; information sharing among all hierarchical levels
  - Employee training and team-based rewards
- Complementarities with Pollution Prevention

Research Objectives

- Determinants of the decision to adopt TQEM
  - Demand side pressures and supply side influences
- Determinants of the decision to adopt P2 techniques
  - Internal organizational changes: TQEM
  - External Pressures: Regulatory and Market
  - Technical capabilities
- Types of P2 techniques adopted by TQEM firms
  - Classify P2 practices according to
    - Functional characteristics (modifications to equipment, materials, procedures or other/customized)
    - Visibility to consumers
    - Efficiency enhancing/auxiliary cost savings
- Impact of P2 Adoption on Toxic Releases
  - Presence of lagged effects of P2
  - Path dependence in toxic releases

Data

- Sample of S&P 500 firms: Survey data on TQEM adoption (Investor Research Responsibility Center) for 1992-1996
- Sample of facilities of S&P 500 firms reporting to TRI (1991-2001)
- Toxic releases and pollution prevention activities- USEPA's TRI data
- Regulatory data from USEPA; Financial Data from Research Insight
- Pollution prevention practices: 8 broad categories adopted for each toxic chemical by each facility – aggregated for parent company
  - changes in operating practices, spill and leak prevention; modifications to equipment, processes, products or raw materials



Research Question 1

What motivates the voluntary adoption of TQEM?

Key Findings

Internal motivations driving TQEM adoption rather than concerns about external stakeholders.

Demand Side (External Benefits)	Final Good Dummy Final * Market Share Final *Total Toxic Releases Superfund Sites, Penalties, Inspections
Demand Side (Internal Benefits)	Toxic Releases (+) *
Supply Side (Internal Capabilities/ Costs)	R&D Intensity (+)*** Sales (+)*** Number of Facilities (-) *** Market Share (+) ***
Industry Controls	Percent of Peer Firms Adopting TQEM (within 4 digit SIC) Industry Concentration (HH Index) SIC codes

Research Question 2

Does TQEM lead to the adoption of pollution prevention practices?

Do regulatory pressures encourage or discourage pollution prevention activities?

Measure of P2 Activities

- Sum of all New P2 activities adopted that year across all chemicals and facilities
- Count of Chemicals for which any P2 activity undertaken summed across chemicals and facilities
- Weighted Sum of New P2 across facilities with weights being facility's share in the five-year lagged toxic releases of the parent company

Significant Motivators of P2

- TQEM
- Regulatory Pressure
  - Penalties, inspections, location in non-attainment counties have a positive impact on P2 but not on Weighted P2
    - Not motivating more pollution intensive facilities within the firm
  - Larger volume of HAP
  - Smaller threat of liabilities for Superfund Sites
- R&D Intensity
  - Stronger indirect effect by motivating TQEM than direct effect on P2
- Larger Number of Chemicals, Market Share of Sales
- Smaller toxic releases in the past
- Higher toxicity weighted releases in the past
- No effect
  - Market pressures from consumers and environmental groups, age of assets, sales

Key Findings on Motivators of P2

- TQEM does lead firms to adopt more P2 activities
- Firms and facilities within firms with high toxic releases face higher costs of P2 and adopt fewer P2
- Regulatory pressures, particularly, HAP motivate P2
- Technical capability an important determinant of P2 adoption

Research Question 3

Types of P2 Practices Responsive to TQEM

Channels through which TQEM affects operations

Types of P2 practices

- Four mutually exclusive functional attributes:
  - Physical changes in equipment
  - Change in materials usage
  - Change in operating procedures
  - Other customized modifications
- Two strategic classifications:
  - Visibility to consumers
  - Efficiency-enhancing

Classification of Pollution Prevention Practices

P2 Activities	Equipment	Material	Procedural	Efficiency	Consumers
Spill and Leak Prevention					
31 Improved storage or stacking procedures			X	X	
32 Improved procedures for loading, unloading, and transfer operations			X	X	
33 Installed overflow alarms or automatic shut-off valves	X			X	
36 Implemented inspection or monitoring program of potential spill or leak sources			X	X	
39 Other changes made in spill and leak prevention				X	
Process Modifications					
51 Instituted re-circulation within a process	X			X	
52 Modified equipment, layout, or piping	X				
58 Other process modifications made					
Product Modifications					
81 Changed product specifications					X
82 Modified design or composition of product		X			X

- 42 such categories of practices

Empirical Analysis

- Dependent variable
  - Number of P2 practices of a specific category adopted
- Explanatory variables
  - TQEM
  - TQEM * attributes (with the unclassified category as default)
  - Number of Chemicals
  - Cumulative $P2_{t-1}$
  - Total Lagge $P2_{t-1}$
  - Practice fixed effects
  - Firm fixed effects
  - Time fixed effects
- Five year panel data (1992-96)

Motivators of P2 and Types of Practices

- TQEM has a significant effect in motivating practices with
  - Unclassified/Customized attributes
  - Procedural Modifications
  - One of the above + Visible to consumers or Efficiency enhancing features
- Stimulus from recent experience with P2 practices
  - Number of P2 practices of all types adopted last year
- Diminishing returns to P2 adoption
  - Number of all P2 practices adopted since 1991

Simulation –Effect of Delaying TQEM Adoption by One Year

SIC Code and	Industry Name	Mean % Change in Pollution Prevention Counts due to TQEM
13	Oil & Gas Extraction	14.2
20	Food and Kindred Products	13.6
21	Tobacco Products	14.0
26	Paper & Allied Products	12.0
28	Chemicals & Allied Products	20.1
29	Petroleum Refining & Related Industries	27.7
32	Stone, Clay, Glass, & Concrete Products	17.9
33	Primary Metal Industries	19.2
34	Fabricated Metal Products	10.8
35	Ind. & Comm Machinery & Computer Equip.	10.0
36	Electronic & Other Electrical Equipment	18.9
37	Transport Equipment	15.5
48	Communication	19.4
	All Industries	16.1

Key Findings

Impact of TQEM on different pollution prevention activities is not uniform.

TQEM is more likely to

lead to adoption of non-generic P2 practices and firm-specific changes in operating procedures

rather than to

off-the-shelf modifications in materials and equipment

- Enhances P2 in industries with operations that are more dependent on procedures and customized practices

Research Question 4

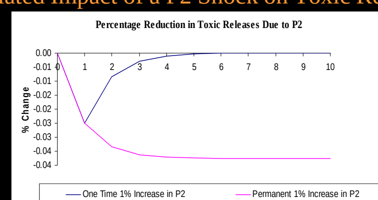
What is the impact of P2 adoption on toxic releases?

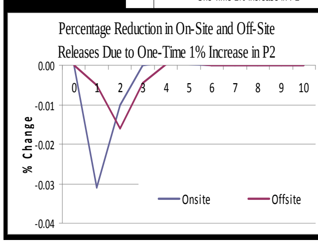
To what extent are toxic releases affected by past activities, current regulatory and public pressures?

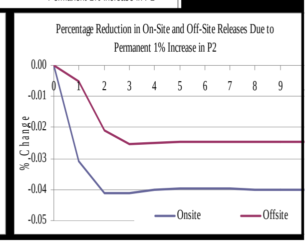
Key Determinants of Toxic Releases

- Previous year's toxic releases (+)
- Previous year's count of New P2 adopted (-)
  - Impact stronger on on-site discharges than on off-site disposal
  - Both direct and declining indirect impact on future toxic releases
- Previous year's toxicity weighted releases (-)
- Location of facility in high income county (-)
- No impact of
  - contemporaneous P2 and earlier lags of P2 and toxic releases
  - regulatory and other locational pressures

Simulated Impact of a P2 Shock on Toxic Releases







Summary of Findings

- Voluntary environmental management efforts by firms do lead to environmentally friendly P2 innovations
- Trend towards P2 adoption diminishing over time
- Short term learning effect from past P2 adoption but longer term diminishing effect on P2 adoption
- P2 adoption reduces toxic releases with a 1 year lag but effect is transitory

Policy Needs to Promote Prevention of Toxic Releases

- Targeted public policy efforts to promote TQEM
  - In the form of technical assistance: lower costs of adoption
    - By firms in certain industries (e.g. chemical and petroleum)
    - For smaller, less technically innovative firms
- Regulatory pressures for environmental improvement
  - Targeted regulatory threat towards toxic pollutants (e.g HAP regulations)
- Emphasize concerns for toxicity of pollutants
  - To stimulate public and regulatory pressure for reduction

Conclusions

- Need to supplement voluntary incentives for P2 and toxic release reduction with regulatory stimulus
  - Adoption of P2 and current policies for toxic release reduction may not lead to large reductions in toxic releases
  - Doubling of P2 adoption would reduce releases by 4%
- Toxic release reduction is path and technology dependent
  - Need for regulatory, flexible stimulus to supplement voluntary incentives for adopting P2 and reducing toxic releases
- Future Research:
  - Type of P2 that are more environmentally effective
  - Effectiveness of P2 at chemical specific level

Certified Environmental Management Standards:
An Institution for Removing Information Asymmetries in the Market for Corporate Environmental Performance?

Ann Terlaak
Wisconsin School of Business
Madison, Wisconsin

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The Bigger Picture

- Project focuses on exploring environmental certified management standards (CMS).
  - "EMAS with certification: ISO 14001"
- Previous research suggests that the use of CMS is influenced by information asymmetries.
  - Application of Spence's signaling ideas to the analysis of CMS.

The Bigger Picture – cont'

- BUT… data on CMS adoption doesn't entirely cooperate with a simple signaling story.
- Lower performing firms select into certification (King et al, 2002) and certified firms do not have better performance (Andrews et al, 2001).

Original Research Effort

The Signaling Story that Wasn't

Disturbances in the Simple Signaling Notion

- Different signaling equilibriums in different industries
  - Certified firms have environmental performance that systematically varies across industries
  - Too-cool-for-school effect
- Endogeneity of environmental performance
  - CMS prescribes best practices that may affect firm environmental performance
  - Such endogeneity manageable if performance effects are systematic across firms/industries

Two (Plus One) Revised Research Efforts

- 1) Conceptual study on the power and limitations of CMS to guide environmentally responsible firm behaviors.
- 2) Empirical study on how corporate strategic behaviors shape adoption patterns and use of CMS
- Plus One) Studies exploring how cross-firm observations influence adoption behaviors

Revised Research Effort I

The "Can-do Can't-do" Project

Terlaak, A. (2007)"Order without Law: The Role of Certified Management Standards in Shaping Socially Desired Firm Behaviors". *Academy of Management Review*, 32(3): 968-985.

Background

- Compare design of CMS to the design of other institutions that guide firm environmental behavior.
  - CMS (ISO 14001), Industry Programs (Responsible Care), laws, norms
- Lack of legal backdrop and decentralized enforcement distinguish CMS from industry programs and laws, and make them most similar to norms.
- When compared to norms, two elements – codification and certification of practices – enable and constrain CMS in guiding desirable firm behaviors.

Enabling Effects of Codification & Certification

Codification and certification enable CMS to shape firm activities more effectively than norms

- when consensus about activities is incomplete
  - emerging management areas and cross-cultural transactions
- when behaviors are difficult to observe
  - practices that are physically removed from transacting parties and that do not manifest in product/service attributes

Constraining Effects of Codification & Certification

Codification and certification limit the ability of CMS to shape firm activities as

- codification of practices attracts poor performers
- certification of practices attracts good performers

→ Codification causes failure in the sorting effect of certification. Both poor and good performers adopt. This causes inconsistencies and weakens the decentralized enforcement processes from which CMS derive their power.

Implications for Policy Makers

- Design matters! Although codification and certification may broaden the applicability of CMS, they may reduce CMS's effectiveness in guiding firm behaviors by weakening enforcement processes
  - Improvement tool and signal of superior performance exclusive endeavors?
- What does that mean for future CMS (ISO 14001s)?
  - ~~Centralize enforcement on the industry level~~
  - Remove the certification element and return to EMAS
  - Encourage involvement of industry bodies and allow for differing cross-industry uses/interpretations of CMS

Revised Research Effort II

How Corporate Social Strategy Shapes Adoption Patterns

Terlaak, A. (2007) "Satisficing Signaling: Corporate Social Strategy and Certified Management Standards. *Best Paper Proceedings, Academy of Management Annual Conference*.

The Findings in a Nutshell

- Facilities that perform poorly relative to industry peers certify with ISO 14001.
- However, these facilities
  - are better performers when compared to other facilities within the firm.
  - operate in relatively cleaner industries
  - have prior experience with CMS

The Story Behind

- Stakeholders exert adoption pressures on firms that own poor performing facilities (Eesley & Lenox, 2006)
- For the firm, the returns to adopting and certifying social CMS practices are debatable
  - Operational benefits are conditional (e.g., King & Lenox, 2002; Russo & Fouts, 1997)
  - Market benefits depend on WTP which may be below costs of producing environmental protection
- Adoption & certification costs, in contrast, are concrete.

The Story Behind – cont'

- Corporate HQ chooses which facility to certify (Darnall, 2003)
- Faced with uncertain payoffs, HQ will choose better performing facility to be certified in an effort to lower adoption costs (maximize net benefits).

Data & Model

- Sample draws on and extends dataset built under past NCER STAR grant by A. King et al.
  - 5,215 U.S. manufacturing facilities that are part of multi-plant firms
  - Timeframe: 1995 – 2002.
  - Discrete-time random-effect logistic model to predict facility certification with ISO 14001 in t+1 given a set of independent variables and control variables in t (Cox regressions for robustness checks).

Data & Model – cont'

- **Independent Variables:**
  - Facility environmental performance relative to (i) industry peers and (ii) other firm facilities
  - Emissions of industry of each facility relative to industry emissions of other firm facilities
  - Prior facility experience with CMS
- **Control Variables**: information asymmetries, regulatory stringency, supply chain pressures, size, etc.

Results

Facilities that are poor performers when compared to industry peers are more likely to select into certification with ISO 14001.

But these facilities
- are above average performers within the firm
- operate in relatively cleaner industries
- have prior experience with CMS

Introducing ISO 9000 into the Mix

- Notion is to validate story behind these results by comparing inter-firm adoption patterns of ISO 14001 with adoption patterns of ISO 9000 (which produces more of a private good)
- When predicting adoption of ISO 9000, better firm performers more prone to adopt
- When predicting adoption of ISO 9000, versus ISO 14001, poorer firm performers adopt ISO 9000, and better firm performers adopt 14001

Implications for Policy Makers

- CMS once more stuck in the middle: It is not a reliable signal of superior environmental performance, and also only an ineffective improvement tool if it isn't adopted by those that most urgently need to improve.
- Remove certification element so as to focus CMS on potential operational benefits & facilitate those?
- Retain certification element and subsidize a market premium that (ideally) is proportional to improvements? (difficult to design and implement!)
- CMS in their current form not suitable as a stand alone instrument in the regulatory toolbox.

"Plus One" Research Effort

How Vicarious Learning Influences Adoption Behaviors

Terlaak, A. & Gong, Y. (2008) "Vicarious learning and inferential accuracy in adoption processes". Accepted for publication at *Academy of Management Review*.

Terlaak, A. & King, A. (2007) "Follow the Small? Information-Based Adoption Bandwagons when Profitability Expectations are Related to Size". *Strategic Management Journal*, 28: 1167-1185.

Get the Underdogs to Participate!

- Firm adoption propensities can be most strongly influenced by previous adopters that benefit less from adoption/that are less prestigious.
- For policymakers, targeting the GEs, DuPonts, and HPs of the world as flagship adopters may create publicity for a voluntary standard/program yet can discourage further adoption by the average firm.
- Pursuing a two-sided strategy that also targets average and below average performers may lead to a broader/quicker uptake of new programs.

Summary

- The current design of CMS like ISO 14001 has encouraged multiple (and often conflicting) uses and interpretations of what CMS can and cannot do.
- Because essential to CMS seems the codification of best practices (an improvement element), certification may at best be meaningless (and at worst confusing) because the magnitude of improvements varies widely.
    - Certification as a signal of willingness to improve?
    - Certification as a signal of improvement?
    - Certification as a signal of superior performance?
- Separate certification program from improvement program

Future Research Efforts

- Incorporate PCS data (Permit Compliance System) to triangulate environmental performance measure.
- Perform comparative studies with ISO 9000 to explore further the degree to which the public good nature of environmental protection inhibits the functioning of environmental CMS.

Detailed Results

Variables	Full Model
Facility Environmental Perf.	-0.168**
Cleaner Firm Performer	0.292*
In Cleaner Industry	0.267*
ISO 9000 Certification	0.464**
R&D Intensity	10.215*
Export	-0.208
Auto Supplier	24.772**
Regulatory Stringency	3.456
Industry Certification	-0.034
Relative Facility Size	0.381**
Firm Size	0.001*
Publicly Held	-0.312*
EMS Practices	0.410**
Year Fixed Effects	Incl.
Industry Fixed Effects	Incl.

Evaluating Voluntary Programs in the United States+

Dick Morgenstern, Billy Pizer, and Jhih-Shyang Shih

November 28, 2007

RESOURCES FOR THE FUTURE

Voluntary Climate Programs: Climate Wise

- Established 1993; continued until 2000. Focus on non-utility industrial sector.
- Required baseline emission estimate (but not inventory).
- Required to identify mitigation actions, goal for 2000.
- Report activities via 1605(b).
- Gained technical assistance; annual workshop.

RESOURCES FOR THE FUTURE

Voluntary Climate Programs: 1605(b)

- Established under EPACT 1992; began 1994.
- Required reporting of emission reductions, with flexibility over
  - Whether entity or project
  - Reference year or hypothetical reference
  - Absolute or intensity reductions
- Open to any individual or business; dominated by electric power industry
- Important benefits (EIA, 2002):
  - Teach corporations how to estimate emissions and mitigation options
  - Sharing experience concerning mitigation activities
  - Evidence for evaluating other voluntary programs
  - Illuminate accounting issues related to future emission regulation

RESOURCES FOR THE FUTURE

Participation in Programs (raw / not linked to LRD)

Join year	1605(b)	ClimateWise
1994	43	8
1995	105	37
1996	37	179
1997	26	138
1998	17	106
1999	61	89
2000	35	144
2001	59	
Subtotal	383	671

RESOURCES FOR THE FUTURE

Key Challenges

- Measuring outcome
  - Need data on emission outcomes before and after policy, for both participants and non-participants.
- Addressing selection
  - Participants and non-participants may not look the same and/or participation may depend on various characteristics unrelated to the program but correlated with outcome.

RESOURCES FOR THE FUTURE

Proposed Solutions

- Use Census data on energy use (expenditures on fuel and electricity) to proxy for emissions. Available for both participants and non-participants; requires working at Census Bureau to access confidential data and link to participation information.
- Address selection through two alternative models.

RESOURCES FOR THE FUTURE

Selection Problem and Solutions

$$Y_{i,t} = f\left(X_{i,t}\right) + g\left(X_{i,t}\right) D_{i,t} + u_{i,t}$$

- *Y* is emissions / energy use; *D* is participation; *X* are covariates (location, industry, size).
- $g(X_{i,t})$ measures program effect on outcome.
- Potential problems
  1. μ correlated with *D*.
  2. miss-specification of *f* and *g*.
- Solutions
  - Structural model of selection and correlation with μ (Heckman-Hotz). *Requires excluded variable predicting selection and not outcome.*
  - Propensity score matching.

RESOURCES FOR THE FUTURE

Heckman-Hotz

- Consider joint estimation of selection model and outcome model:

$$D^*_{i,t} = \delta \cdot Z_{i,t} + v_{i,t}$$
$$Y_{i,t} = f\left(X_{i,t}\right) + g\left(X_{i,t}\right) D_{i,t} + u_{i,t}$$

- Here, $(u_{i,t}, v_{i,t})$ are jointly normal, $Z_{i,t}$ includes at least one additional variable than $X_{i,t}$, and $D_{i,t}^*$ is a continuous latent variable, with $D_{i,t} = 1$ when $D_{i,t}^* > 0$.
- Estimate selection model using probit; insert additional regressor in outcome model, $E[u_{i,t} \mid v_{i,t}] = \lambda(D_{i,t}, Z_{i,t})$

RESOURCES FOR THE FUTURE

Problems with Heckman-Hotz

Table 1: EPA Climate Wise program, effect of program on logged cost of electricity after 2 years, Heckman-Hotz approach

Cohort	w/o correction	with correction	sample	participants
1994	0.06 (0.02)*	0.60 (0.09)*	19627	809
1995	0.04 (0.04)	-0.16 (0.14)	34880	335
1996	0.02 (0.03)	0.36 (0.21)	31253	656
1997	-0.02 (0.03)	-0.29 (0.18)	17534	835
1998	0.01 (0.02)	-0.75 (0.16)*	30693	1063
1999	0.05 (0.12)	-1.42 (0.71)*	33971	96

- Program effects on energy costs are ±100%.
- *Excluded variables (membership in advocacy organization & distance to EPA regional office) are not effective at predicting participation.*

RESOURCES FOR THE FUTURE

Propensity Score Matching

- Estimate participation model and predict propensity to join for each plant in each year.
- Consider each participating plant; find non-participating plant with closest propensity value (nearest neighbor) in the join year.
- Sample without replacement.
- Estimate separate selection model for each horizon (1, 2, and 3 years) where program effects are computed.

RESOURCES FOR THE FUTURE

Participation Model

$$\begin{array}{c}\text{probability of joining in year } t\\ \text{(assuming plant } i \text{ has not yet joined)}\end{array} = h(t)\exp\begin{pmatrix} \beta_{size}\ln TVS_{i,t-1} + \beta_{elec}\ln EE_{i,t-1} + \beta_{fuels}\ln CF_{i,t-1} \\ +[\text{all quadratic combinations of size, elec, fuels}] \\ +\beta_{growth}\left(\ln TVS_{i,t+h} - \ln TVS_{i,t-1}\right) \\ +\sum_{\text{industries } j}\beta_j 1(M_i = j) + \sum_{\text{region } k}\beta_k 1(G_i = k) \end{pmatrix}$$

- Cox proportional hazard model of probability of plant *i* choosing to join in year *t*.
- includes lagged total value of shipments (TVS), electricity expenditures (EE), cost of fuels (CF), plus linear and quadratic terms, interactions
- future growth rate in shipments (h = 1-, 2-, or 3- year lead vs. 1 year lag).
- includes census region *G* (9 values) and industry *M* (2-digit) dummy variables.

RESOURCES FOR THE FUTURE

Model of Program Effects Using Pairwise Matched Participants / Controls

$$\Delta Y_s = \frac{\sum_{i,t}\left(Y_{\text{participant } i,t+s} - Y_{\text{participant } i,t-1}\right) - \left(Y_{\text{control } i,t+s} - Y_{\text{control } i,t-1}\right)}{\sum_{i,t} 1\begin{pmatrix}\text{participant } i \text{ joined in } t \\ \text{and observed in } t+s \text{ and } t-1\end{pmatrix}}$$

- $Y_{d,i,t}$ is the relevant variable (total value of shipments, fuel and electricity expenditure) in pair *i* at time *t*.
- ΔY_s is the average program effect after *s* years relative to the year before the joinyear (for output, fuel and electricity expenditures)

RESOURCES FOR THE FUTURE

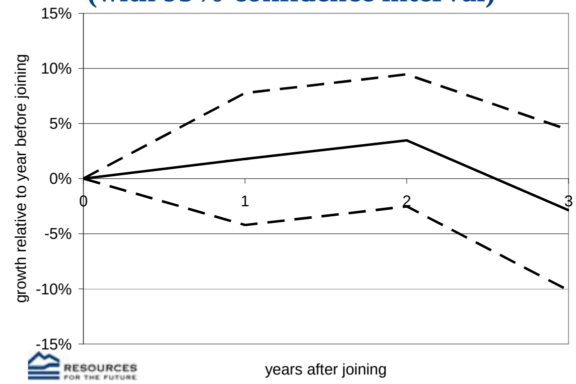
Propensity Score Results (median estimates with all controls)

Effect of program participation on energy expenditures (fractional change)

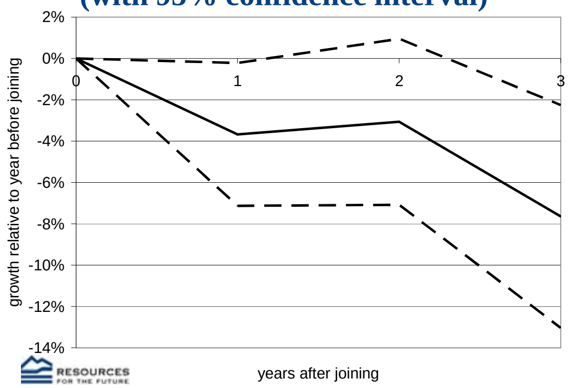
	1605(b)		ClimateWise	
	Fuel	Electricity	Fuel	Electricity
1-year effect	0.02	-0.04*	-0.01	0.00
	(0.03)	(0.02)	(0.03)	(0.01)
2-year effect	0.03	-0.03	0.03	0.02
	(0.03)	(0.02)	(0.03)	(0.02)
3-year effect	-0.05	-0.05*	-0.01	-0.01
	(0.06)	(0.03)	(0.03)	(0.02)

- Effects are no more than 5% with most general specification. Zero for ClimateWise.
- Other specifications lead to a wider range of median estimates from –8% to +5% (positive effect is transitory)

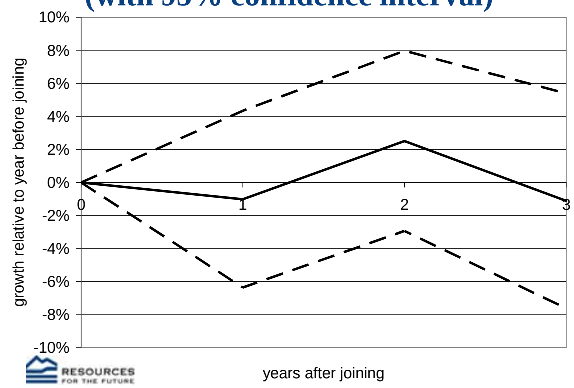
1605(b) Effect on Fuel (with 95% confidence interval)



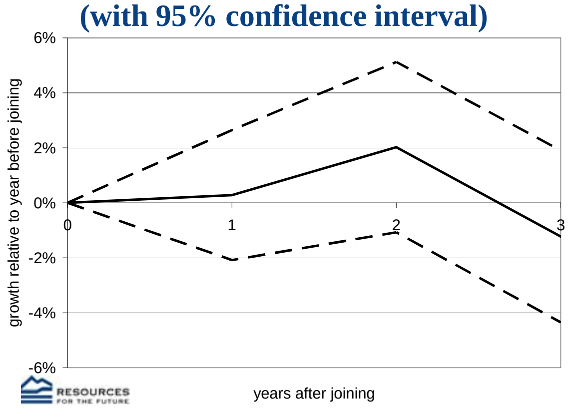
1605(b) Effect on Electricity (with 95% confidence interval)

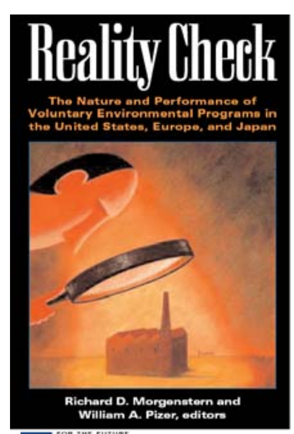


ClimateWise Effect on Fuel (with 95% confidence interval)



ClimateWise Effect on Electricity (with 95% confidence interval)





What are "voluntary programs"? Why do we care?

- Types of programs
  - Unilateral agreements
  - Public voluntary programs
  - Negotiated agreements
- Varied and expanding use
  - 87 EPA programs, 1.6% operating budget
  - Dozens more in states, other federal agencies
  - Hundreds of VP/VAs in Europe
  - Thousands in Japan
- BUT, do voluntary programs deliver significant environmental gains relative to a realistic baseline, i.e., do they change behavior?
  - If so, how large are the gains?
  - Do results differ for toxics vs energy programs?
  - What else affects program impact?

RESOURCES FOR THE FUTURE

Motivation

- Business
  - Get 'hands on' experience
  - Enhance reputation with customers, government, investors, communities, etc.
  - Benefit from government-provided technical assistance.
  - Help shape future requirements; improve relationship with regulators
- Government
  - Get 'hands on' experience in the absence of regulatory mandate
  - Experiment with more holistic approaches vs traditional regulation
  - Build public support for future action
  - Build bridges to industry, e.g., via technical assistance
- Environmental groups (mixed reaction)
  - Some applaud VP's as means to build support in public, industry
  - Some fear regulatory capture, distraction from real work of environmental protection, shift in focus from worst polluters to more progressive firms

RESOURCES FOR THE FUTURE

Table 1-1: Selected Characteristics of Case Studies

Program	Author(s)	Years of Operation	Energy, CO2 (GHGs), or Toxics	Industry or Household	Program Type
33/50 (US)	Khanna	1991-1996	Toxics	Industry	Public Voluntary Program
Japanese Keidanren	Wakabayashi and Sugiyama	1997-	CO2	Industry	Negotiated agreement
UK Climate Change Agreements	Glachant and Muizon	2001-	CO2	Industry	Negotiated agreement
Danish Energy Efficiency Agreements	Krarup and Millock	1996-	CO2	Industry	Negotiated agreement
German Cement Industry	Bohringer and Frondel	1995	CO2	Industry	Unilateral agreement
Climate Wise (US)	Morgenstern, Pizer and Shih	1993-2000	GHGs	Industry	Public Voluntary Program
California Demand Side Management	Sanstad	Early-mid 1990s	Energy	Household	Public Voluntary Program

RESOURCES FOR THE FUTURE

33/50 Program

- Followed development of TRI
- Focus on measurable reductions (33%, 50%) for 17 TRI chemicals in major industries (1991)
- Actual reductions clearly exceeded goals
- Sophisticated studies find program reduced emissions, controlling for self-selection, especially for larger firms
- Partly attributable to fear of regulations
- Some evidence suggests no/negative gains beyond Montreal Protocol substances

RESOURCES FOR THE FUTURE

Keidanren Voluntary Action Plan

- Involves large firms representing 80% of industrial, electric emissions (almost half of Japan's total emissions) (1997)
- Targets negotiated for sectors, not firms
- So far, emissions below target levels
- Reductions attributed to industry, gov't cooperation, fear of regulation, firms' social awareness
- Questions about BAU estimates, stringency of goals
- Is program really voluntary?

RESOURCES FOR THE FUTURE

UK Climate Change Agreements

- CCAs part of tax ($9-18/ton of CO_2), and emissions trading policies (2001)
- Intensity or fixed targets negotiated with gov't
- Covering 12,000 sites = 44% UK emissions
- 80% rebates of levy for meeting CCA goals
- Goals exceeded (based on observed permit prices), although stringency in question
- Overall, authors find that CCAs make small contribution

RESOURCES FOR THE FUTURE

Denmark's Energy Efficiency Agreements

- VAs part of policy package involving CO_2 taxes ($18/ton) on industry (1996)
- Negotiated agreements based on audits, adoption of energy efficiency measures. No quantitative targets
- 100% tax rebates for participants
- Audit eventually dropped
- Using data from 60 firms, authors find some reductions in early years, although quite modest reductions overall

RESOURCES FOR THE FUTURE

German Cement Industry

- Unilateral commitment by major sectors (not firms) for 20% cuts below 1987 levels by 2005; case focuses on cement industry (1995)
- By 2000 most goals met; target raised to 28% reduction
- Trend regression used to establish baseline using historical data
- Actual emissions same as forecast BAU (+/- 5%)
- Authors recommend firm specific targets; negotiated instead of unilaterally set

RESOURCES FOR THE FUTURE

Climate Wise

- EPA program involving negotiated agreements with 600+ firms (1993)
- Emissions based program; TA, other incentives offered for joining
- Comparisons with matched set of non-participants used to determine what would have happened anyway
- Authors find modest differences in fuel (-) and electricity (+) use in early years; no significant differences later on

RESOURCES FOR THE FUTURE

Residential DSM in California

- Utilities started providing free technical information to single family houses in 1970s
- Two of three evaluations indicate savings 'that would not have occurred without programs'
- One study finds changed maintenance and other practices more important than use of new equipment
- Some evidence that provision of information by authoritative source is key

RESOURCES FOR THE FUTURE

Table 9-1: Quantitative comparison of the effect of voluntary programs on behavior

	Quantity measured	Estimated Effect	Scope	Baseline	Comment
33/50 Program	Aggregate toxic releases	28%	Participating chemicals facilities	Non-participants with self-selection model	Effect reversed when ODS excluded.
UK Climate Agreements	GHG emissions	9%	Participating industries	Negotiated forecast	Baseline criticized; considerable over-achievement.
Danish Energy Efficiency Agreements	Energy Use	4-8%	Participating facilities	Non-participants	Estimate based on 60 participants.
German Cement Industry GWP Declaration	Energy per unit of cement	0	German cement industry	Econometric forecast using historic performance	Baseline error band is +/- 5%. 2005 target achieved by 2000.
Japanese Keidanren	CO_2 emissions	5%	Participating industries	Keidanren forecast of 2010 BAU	Basis of BAU estimate unclear.
Climate Wise	Fossil energy expenditures	3%	Participating facilities	Matched non-participants	Electricity expenditures estimated to rise 6%. Margin of error is +/- 5% and both effects vanish after 1-2 years.
California Demand Side Management	Natural gas & electricity demand	2-4%	Participating households	Non-participants	Covers three programs; some evaluations more carefully matched non-participants / controlled for self-selection

Conclusions

- Hard to reject conclusion of 5% reduction for energy programs, +/- 5%. Thus, evidence that VPs do change behavior, but not suitable for major reductions
- Significant differences exist between energy and toxics, although clear limitation on toxics as well
- Incentives have modest impact on reductions achieved among participants, potentially larger impact on level of participation
- Efforts to increase program breadth (i.e., many participants) may yield greater environmental gain than efforts to increase depth (big cuts in emissions for individual firms) (broad vs deep)
- More attention needed on baselines for evaluation, including both forecasts and control group approaches
- Subtle changes in social attitudes and corporate practices may be significant but are difficult to measure

RESOURCES FOR THE FUTURE

Voluntary agreements to improve environmental quality: Are late joiners the free riders?

Magali Delmas
University of California, Santa Barbara

Maria J. Montes-Sancho
University Carlos III, Madrid

Voluntary agreements to improve environmental quality (VAs)

- Engage firms and regulatory agencies to improve environmental performance
- Associate private benefits with the voluntary provision of public good
  - Enhance firm reputation
  - Technical assistance
  - Help prevent regulations
- 300 VAs in Europe, 200 in the US
- Examples: Wastewise, Climate Challenge…

Climate Challenge 1995-2000

- US DOE & Electric utility industry
- Firms committed to
  - Reduce, avoid or sequester greenhouse gas emissions
  - Report annually their achievement and activities
- Potential benefits
  - an effective voluntary effort may negate the need for legislation or regulation"
  - "emission reductions could possibly be used for 'credit' against future mandatory requirements."

VAs and the collective action problem

- In VAs benefits are available to all regardless of their personal contributions
- Free riding might be particularly salient in VAs because most of them lack explicit penalties to sanction free riders.
- Reservations about VAs' effectiveness:
  - firms may pursue these collaborative strategies as merely symbolic actions …

Symbolic vs Substantive cooperation

Participation In voluntary agreement

Symbolic cooperation: "ceremonial conformity" decoupling of participation with actual performance improvement: no environmental performance improvement

Substantive cooperation Change in environmental performance after participation in VA

Non Participation in voluntary agreement

Research question

- Since most of these VAs lack explicit measures to sanctions firms that are only undertaking symbolic action, how can these programs effectively encourage cooperation?
- Why and <u>when</u> will firms provide public goods within VAs?
- Under what conditions will a firm undertake substantive cooperation within a VA and how will this vary over time?

Our main thesis

- Incentives/private benefits of participation vary over time and are shaped by the institutional environment
- There is a difference in cooperative behavior between early and late entrants within the VA because private incentives vary with the timing of joining collective action

Empirical issues associated with studying effectiveness

- Need to be able to control participants with a group of non-participants
- Need to evaluate environmental performance, often limited environmental performance data available
- Need to obtain longitudinal data to study evolution over time
- In our study we have information on environmental performance for participants and non participants and information over time

Climate Change political context

- Regulatory Threat?
  - Climate Change Action Plan (CCAP), where President Clinton announced the nation's commitment to reducing U.S. emissions of greenhouse gases to their 1990 levels by the year 2000.
- Incentives outlined by DOE
  - Regulatory benefits: "an effective voluntary effort may negate the need for legislation or regulation" or that "emission reductions could possibly be used for 'credit' against future mandatory requirements."
- Industry position
  - Tom Kuhn, president of the Edison Electric Institute (1996) :

  "Our industry has demonstrated that a vigorous, voluntary approach toward curbing greenhouse gas emissions is the way to go. We will continue to put these programs in place while opposing government and international mandates that would cost the U.S. economy thousands of jobs. Utilities have met the challenge and are continuing their leadership role in working with the government to find creative and effective ways to improve the environment."

H1 Political pressure

- Firms' participation as a signal of "good intention," resulting in a potential future reduction of their level of enforcement
- Firms subjected to a higher level of political and regulatory pressure have more incentives to enroll in a VA and to do it early if its individual benefits outweigh the costs of organizing the collective effort

H1. Early participants in the Climate Challenge Program are subjected to higher political pressure than late joiners and non-participants

H2 Links with the industry association

- Trade associations play an important role in facilitating collective action
  - Information
  - Normative pressure

H2. Early participants in the Climate Challenge Program are more likely to be members of the industry trade association than late joiners and non-participants

H3 Firm's past environmental effort

- If a firm has already been successful at reducing its emissions, it is more likely to join the program early (to get credit for its efforts).

H3. Late joiners of the Climate Challenge Program are less likely than late joiners and non-participants to have undertaken efforts to reduce their emissions prior to the start of the program

H4 Substantive vs Symbolic collaboration

- Because of these different incentives and pressures:

H4. Late joiners are more likely to cooperate symbolically while early joiners are more likely to cooperate substantively within the Climate Challenge Program.

Sample & Data

- Sample: 133 Investor-owned US utilities
  - 61% of US generation & 75% of CO2 emissions emitted by the electricity sector. [Years 1995-2000]
  - 82 firms participate in CCP
- Data came from several public sources
  - FERC Form 1, on which utilities report "everything".
  - U.S. Environmental Protection Agency (EPA), Clean Air Market programs website.
  - U.S. Department of Energy, Climate Challenge website.
  - League of Conservation Voters, Sierra Club, DSIRE, etc.

Empirical challenges

- Decision to participate in the program is likely to be influenced by the same observed and unobserved factors that determine emissions
- Two-stage estimation model that determines simultaneously the outcome of the program participation (here CO2 emission rate) and the determinants of a firm's participation decision
- In the first stage, we wanted to predict not only the probability of participation in the VA, but also to differentiate early and late joiners

Stage 1: participation in program

- In the first stage, we use a multinomial logit model to predict the type of participant as a categorical variable representing three groups:
  - (i) non-participant
  - (ii) late joiner
  - (iii) early joiner (member of the initial meeting of the program in 1995)

Stage 2: performance evaluation

- In the second stage, we used the predicted values of the different types of participation to test whether they explain reductions in emissions.

$$\text{Change in CO2 rate} = \left(\frac{\text{CO2emissions}_t}{\text{Generation}_t}\right) - \left(\frac{\text{CO2emissions}_{t-1}}{\text{Generation}_{t-1}}\right)$$

Independent variables

VARIABLES	DESCRIPTION
H1 Political pressure	**League of Conservation Voters (LCV) :** Environmental Scores of the members of the US House Representatives and Senate (0-100)
	Regulatory Expenses Annual amount of regulatory expenses paid by the firm
H2 Trade association	**Trade association membership** (Edison Electric Institute)
H3 Environmental effort	**Environmental effort:** Expenses that a firm spends for environmental purposes. Source FERC

Controls

VARIABLES	DESCRIPTION
Productive efficiency	Annual Productive Efficiency Index (0-1) using DEA: Output Factors: Low (residential+commercial), industrial, sales for resale. Input Factors: Labor cost, Plant Value, Production expenses, Transmission Expenses, Distribution expenses, Sales Expenses, Administrative Expenses, Purchases in Mwh. Source FERC
Number of subsidiaries	Proxy for the size of the utility
Big player	# of times that a firm is among the top four sellers in a state
State's environmt employees	# of State's environmental employees from Environmental Council of the States (ECOS)
Sierra Club	Number of paying membership of Sierra Club per 1000 state residentsSierra Club
State's dirtiness	State's toxic emissions / land area

Dependent variable	Late joiners	Early Joiners	Early Joiners
Reference group	Non-participants	Non-participants	Late Joiners
Regulatory expenses		+*	+*
League of Conserv Voters	+	+**	+**
State's envir employees	+	-	-
Sierra Club	+	-	-
State's pollution	-	+	+
Trade association's member	+	+**	+**
Productive efficiency	+*	+	+
Environmental effort	-**	+**	+**
% of generation from fossil fuel	-**	-	-*
Visibility / Big player	-	+**	+**
Number of subsidiaries	+	+**	+**
Observations	633	633	633
% correctly classified		78.80%	

Dependent variable: Changes in CO_2 rates (CO_2 rate $_t$ - CO_2 rate $_{t-1}$)	Random GSL	Random GSL
Probability of Participation	-	
Probability of Participation (late joiners)		+
Probability of Participation (early joiners)		-*
Change in percentage of gen from fossil fuel	+**	+**
Change in the number of operating plants	+**	+**
Environmental Effort	+	-
Year of installations (average)	-+	-+
Merger process with electric utility	-	-
Merger process with gas utility	+	+
Information disclosure	+	-
Renewable standard portfolio	-	-
Observations	633	633
R-squared	0.14	0.21

Findings

- Firms were more likely to enter the program early if they
  - experienced a a higher level of political pressure,
  - were part of the trade association
  - were more visible,
  - more efficient,
  - and had already undertaken environmental efforts...
- Symbolic collaboration was more likely with later entrants than with early entrants.
- Late entrants free rode on the efforts of early joiners
- Late joiners that engaged only in symbolic collaboration could potentially endanger the overall effectiveness of the VA

Conclusion

- Our research identifies conditions that trigger different types of collaborative behavior
  - Symbolic and substantive collaboration within VA, and non-participation in the VA
  - Non-participants were significantly different from symbolic participants
- Our findings also challenges some of the findings of previous literature
  - that found a positive link between the quality of early adopters and subsequent adoption
  - Here the quality of early adopters does not guaranty the quality of late joiners

Policy implications

- VAs might not be an effective tool if it they are associated with no sanctions for free riders
- Importance of political pressure to push for reductions
- However, would VAs with sanctions attracts firms to participate?
- VAs with various incentives according to various levels of performance?

Day 2 Presentations

What Drives Participation in State Voluntary Cleanup Programs? Evidence From Oregon

Allen Blackman, Resources for the Future
Thomas Lyon, University of Michigan
Kris Wernstedt, Virginia Tech.
Sarah Darley, Resources for the Future

EPA-NCER Workshop on
Environmental Behavior and Decision-Making
New York, NY
January 14–15, 2008

Outline

- Introduction
- Literature
- Oregon's cleanup programs
- Analytical framework
- Data and variables
- Econometric model
- Results
- Conclusion

Introduction

- 1980: Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Today: over 100,000 contaminated sites still not remediated
  - Liability concerns
  - Limited regulatory resources
- Nearly all states have established voluntary cleanup program (VCPs) to provide incentives for remediation
  - Liability relief
  - Variable cleanup standards
  - Regulatory flexibility
  - Financial incentives
- Today: over 20,000 sites participating in VCPs

What drives participation in VCPs?

- Very little rigorous research
- Lack of data on non-participating sites needed to construct a control group
  - Such sites often "mothballed"
- Alberini (2007)
  - Focuses on Colorado's VCP
  - Uses CERCLIS to construct a control group
  - Finds VCP mainly attracts sites not listed in CERCLIS with little contamination and high development potential

Alberini (2007)

"... these findings cast doubt on whether the [Colorado] VCP is truly attaining its original cleanup and environmental remediation goals and hints at the possibility that participation might be driven exclusively by the desire to rid the parcel of any stigma associated with the current or previous use of land (or to prevent such an effect with future buyers)."

Our study

- Oregon
  - Has a robust VCP
  - Maintains a registry of known contaminated sites (ECSI) including those NOT participating in VCP
- Main findings
  - VCP does attract sites with significant contamination
  - A key driver of participation is publicly "listing" sites with significant confirmed contamination
  - Hence, Oregon has been able to spur voluntary remediation through public disclosure

Literature: drivers of participation in voluntary environmental public programs

- Regulatory pressure
  - Theory (Segerson & Miceli 1998, Maxwell, Lyon & Hackett 2000)
  - Evidence: firms named as superfund responsible parties and firms out of compliance with RCRA and CAA more likely to join EPA's 33/50 program (Khanna & Damon 1999, Videras & Alberini 2000, Sam & Innes 2006, Vidovic & Khanna 2007)
  - Evidence: firms that join voluntary programs receive preferential treatment from regulators (Cothran 1993, Decker 2003)

Literature: drivers of participation in voluntary public programs (cont'd)

- Market pressure
  - Theory (Arora & Gangopadhayay 1995)
  - Evidence: firms with higher advertising/sales ratios and more direct contact with consumers more likely to participate in the 33/50, WasteWi$e & Green Lights programs (Arora & Cason 1996, Vidovic & Khanna 2007, Videras & Alberini 2000)
- Community and NGO pressure
  - Informal regulation (World Bank 2000)
- Transactions costs
  - Project XL (Blackman & Mazurek 2001)

Literature: drivers of remediation

- (Alberini et al. 2005, Wernstedt, Meyer & Alberini 2006, Sherman 2003, Lange & McNeil 2004, Schoenbaum 2002)
  - Liability relief
  - Subsidies
  - Regulatory relief
  - Level of contamination

Literature: public disclosure

- Does it improve environmental performance?
  - Toxic Release Inventory (Bui 2005, Greenstone 2003, Koehler & Spengler 2007)
  - National valuation and ratings programs (García et al. 2007, Powers et al. 2008)
  - 1996 SDA amendments requiring community drinking water systems to publicly report violations (Bennear & Olmstead 2007)
  - Public reporting by electric utilities on fossil fuels use (Delmas, Montes-Sancho & Shimshack 2007)
  - Public reporting of noncompliance in pulp and paper sector in British Colombia (Foulon, Lanoie & Laplante 2002)

Oregon Department of Environmental Quality (DEQ) Cleanup Programs

- Environmental Cleanup Site Information (ECSI) data base
  - Known contaminated, potentially contaminated, formerly contaminated sites
  - July 2006: 4,223 sites
- Confirmed Release List (CRL), a subset of ECSI
  - Sites where contamination is
    - Confirmed
    - Significant in quantity or hazard
    - Not yet cleaned up
  - Formal listing/delisting process w/ public comment period
  - Listing subjects site manager to enhanced pressure from regulators and other stakeholders (e.g., lenders)

Oregon DEQ Cleanup Programs (cont'd)

- Mandatory Site Response Program (10% of ECSI sites)
  - Mainly "high priority" sites
  - DEQ provides oversight and dictates remedial action
- Voluntary Cleanup Program (VCP) (27% ECSI sites)
  - Medium- and low-priority sites
  - Site manager & DEQ jointly develop a cleanup plan
  - Public comment periods
  - Upon successful completion of cleanup plan and public comment, DEQ issues No Further Action (NFA) or Conditional NFA letter
  - Site manager must pay for DEQ time
  - Benefits (according to DEQ)
    - Possible regulatory exemptions from permits
    - Ability to redevelop part of site before cleanup complete
  - Risks (according to DEQ)
    - Sites added to ECSI
    - May be forced into Site Response Program

Oregon DEQ Cleanup Programs (cont'd)

- Independent Cleanup Pathway (ICP) (7% ECSI sites)
  - High-priority sites excluded
  - Less oversight than VCP
  - Site managers may independently conduct cleanup and then request approval from DEQ
  - No waivers of DEQ permits

Analytical Framework

- Managers join VCP/ICP if expected benefits > costs
  - Expected benefits of joining
    - Avoided cost of future liability for cleanup from obtaining NFA
    - Appreciation in property value from obtaining NFA
    - Avoided costs imposed by community/NGOs
    - Avoided additional (transactions and cleanup) costs of mandatory SRP
  - Expected costs of joining
    - Transactions costs (pecuniary & nonpecuniary)
    - Cleanup costs
    - For non-ECSI sites, costs associated with informing DEQ about contamination
- These expected benefits & costs vary across sites
- We don't observe benefits & costs directly, but do observe proxies

Regression samples

- Beginning with 4,223 ECSI sites, drop sites…
  - For which data is missing or inconsistent
  - Which are not eligible to participate
  - For which participation was not fully voluntary
- VCP sample
  - 1680 sites of which 36% joined VCP
- ICP sample
  - 1642 sites of which 9% joined ICP

Variables in Econometric Analysis

Variable	Description	VCP Sample		
		All n=1,680	Parts. n=613	Nonparts. n=1,067
DEPENDENT				
VCP	Participant in Voluntary Cleanup Program?*	0.365	1	0
ICP	Participant in Independent Cleanup Pathway?*	0.107	0.109	0.105
INDEPENDENT				
Regulatory activity				
CRL	On Confirmed Release List?*	0.255	0.423	0.159
CERCLIS	In CERCLIS?*	0.168	0.119	0.197
PERMIT	Has DEQ permit?*	0.168	0.194	0.150
E_REGION	In DEQ eastern region?*	0.263	0.321	0.229
W_REGION	In DEQ western region?*	0.371	0.238	0.448
NW_REGION	In DEQ northwestern region?*	0.366	0.440	0.323
Neighborhood characteristics				
HOUSEVAL	Median house value in census block group ($)	142,237.1	145,068.4	140,610.5
TR_TIME	Med. travel time to work in census block group (min.)	12890.9	13,120.9	12,758.8
Prior use				
14 dummies	Two-digit SIC code categories			

Duration model

$$h(t, \mathbf{X_t}, \beta) = f(t, \mathbf{X_t}, \beta)/(1 - F(t, \mathbf{X_t}, \beta))$$

where
f = density gives pr(event at time t)
F = cumulative density

$$h(t) = h_0(t)\exp(\mathbf{X_t}'\beta)$$

where
$h_0(t)$ = baseline hazard rate

Advantages of duration model

- Controls for potential endogeneity of *CRL* and *PERMIT*
- Controls for right censoring: sites may join VCP/ICP after our panel ends

Regression Results
(hazard ratios and S.E.s)

Variable	Model 1 Dep. var. = VCP	Model 2 Dep. var. = VCP	Model 3 Dep. var. = ICP
Regulatory activity			
CRL	1.280** (0.125)	1.021 (0.212)	0.743 (0.167)
CERCLIS	1.024 (0.149)	1.026 (0.150)	1.455 (0.425)
PERMIT	1.303** (0.139)	1.310** (0.139)	0.956 (0.259)
W_REGION	1.122 (0.131)	1.126 (0.132)	3.240*** (0.815)
NW_REGION	1.342** (0.165)	1.327** (0.165)	2.577*** (0.737)
Neighborhood characteristics			
HOUSEVAL	1.000 (0.00000069)	1.000 (0.0000074)	1.000 (0.0000011)
TR_TIME	1.000* (0.000004)	1.000** (0.0000048)	1.000 (0.0000083)
Interaction terms			
CRL_HOUSEVAL	n/a	1.000** (0.0000012)	n/a
CRL_TR_TIME	n/a	1.000 (0.0000075)	n/a
Prior use			
13 dummies	13 significant	13 significant	4 significant
Number of observations	1,680	1,680	1,642
Log pseudolikelihood	-3687.138	-3685.5098	-771.856

*** significant at 1% level
** significant at 5% level
* Significant at 10% level

Results

- The probability of joining the VCP is significantly greater for sites that are
  - Both on the Confirmed Release List *and* that are relatively valuable
  - Permitted
  - In the northwest DEQ region
  - Relatively far from employment centers
  - In certain economic sectors
- The probability of joining the ICP is significantly greater for sites that are
  - In the west or northwest DEQ region
  - In certain economic sectors

Conclusions and policy implications

- Both VCP and ICP are attracting sites with significant contamination
  - VCP: 42% of 613 participating sites “listed” in CRL
  - ICP: 25% of 155 participating sites “listed” in CRL
- Listing high-value sites increases probability of joining VCP
  - By increasing regulatory & non-regulatory pressure and therefore raising expected benefit of joining?
- Together, these 2 findings imply DEQ is able to spur voluntary remediation via public disclosure (CRL)
  - A mechanism for encouraging voluntary remediation that has received little attention
  - Presumably relatively inexpensive
  - Comports with literature on public disclosure

Thank you

Should You Turn Yourself In? The Consequences of Self-Policing

Sarah L. Stafford
The College of William and Mary

Research Supported by EPA STAR Grant R831036

Self-Policing and the Audit Policy

- Self-policing occurs when a regulated entity voluntarily notifies authorities that it has violated a regulation or law.
- EPA encourages self-policing through the Audit Policy.
  - No "gravity-based" penalties for disclosed violations that meet the policy's conditions. EPA also will not recommend criminal prosecution for such violations.

"The Audit Policy is designed to provide incentives for regulated entities to come into compliance with the federal environmental laws and regulations. These incentives are for regulated entities that voluntarily discover, promptly disclose and expeditiously correct noncompliance, <u>making formal EPA investigations and enforcement actions unnecessary</u>."

EPA Website on Compliance Incentives and Auditing,
Accessed December 5, 2007

Theoretical Framework

- Based on Harrington's (1988) Targeted Enforcement Model:
  - Facilities divided into groups based on past compliance.
  - "Bad" facilities are targeted, i.e., inspected with higher probability than facilities with good compliance records.
  - Facilities move between groups based on inspection results.

Theoretical Framework

- When self-policing is added to a targeted enforcement regime, disclosures provide additional information that can be used to move facilities between groups.
- Also, to make the model consistent with hazardous waste compliance, there are both deliberate and inadvertent violations.

Theoretical Framework

- In the model, facilities have two choices to make:
  - Whether to deliberately violate the regulations.
  - Whether to audit to discover inadvertent violations.
- The optimal strategy depends on the facility's cost of compliance, cost of auditing, the probability of an inspection, the fine for a violation, the fine for a disclosure, and the transition probabilities.

Theoretical Framework

- A regulator can alter a facility's optimal strategy by changing inspection rates, fines, or the transition probabilities.
  - Decreasing the fine for a disclosure leads to more disclosures, and potentially more audits, at facilities in the target group.
  - Increasing the transition probability for facilities that disclose increases disclosures and audits at facilities with poor compliance records.

Theoretical Framework

- However, if facilities that disclose are rewarded with a lower probability of future inspections, they may decrease the level of deliberate compliance.
  - The leverage of the targeted enforcement regime is reduced.

Empirical Analysis

- Uses data on all facilities in the US subject to hazardous waste regulations.
  - 631,000 facilities according to RCRAInfo.
- Uses data on 2001 self-disclosures.
  - At least 1,158 facilities involved in disclosures, 325 subject to RCRA regulations.

Empirical Analysis

- Examines the effect that a 2001 disclosure has on probability that facility is inspected in 2002.
- Uses a bivariate probit regression, as decision to disclose depends in part on expected enforcement actions.
  - Model identified through exclusion restriction (State Audit Immunity).

Empirical Results – Facility Characteristics

	Inspection Equation	Disclosure Equation
Large Quantity Generator	0.73**	0.64**
Small Quantity Generator	0.21**	0.19**
Conditionally Exempt Generator	0.12**	0.03
Treatment, Storage, or Disposal Facility	0.63**	-0.29**
Transporter	0.22**	-0.11
Other Permit	0.21**	0.33**

**Significant at 95%, *Significant at 90%

Empirical Results – Enforcement and Compliance Variables

	Inspection Equation	Disclosure Equation
Inspected in 2001	0.07**	0.09
Five Year Inspection History	0.39**	0.12**
Ignored	0.04**	-0.18**
Violated in 2001	0.12**	0.04
Newly Caught in 2001	0.18**	0.02
Five Year Violation History	0.01**	-0.0003
Good Compliance Record	-0.17**	-0.02
Disclosure in 2001	-1.34**	
Disclosure in 2001 x Good Comp. Record	0.35*	

**Significant at 95%, *Significant at 90%

Empirical Results – State Variables

	Inspection Equation	Disclosure Equation
State Audit Privilege	-0.08**	-0.04
State Audit Immunity		0.18**
State Self-Policing Policy	-0.06**	0.10*
State Inspections	7.07**	0.53
State Inspection Intensity	-0.28**	-0.18**
State Violations	1.67**	1.59*
State Regulated Facilities (in 100,000s)	-0.58**	-0.74**

**Significant at 95%, *Significant at 90%

Empirical Results

- Disclosures affect the probability of inspection.
  - The magnitude of the effect depends on compliance history, but the effect is always a reduction in the probability of inspection.
- Facilities with a high probability of inspection are more likely to disclose.

Policy Implications

- The empirical analysis generally supports the targeted enforcement model with self-policing.
- In the theoretical model, facilities may increase auditing and abatement without making disclosures, so we should not evaluate the effectiveness of self-policing solely based on disclosures.

Policy Implications

- Facilities may make tradeoffs between self-policing and other forms of regulatory compliance when disclosures affect future enforcement.
  - If reduced penalties alone are not enough to induce auditing and disclosure, decreased future enforcement may be necessary to motivate self-policing.
  - Regulators need to carefully weigh the benefits of increased self-policing against the potential that facilities may strategically disclose.

Policy Implications

- How significant is the potential for strategic disclosures?
  - Disclosure rates in the regulated community are currently low, but they are likely to increase for many reasons.

Policy Implications

- Facilities with very low probabilities of inspection do not disclose.
  - However, these facilities have the lowest level of contact with regulators and thus are more likely to inadvertently violate.
  - Regulators might want to focus outreach efforts on such facilities or consider methods for increasing the incentives for these facilities.

Green Production through Competitive Testing

Erica Plambeck
Stanford University
Graduate School of Business

Terry Taylor
U.C. Berkeley
Haas School of Business

LARGE MARKETS ARE RESTRICTING USE OF HAZARDOUS SUBSTANCES (RoHS)

EU, China, California RoHS: illegal to sell electronics containing lead, mercury, cadmium, brominated flame retardants

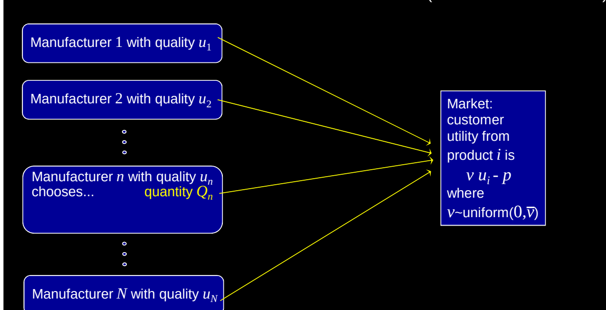
Dutch authorities, acting on tip-off from competitor about cadmium in a cable, halted sale of Sony Playstations; Sony lost $110 million in revenue.

Should regulator rely on manufacturers for testing?

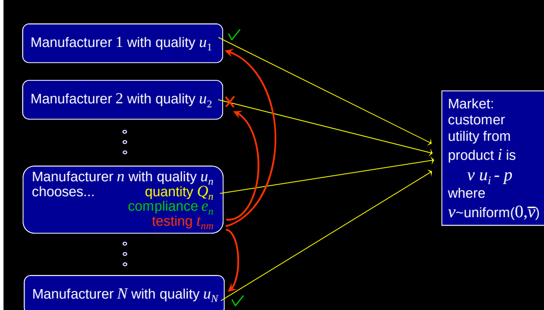
What is the impact of competitive testing on
- *industry structure*
- *output*
- *profitability*
- *environmental impacts*

MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS

(Shaked and Sutton 1982)



MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS



MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS

Regulator

Manufacturer 1 with quality u_1

Manufacturer 2 with quality u_2

Manufacturer n with quality u_n chooses... quantity Q_n, compliance e_n, testing t_{nm}

Manufacturer N with quality u_N

MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS

Regulator

t_{Rn} less effective in testing $\alpha \in (0,1]$

Manufacturer 1 with quality u_1 — t_{1n}

Manufacturer 2 with quality u_2 — t_{2n}

Manufacturer n with quality u_n chooses... quantity Q_n, compliance e_n, testing t_{nm}

Manufacturer N with quality u_N — t_{Nn}

Manufacturer n sells

$$\tilde{Q}_n = \begin{cases} 0 & \text{w.p. } (1-e_n)\, d\left(\alpha t_{Rn} + \Sigma_{i \neq n}\, t_{in}\right) \\ Q_n & \text{otherwise} \end{cases}$$

at price $p_n = \bar{v}\left(u_n - \Sigma_{i=1}^{N} \min(u_n, u_i)\tilde{Q}_i\right)$

MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS

Regulator

t_{Rn} less effective in testing $\alpha \in (0,1]$

more poorly informed of compliance cost $\theta\left[c(e_n)Q_n + F(e_n)\right]$

manufacturers know realization of r.v. θ

regulator only knows distribution

Manufacturer 1 with quality u_1 — t_{1n}

Manufacturer 2 with quality u_2 — t_{2n}

Manufacturer n with quality u_n chooses... quantity Q_n, compliance e_n, testing t_{nm}

Manufacturer N with quality u_N — t_{Nn}

Manufacturer n sells

$$\tilde{Q}_n = \begin{cases} 0 & \text{w.p. } (1-e_n)\, d\left(\alpha t_{Rn} + \Sigma_{i \neq n}\, t_{in}\right) \\ Q_n & \text{otherwise} \end{cases}$$

at price $p_n = \bar{v}\left(u_n - \Sigma_{i=1}^{N} \min(u_n, u_i)\tilde{Q}_i\right)$

MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS

Regulator

Manufacturer 1 with quality u_1

Manufacturer 2 with quality u_2

Manufacturer n with quality u_n chooses... quantity Q_n, compliance e_n, testing t_{nm}

Manufacturer N with quality u_N

Begin by focusing on
- short run equilibrium in compliance and testing (quantity/capacity fixed)
- symmetric firms and equilibria

Results extend (numerically) to setting with endogenous capacity and entry decisions

Environmental cost is $x\, \Sigma_{i=1}^{N}(1-e_i)Q_i$

REGULATOR SHOULD RELY ON COMPETITIVE TESTING WHEN ENVIRON. COST IS MODERATE

Analytical Result:

Regulator maximizes expected social welfare by…

not imposing RoHS	imposing RoHS and relying on competitive testing	imposing RoHS and directly testing

$\underline{x}$ ... $\overline{x}$ — environmental cost parameter x

REGULATOR SHOULD RELY ON COMPETITIVE TESTING WHEN ENVIRON. COST IS MODERATE

Analytical Result:

Regulator maximizes expected social welfare by…

not imposing RoHS	imposing RoHS and relying on competitive testing	imposing RoHS and directly testing

$\underline{x}$ ... $\overline{x}$ — environmental cost parameter x

Numerical Results:

Relying on competitive testing is attractive ($\overline{x}/\underline{x}$ is large) when…

- Number of firms is small
- Testing is effective
- Compliance cost is low

} compliance high under competitive testing alone

- Regulator is highly uncertain of compliance cost and less effective in detecting noncompliance } regulator ineffective in encouraging compliance

Range of environmental cost where relying on competitive testing is optimal is “large” (in study $\overline{x}/\underline{x}$ averaged 2.5)

FIRMS MAY BENEFIT BY REGULATION

Numerical Result:
For some parameters

mfg. expected profit without RoHS < mfg. expected profit with RoHS and only competitive testing < mfg. expected profit with RoHS and regulator testing

Intuition:

Negative Impact of RoHS/Testing on Mfg.
- Possible blocking of mfg's product
- Higher production cost

may be outweighed by

Positive Impact of RoHS/Testing on Mfg.
- Higher expected price
- Regulator testing saves mfg. cost of testing

FIRMS MAY BENEFIT BY REGULATION

Numerical Result:
For some parameters

mfg. expected profit without RoHS < mfg. expected profit with RoHS and only competitive testing < mfg. expected profit with RoHS and regulator testing

If, in addition, the environmental cost is moderate $x \in (\underline{x}, \bar{x})$,
then both firms and society are better off under competitive testing

COMPETITIVE TESTING INEFFECTIVE WITH LARGE NUMBER OF FIRMS

Analytical Result:
Under competitive testing, equilibrium compliance effort is decreasing in the number of firms N

Intuition:
As number of firms increases…
- total equilibrium testing applied to each firm decreases
  because
  - value of knocking out a competitor is smaller
  - free rider problem in testing is exacerbated

COMPETITIVE TESTING INEFFECTIVE WITH LARGE NUMBER OF FIRMS

Analytical Result:
Under competitive testing, equilibrium compliance effort is decreasing in the number of firms N

Intuition:
As number of firms increases…
- total equilibrium testing applied to each firm decreases
  ↓
  smaller chance of getting caught → invest less in compliance
- market is more competitive, decreasing value of bringing goods to market → invest less in compliance

Competitive testing fails in competitive industries (many firms) and only succeeds in uncompetitive industries (few firms)

COMPETITIVE TESTING INEFFECTIVE WITH LARGE NUMBER OF FIRMS <u>OF LOW QUALITY</u>

Analytical Result:
Under competitive testing, equilibrium compliance effort is decreasing in the number of firms N and
<u>increasing in the quality level u</u>

Intuition:
As customer willingness to pay increases, firms have more to lose from being discovered as noncompliant

Conclusion:
In industries with many manufacturers, each with weak brands, compliance under competitive testing will be low, with consequent environmental damage

COMPETITIVE TESTING ENCOURAGES ENTRY BY "WHITE BOX" MANUFACTURERS

Analytical Result:
If manufacturer *n*'s "quality" u_n is sufficiently small, then in any Nash equilibrium, manufacturer *n*…

- draws less testing from its competitors ← value of knocking out low-quality mfg. is small
  $\Sigma_{i \neq n}\ t_{in} < \Sigma_{i \neq m}\ t_{im}$ for all $m \neq n$
- does not comply with RoHS ← market is less valuable to low-quality mfg.
  $e_n = 0$
- does not test its competitors' products ← market is less valuable to low-quality mfg.
  $t_{nm} = 0$ for all $m \neq n$
- has strictly greater expected profit

COMPETITIVE TESTING ENCOURAGES ENTRY BY "WHITE BOX" MANUFACTURERS

Analytical Result:
If manufacturer *n*'s "quality" u_n is sufficiently small, then in any Nash equilibrium, manufacturer *n*…

- draws less testing from its competitors
  $\Sigma_{i \neq n}\ t_{in} < \Sigma_{i \neq m}\ t_{im}$ for all $m \neq n$
- does not comply with RoHS
  $e_n = 0$
- does not test its competitors' products
  $t_{nm} = 0$ for all $m \neq n$
- has strictly greater expected profit

value of knocking out low-quality mfg. is small

market is less valuable to low-quality mfg.

SUMMARY OF RESULTS

Relying on competitive testing to enforce regulations is effective in a range of circumstances…

Competitive testing fails in competitive industries (many firms) and only succeeds in uncompetitive industries

Competitive testing creates incentive for entry by environmentally-damaging "white box" manufacturers

Results apply more broadly to competitive markets governed by product-based health, safety standards

EXTENSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Possibility of collusion — reduced by private reporting, but relevant with few firms

RoHS violations reduce brand value in subsequent periods

Environmental nonprofits test products

— reinforces conclusion that firms with stronger brands will have higher compliance

Environmental costs depend on hazardous substance content and how disposed at end-of-life

POLICY IMPLICATIONS

Relying on competitive testing to enforce regulations will tend to be effective when…

…the industry is dominated by a small number of players (but enough players to discourage collusion)

…firms have strong brands to protect and "pricing power"; market in which the firms compete is attractive/profitable

…firms are better informed about:
- the costs and means of compliance (environmental improvement)
- how to detect violations by other firms

…the social cost of noncompliance is "moderate"

…barriers prevent entry by small firms that could produce in an environmentally damaging way

Disclosure As a Regulatory Instrument for the Environment: A Study of the PCB Industry

Linda T.M. Bui

Jennifer F. Helgeson

(January 2008: EPA Conference)

How Does Mandatory Disclosure Affect Firm Behavior?

Two important requirements:

- 1. Public disclosure must provide **new** information to economic agents.
- 2. The economic agents must be able to use that information to affect firm profitability.

Successful Examples of Disclosure as a Regulatory Mechanism

- Food labeling
- Medical package inserts
- Securities laws

In each case, negative information can reduce firm profitability directly through reduced demand

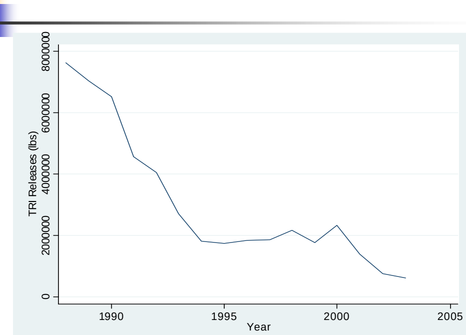
Potential Difficulties Using Disclosure for Pollution Abatement

- The relationship between the agents who receive the information and firm profitability is not clear:
  - Consumers may not be aware of, understand, or care about, the pollution embodied within a good. (Green marketing has not always been so important.)
  - Households living near dirty plants do not necessarily value lower toxic releases; firms may benefit from having lower property values surrounding their facilities.
  - Liability issues are difficult to asses – particularly as many of the effects from toxic exposure are long-term.

Why Study the PCB Industry?

- PCB production is one of the largest contributors to pollution in the micro-electronics industry, but is still small relative to industries such as petroleum or pulp and paper. (Primarily water pollution.)
- Most studies have focused on the biggest and dirtiest industries.
- Significant changes in market structure over the past 50 years make it less likely for the industry to respond to voluntary pollution abatement programs (decreasing concentration; increasing foreign competition on cost).
- Yet, we see in this industry that reported releases fell by more than 96% between 1988-2003.

Aggregate TRI Releases in the PCB Industry: 1988-2003



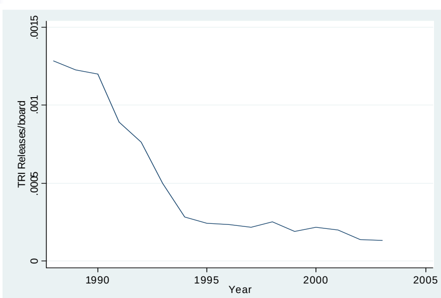
Possible Explanations for the Observed Reductions

- Changes in output
- Paper reductions
- Substitution away from listed to unlisted substances
- Reductions attributable to command and control regulations for other pollutants
- Response to mandatory disclosure

Issues of Concern

- Correct normalization of releases?
  - By number of boards?
  - By size of boards?
  - By TVS?
- Plant exit.
- Reduction of toxic releases due to other Federal regulations or policies.
- State-level programs.

TRI Releases Per Board: 1988-2003



Accounting for Plant Attrition

We find that:

- Exiting plants are dirtier than remaining plants.
- However, those plants that do not exit from the sample show a similar pattern in (aggregate) reductions over time.
- If we restrict ourselves to the balanced panel of plants that are in the sample for the entire period (only 24 of 597 facilities), reductions are also of the same order of magnitude.

The Basic Model

1. $TRI_{it} = \beta_0 + \beta_1 PUBLIC_{it} + \beta_2 PC3350_{it} + \beta_3 POST\ 3350_{it} + \beta_4 NON_{it}$

$$+ \beta_5 SRANK_{i\,t-2} + \beta_6 SREG1_{it} + \beta_7 SREG2_{it} + \delta_t + \varepsilon_{it}$$

Where:
PUBLIC = 1 if the parent company is publicly traded at time t
PC3350 = 1 if the parent company participated in 33/50 program
POST3350 = 1 if pc3350=1 and year > 1995
NON = 1 if facility located in a non-attainment county
SRANK2 = facility's state ranking at t-2
SREG1 = SRANK2 * REG1; REG1 = 1 if in state with TRI reduction goals
SREG2 = SRANK2 * REG2; REG2 = 1 if in state with additional TRI programs but no numeric reduction goals.

** Also estimated in "first-differences" with changes in attainment status

Possible Modifications to the Model

- Break down releases into different pollution media (eg. air, water)
  - Note that not all facilities report toxic releases in all forms
  - Take into account ratio of hazardous air pollutants in air model
  - Take into account ratio of CWA pollutants in water model

Descriptive Statistics on the Regression Sample

Variable	Mean	Standard Deviation
TRI (lbs)	11348.01	38747.07
Initial (year = 1988)		
- Total	59050.82	222048.5
- Air	35005.38	134097.6
- Water	967.15	10691.31
One-Time Release	14.95	333.36
33/50 Participant	0.07	0.26
Publicly Traded	0.24	0.43
State TRI Program		
- REG1	0.48	0.50
- REG2	0.08	0.27
Non-Attainment	0.77	0.42
Number of Obs: 1939		

Aggregate TRI Releases: Levels and First-Differences (Select Results)

Variable	TRI	ΔTRI
PC33/50	38,054.45* (20661.97)	-35,351.98*** (15232.42)
POST 3350	5,737.39 (25518.74)	26,657.04 (16670.73)
PUBLIC	9,554.37** (4541.00)	-135.96 (2371.12)
SRANK2	-2,130.56*** (376.53)	586.028*** (193.04)
SREG1	1,808.82*** (360.48)	-471.03*** (183.61)
SREG2	604.92 (438.97)	-224.54 (245.30)
NON	-10,664.42*** (4242.58)	2951.78 (2407.76)
Year Indicator	X	X
R-Squared	0.12	0.06

TRI: Air Releases for Facilities Reporting Non-Zero Air (Select Results)

Variable	TRI-Air
NON-ATTAINMENT	-4,745.55* (2239.66)
RATIOH	-9875.75** (4218.57)
H	27,822.81* (12243.32)
SRANK2	-1,198.29*** (264.40)
SREG1	991.38*** (251.93)
SREG2	435.14 (320.06)
YEAR INDICATORS	X
H x YEAR INDICATORS	X
R-SQUARED	0.29

TRI: Water Releases for Facilities Reporting Non-Zero Water (Select Results)

Variable	TRI-Water
NON-ATTAINMENT	-2,655.64 (2171.64)
RATIOW	-5,644.30** (2850.33)
W	2818.72 (2092.25)
SRANK2	-602.59* (360.56)
SREG1	588.63* (352.19)
SREG2	278.52 (352.85)
YEAR INDICATORS	X
H x YEAR INDICATORS	X
R-SQUARED	0.20

Explaining Toxic Releases in the PCB Industry, Part I

- 1. Exit from industry by the dirtiest facilities led to part of the over-all reduction in industry level releases.
- 2. Facilities located in non-attainment counties have significantly lower levels of releases. We find some evidence that changes in attainment status also are associated with larger reduction in toxic releases.

  We estimate that TRI levels would be between 125%-245% higher than current levels if no facilities were located in non-attainment counties.
- 3. Federal regulations for water pollution (CWA) and for hazardous air pollutants (HAPS) also play an important role in the reduction of toxics.

Explaining Toxic Releases in the PCB Industry, Part II

- 4. Although facilities located in attainment counties start out being significantly dirtier than facilities located in non-attainment counties, all other things being equal, attainment facilities reduced their toxic releases more rapidly than non-attainment facilities such that by 2003, the facilities were not significantly different from one another.
- 5. State-level TRI programs make a difference. Facilities located in states with specific reduction targets for TRI substances showed significantly compressed distributions of releases of all types. We find evidence that states only with out-reach programs for TRI polluters have compressed distributions of air releases.

Policy Implications/Recommendations

- 1. State level policy perceived as being a "threat" of future formal regulation, if not met voluntarily, may induce firms to abate.
- 2. Outreach programs that provide information to polluters on pollution prevention or pollution reduction methods may also have a beneficial effect on releases. This may be especially true for industries that are dominated by small and medium sized polluters who do not have the resources to carry out research and development on PPP.
- 3. There are positive externalities for toxic releases that exist from formal regulation of non-toxic pollutants.
- 4. A better understanding of the mechanism through which public disclosure affects firm behavior is extremely important if policy makers wish to rely upon it as a regulatory tool.

The Effectiveness of Information Disclosure: An Examination of the TRI

Nicholas School of the Environment and Earth Sciences
DUKE UNIVERSITY

Lori Bennear, Madeleine Baker, Michael Lenox, and Andrew King

EPA Workshop
January 15, 2008

RESULTS ARE PRELIMINARY
DO NOT CITE OR QUOTE

1

Decision-Making Scenario

- Thinking about implementing (or expanding or reducing) an information disclosure requirement
- The program is costly
  - Time for regulated entities
  - Time to process data, administer program
  - Costly to make changes, if any are made, to improve performance
- Benefits are real, but less tangible

2

Information Disclosure as Policy Tool

- Overcome informational asymmetries
- Improve allocation of public resources
  - Public safety, enforcement, outreach
- Provide data for analysis
  - Internal and external
- Motivate changes in behavior
  - Pollution control instrument
  - Complement or substitute traditional regulation

3

Information Disclosure as a Pollution Control Instrument

- Causal Inference
  - Under what circumstances does information disclosure about public goods improve environmental performance?
- Causal Mechanism
  - How does information disclosure about public goods improve environmental performance?

5

Problems With Causal Inference

- Only observe data for entities that are required to report.
  - Only observe data for the “treatment” facilities
  - Can’t compare treatment to control facilities that do not report
- Only observe data during years where reporting is required
  - Can’t compare treatment facilities during a regulated year to treatment facilities during an unregulated year

6

Possible Causal Mechanisms

- Market Mechanism
- Political Mechanism
- Institutional Mechanism

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Our Analysis of TRI

- Capitalizes on major changes in reporting requirements
- "Treatment" is defined as being newly subject to the TRI requirements (e.g. a facility required to report for the first time or a facility reporting for a chemical for the first time)
- The "control" group are facilities that have reported previously.
- Use differences-in-differences estimators of causal effect.

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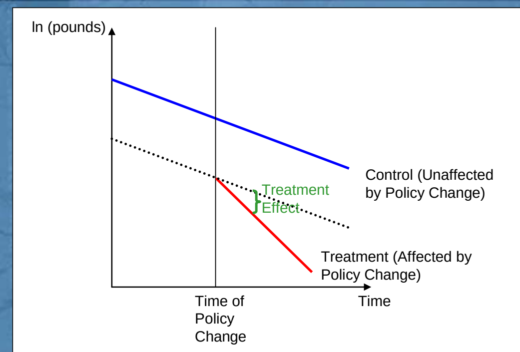

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Identifying Assumptions

- The difference-in-difference estimator will identify the causal affect of the policy change if:
  - In the absence of the policy change the trends in releases for the treatment and control groups would have been parallel.
  - In other words, we are controlling for important differences in the trend.

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Treatment Category 1—New Industries

- At inception the TRI only covered manufacturing facilities (facilities in SIC 20-39).
- The TRI has been expanded several times since 1988 to cover more facilities.
- In 1994, federal facilities were required to report to TRI.
- In 1997, coal mining facilities, metal mining facilities, electrical utilities, chemical wholesalers, petroleum terminals/bulk stations, and solvent recovery services were required to report to TRI.

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Treatment Effect for New Industries

- Comparing reporting facilities in newly reporting industries to reporting facilities in original industries
- Because industry is a key determinant of both the level of releases and the trend in releases over time, differences-in-differences not likely to yield valid causal effect
- Less priority on this analysis

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Treatment Category 2—New Chemicals

- Original list of nearly 300 reportable chemicals.
- In 1995, facilities were required to report releases to the TRI of nearly 300 additional chemicals bringing the total number of chemicals reported to approximately 600.
- "Treatment" is based on chemical and takes a value of 1 if newly reported chemical in 1995.

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Treatment Effect for New Chemicals

- Comparing trends in releases of new chemicals to trends in releases of previously reported chemicals
- Why we might find a result
  - When you report for something for the first time, serves as focusing device.
  - More likely to make changes
  - Once initial changes are made (low hanging fruit), changes are less likely
- Why we might not find a result
  - Cannot do this analysis for first set of chemicals (1987)
  - If newly reported chemicals are used in same processes as previously reported chemicals, all of the release-lowering changes may have already been made

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Finding for New Chemicals

- Do releases of newly reportable chemicals in 1995 differ from trends in chemicals previously reportable.
  - Within the same facility (control for production, facility-specific factors)
  - Control for industry (industry dummies and separate regressions by 2-digit SIC)
  - Control for common time shock (time dummies)
- Limited evidence of this
  - Usually not statistically significant
  - For a couple of industries you can see a small negative (improved performance) effect

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Treatment Category 3—Lowered Thresholds

- Most chemicals facilities are only required to report releases to TRI if they manufacture or process more than 25,000 pounds or otherwise use more than 10,000 pounds of a listed chemical.
- In 2000, Mercury threshold lowered to 10 pounds.
- In 2001, Lead threshold lowered to 100 pounds.
- Treatment in this case is reporting for lead or mercury for the first time in 2001 or 2000, respectively.

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Treatment Effect for Lowered Thresholds (1)

- Comparing trends in releases of newly reporting facilities to trends in releases of previously reporting facilities for lead and mercury only
- Why we might find a result
  - When you report for something for the first time, serves as focusing device.
  - More likely to make changes
  - Once initial changes are made (low hanging fruit), changes are less likely
- Why we might not find a result
  - Comparing across facilities
  - Facilities that reported for lead and mercury under higher thresholds may be quite different in ways that affect both the level of releases and the trend in releases

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Treatment Effect for Lowered Thresholds (2)

- Also compare trends in lead/mercury to trends in other chemicals for facilities that previously reported for other chemicals, but are newly reporting for lead/mercury.
- Eliminates cross facility comparison problems.
- May not find anything if changes were already made when facility reported for earlier chemicals. Same problem as with new chemical analysis.

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Findings for Lowered Thresholds

- In the cross-facility comparison
  - No statistically significant effect for mercury
  - Often statistically significant but POSITIVE effect for lead (opposite of our hypothesis)
  - True even when we eliminate outliers
- In the within-facility comparison
  - Often is statistically significant effect, but POSITIVE (opposite of our hypothesis)

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Caveats

- These results are preliminary
- Lack of evidence of causal effect does not mean information disclosure is not worthwhile
  - Cannot identify these effects from initial reporting, only from changes
  - All the action may have been at the beginning
- Even if information disclosure doesn't affect performance, may still be worthwhile
  - Facilitates allocation of public and private resources
  - Provides data for analysis

Future Work

- Examine alternative outcome measures
  - On-site releases versus off-site releases
  - Weight releases by toxicity
  - Engage in more source reduction activities
- Connect data to firm and examine strategic responses

Regulation with Competing Objectives, Self-Reporting, and Imperfect Monitoring

Scott M. Gilpatric
Mary F. Evans and Lirong Liu
University of Tennessee

Work partially funded by EPA STAR grant #R832847.

Introduction

- Environmental information disclosure programs may yield both direct and indirect benefits
  - Indirect benefit results from increasing firms' private costs of emitting, and thereby reducing emissions
  - Direct benefit occurs if disclosure itself reduces the social costs associated with a given level of emissions

Introduction

- Firms may incur costs in many ways when disclosing (potentially) harmful emissions:
  - Most directly if reported emissions are taxed
  - Due to increased exposure to liability
  - Market reaction impacting the firm's value
  - Consumer demand response

Introduction

- Timely disclosure of emissions may reduce social costs in several ways
  - Private parties and public agents can respond to mitigate or avoid damages
  - Contaminated resources can be avoided
  - Clean-up can be more efficiently managed
  - Cumulative harm of repeated emissions can be foreseen and mitigated

Introduction

- Focus of both theoretical and empirical literature has been on emissions reductions arising from disclosure programs (the indirect benefit): Malik [1992], Swierzbinski [1994], Hamilton [1995], Khanna et al. [1998], Livernois and McKenna [1999], Konar and Cohen [2001]
- Less attention has been given to the fact that information disclosure may directly improve social welfare
  - "The environmental information embodied in [disclosure programs] has economic value…even in the absence of any changes in emissions by firms." [EPA, 2001]

Introduction

- We present a model of optimal regulatory policy when a disclosure program yields both direct and indirect benefits, but enforcement of disclosure requirements is costly and imperfect
- We first must model the behavior of a firm which chooses both how much to emit and how much of its emissions to disclose as a function of the regulatory environment

Introduction

- Model of firm behavior assumes:
  - Firm pays a tax on disclosed emissions
  - Firm pays a penalty on revealed undisclosed emissions
  - An imperfect audit by the regulator may reveal some (not necessarily all) undisclosed emissions
- Given this understanding of firm behavior, the regulator chooses tax rate and audit probability (i.e. enforcement intensity) to minimize social welfare costs

Introduction

- In our framework a regulator has competing objectives
  - Internalizing socials costs, e.g. through emissions taxes, will deter emissions
  - Increasing the cost firms incur for disclosed emissions generates a disincentive to disclose information
- Regulator must also account for enforcement costs of achieving compliance

Related literature

- Malik [1992] and Swierzbinski [1994] have shown that environmental disclosure programs can improve social welfare, but through a very different mechanism
  - Do not incorporate direct benefit of disclosure
  - Benefit of self-disclosure occurs by enabling regulator to achieve a given level of emissions reductions with lower enforcement costs
  - Utilize framework in which firm's fully reveal their emissions under optimal regulatory policy ("truthful revelation")
  - Audits (if undertaken) perfectly reveal firm behavior

Model of the Representative Firm

- A representative firm is subject to a mandatory disclosure program which requires the firm to report an emissions level
- The firm is audited with probability p
- At time zero
  - The firm emits an amount of pollution, denoted e
  - The firm chooses reported emissions to submit to regulator, with z denoting the share of actual emissions reported
  - The firm is subject to a per unit tax on reported emissions, denoted α

Model of the Representative Firm

- At time one
  - If the firm is audited the audit reveals a quantity of emissions, denoted x, which depends on the firm's actual emissions and a random variable u: $x=eu$
    - Assume u is distributed with pdf $f(u)$ and cdf $F(u)$ on $[0,b]$
    - We allow possibility that audit "reveals" more than is actually emitted, but assume the single mode of the distribution lies at 1
  - If the revealed level of emissions is greater than the reported level, the firm incurs a constant per unit penalty of β on revealed but unreported emissions

Model of the Representative Firm

- Firm chooses report, z, to minimize expected costs,

$$\underset{z}{Min}\ e\left[\alpha z + p\int_z^1 \beta(u-z)\,f(u)du\right]$$

- Condition for optimum:

$$\alpha = p\beta[1-F(z^*)]$$

  - An interior solution on z* requires $\alpha < p\beta$
- This yields a constant marginal cost of emitting

$$\mu^*(\alpha,p) \equiv \alpha z^* + p\beta\int_{z^*}^1 (u-z^*)\,f(u)du$$

Model of the Representative Firm

- Optimal level of disclosure, z*, decreases with the tax rate and increases with the audit probability and the penalty rate
- Unit cost of emitting (given optimal disclosure), μ^*, increases with the tax rate, penalty rate, and audit probability

Model of the Representative Firm

- Given optimal disclosure and consequent unit-cost of emitting, the firm chooses emissions *e* to maximize the net benefit of emitting
  - Let *B*(*e*) represent the value of emissions to the firm, with *B'*(e)>0, *B''*(*e*)<0
  - The firm chooses *e** to maximize $B(e) - C(e, z^*) = B(e) - e \cdot \mu^*$
  - Optimal emissions are defined by $\mu^* = B'(e^*)$
- The firm's emissions decrease with the tax, penalty, and audit probability

Model of the Regulator

- We formalize the direct benefit of disclosure of emissions as follows
  - Let *m* denote the per unit social cost of undisclosed emissions and *s* denote the reduction in the social costs that results from disclosure, with *s* < *m*
  - Given disclosure z*, the per unit social cost of emissions is then given by $m - sz^*$

Model of the Regulator

- Regulator chooses tax, α, and audit probability, *p*
  - Penalty, β, is exogenous
  - Regulator knows how policy choices will impact firm behavior

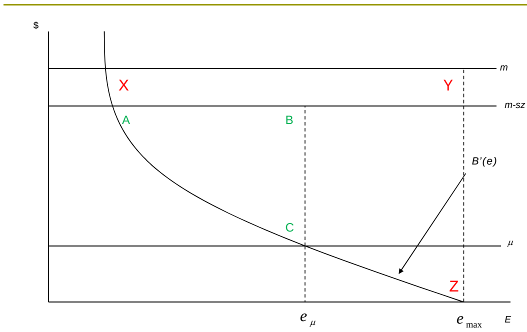
Model of the Regulator

- The regulator's objective is to minimize social costs:

$$V = e(\mu^*)[m - sz^* - \mu^*] + pw - \int_{\mu^*}^{\mu_c^*} e(\rho)d\rho$$

  - The first term is social cost of emissions net of expected payments by the firm
  - Expected auditing costs are *pw*
  - The final term captures the net benefit to the firm of emitting

Regulator's problem



Model of the Regulator

- The first order conditions for an interior solution yield

$$e'(\mu^*)\frac{\partial \mu^*}{\partial \alpha}(m - sz^* - \mu^*) = e(\mu^*)s\frac{\partial z^*}{\partial \alpha}$$

$$e(\mu^*)s\frac{\partial z^*}{\partial p} - e'(\mu^*)\frac{\partial \mu^*}{\partial p}(m - sz^* - \mu) = w$$

Model of the Regulator

- The optimal tax is increasing in *m*, the per unit social cost of undisclosed emissions and decreasing in *s*, the difference between the per unit social costs of undisclosed and disclosed emissions
  - The effect of the cost of auditing on the optimal tax is ambiguous
- The optimal audit probability is decreasing in the cost of auditing, *w*.
  - The effect of a change in *m* or *s* in the optimal audit probability is ambiguous

Policy Implications

- Consider a disclosure program aimed at emissions for which the social cost becomes negligible if disclosed, (as *s* approaches *m* in our model)
  - Optimal policy is then zero tax, which enables full reporting compliance to be achieved with negligible enforcement costs
  - It may even be optimal to insulate firms from other sources of disclosure costs, such as liability, in order to ensure full disclosure

Policy Implications

- Conversely, consider a disclosure program aimed at emissions for which disclosure does not significantly reduce social costs, (as *s* approaches 0 in our model)
  - Optimal policy is then to internalize the social cost while minimizing enforcement costs
  - This implies setting the tax rate $\alpha > p\beta$, which results in no disclosure but maximizes the firm's expected cost of emitting for any audit probability

Policy Implications

- Most cases where disclosure programs are employed almost certainly lie in middle, where achieving both the direct and indirect benefits is desired
  - Our model illustrates the inherent tension between these objectives
  - The model shows how the optimal policy balance depends on the relative costs of undisclosed vs. disclosed emissions, and the cost of enforcement

Competing Environmental Labels

Carolyn Fischer and Thomas P. Lyon
Resources for the Future University of Michigan

EPA- NCER Conference on
Environmental Behavior and Decision-Making
New York, NY, January, 2008

Introduction

- Globalization of trade and environmental issues create problems difficult for governments to address with standard policy tools
- Trade law makes it difficult for governments to regulate attributes of production processes outside their borders
- Many groups have put increasing effort into international market mechanisms such as ecolabeling

Labels Promulgated by a Non-Governmental Organization (NGO)

- Swedish Society for the Conservation of Nature
- Forest Stewardship Council (FSC)

Industry-led Labels

- Pulp and paper
- Tuna canning
- American Forest & Paper Association (AF&PA) Sustainable Forestry Initiative

Research Questions

- How do the incentives and behavior of industry groups and environmental NGOs compare in setting ecolabel standards?
- Is society made better off by multiple ecolabels in an industry, or do competing labels reduce overall effectiveness?
- Is there a role for government intervention in third-party voluntary labeling schemes?

Previous Literature

- Still quite sparse, but growing
- Heyes and Maxwell (2004) compare a mandatory standard adopted by a "World Environmental Organization" (WEO), subject to political pressures, with an NGO-led voluntary ecolabel
  - NGO label may reduce welfare by pre-empting the more socially desirable WEO label.
  - If the two labels coexist, then the NGO label is beneficial
- Baksi and Bose (2007) compare NGO labels with self-labeling by individual firms
  - Self-labels can be better if the government is willing to engage in costly monitoring

Our Analysis

- Formal model of rivalry between NGO and industry-sponsored labels
- Each chooses a standard of stringency
  - NGO wants to minimize damages
  - Industry wants to maximize profits
- Firms are distributed across a spectrum of costs of complying with a standard
- Consumers have some willingness to pay as a function of standard stringency

The Firm Decision

- Firms elect to join a labeling program if the net benefits outweigh the alternatives
- Single label / less stringent label:
  - if the price premium outweighs the costs of meeting the standard
  - i.e., below a cutoff level of the cost parameter
- More stringent of two labels:
  - if the price premium outweighs the costs of meeting the standard
  - *And* if the additional price premium outweighs the additional costs
  - i.e., *above* a cutoff level of preferring the looser standard

Main Results for Industry

- If there is only one label, the NGO adopts a more stringent label than does the industry.
- Industry further relaxes its label if the two labels coexist.
- Industry profits increase with multiple labels.
  - Firms only voluntary if it increases profits
  - Industry only changes its standard if it increases profits

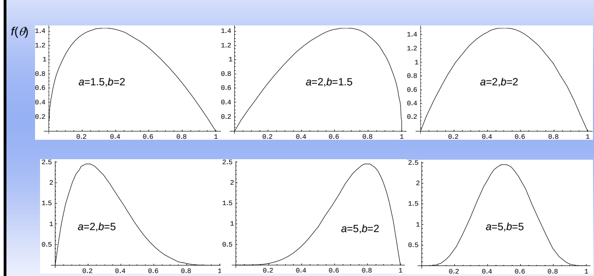
Main Results for NGO and Environment

- NGO may tighten or loosen its standards in response to an industry label
- Environmental damages may be higher or lower with both labels than with the NGO label alone.
- Specific results depend on the distribution of types of firms in the market and consumer demand for label stringency.

Simulations

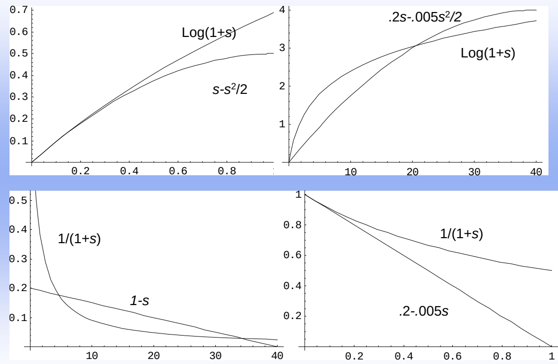
- Explore role of firm-type distribution and consumer willingness-to-pay functions
- Find both kinds of NGO and damages response
- NGO loses substantial participation when industry label present

Distribution Function Examples



(Beta distribution function)

Price Premium Functions



RESOURCES FOR THE FUTURE

Simulation Results

Distribution Parameters		Prices				Participation Rates				Change in Damages		
a	b	pIA	pIB	pNA	pNB	%IA	%NA	%IB	%NB	Industry	NGO	Both
2	5	0.64	0.60	1.23	1.54	82%	29%	80%	5%	-2.75	-4.62	-4.14
1.5	2	0.58	0.55	1.42	1.90	59%	11%	60%	2%	-1.64	-2.71	-3.03
2	2	0.46	0.41	0.89	1.15	59%	22%	60%	5%	-1.12	-1.49	-1.55
5	5	0.34	0.33	0.53	0.81	84%	53%	84%	2%	-1.00	-1.26	-1.06
2	1.5	0.42	0.38	0.80	1.19	51%	20%	52%	3%	-0.83	-1.05	-1.17
5	2	0.21	0.20	0.30	0.67	59%	41%	60%	1%	-0.38	-0.41	-0.40

Price Function	Prices				Participation Rates				Change in Damages		
	pIA	pIB	pNA	pNB	%IA	%NA	%IB	%NB	Ind.	NGO	Both
Log[1+s]	0.53	0.49	1.03	1.38	71%	25%	70%	4%	-1.67	-2.45	-2.44
(.2-.005s/2)s	2.60	2.55	3.07	3.92	1.4%	1.2%	1.4%	0.0%	-0.23	-0.24	-0.23
(1-s/2)s	.127	.125	.192	.191	90%	71%	88%	3%	-.576	-.688	-.578

RESOURCES FOR THE FUTURE

Finer Points

- In more cases, fewer reductions with both labels than with NGO alone
- Dueling labels more likely to be beneficial to the environment if firm types are broadly distributed
  - Else competing within a tight range

RESOURCES FOR THE FUTURE

Thinking About Welfare

- Societal objective function would likely balance profits and environmental damages (and consumer surplus)
- Profits and consumer options increase with more labels, but environmental benefits may decrease
- Role for influencing the number of labels and their criteria
- Incentives for NGOs to work *with* industry groups to avoid excess competition

RESOURCES FOR THE FUTURE

Caveats and Further Research

- Consumer willingness to pay for one label may depend on the qualities of the other labels
  - additional interactions between competing labeling schemes
- We assume standards set targets for reductions in damages; absolute standards may create twin distributions of firms by costs and emissions

RESOURCES FOR THE FUTURE

Thanks!

- To EPA-STAR
  - RD-83285101
- For more information:
  - Resources for the Future www.rff.org
  - Erb Institute for Global Sustainable Enterprise http://www.erb.umich.edu/

RESOURCES FOR THE FUTURE

Environmental Labeling and Motivation Crowding Out

C.D. Clark, K.L. Jensen, C.S. Russell, S. Yen, and W.M. Hanemann

Environmental Behavior and Decision-Making: Corporate Environmental Behavior and Benefits of Environmental Information Disclosure
January 14–15, 2008

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program Grant # R832849

Preview

- Motivation
- Policy Background
- Objectives
- Prior Research
- Economic Model
- Methods & Procedures
- Policy Implications

Motivation

- Environmental Labeling in the US
  - Apparent preference for programs with both *public* and *private* benefits
  - Appeal to "narrow self-interest"
- Cracks in the economic foundation?
  - "Altruism"
  - Motivation Crowding Out (MCO)
- Might MCO affect consumer response to environmental labeling?

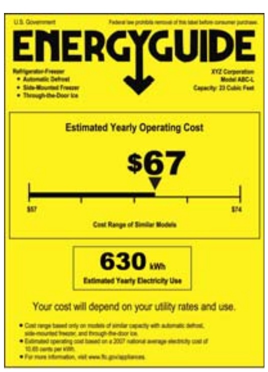
Third-Party Environmental Labeling

Program Type	Information Type	Basis for Participation
Seal-of-Approval	Positive	Voluntary
Single Attribute Certification	Positive	Voluntary
Report Card	Neutral	Voluntary
Information Disclosure	Neutral	Mandatory
Hazard of Warning Label	Negative	Mandatory

Source: USEPA (1993)

Energy Guide

- Information Disclosure
- Home appliances and energy-using equipment
- Since 1980
- FTC/DOE



ENERGY STAR®

- Seal-of-Approval or Single Attribute Certification
- Appliances, light bulbs, buildings, etc.
- Since 1992
- EPA/DOE

"Money Isn't All You're Saving"

"Save Energy, Save Money, Protect the Environment"

Green Power Partnership

- Seal or Certification
- Organizations consuming specified percentage of energy from certain renewable sources
- 2001
- EPA

Objectives

- Analyze influence of extrinsic (energy cost savings) and intrinsic (helping the environment) incentives on willingness to pay for consumer products
  - Evidence of MCO?
- Analyze influence of other factors on willingness to pay for environmentally labeled consumer products
  - Program characteristics
  - Demographics
  - Attitudes and Opinions

Prior Research

- Evidence that environmental labeling programs influence consumer behavior
  - Opinion/Recognition Surveys
  - Stated Preference Surveys
  - Revealed Preference Analyses
    - E.g., Bjørner, Hansen and Russell (2004)

Prior Research

- Energy Efficiency and Green Power Labeling
  - Energy crisis of the 1970's
  - Identification of the "efficiency gap"
  - ENERGY STAR
  - Green Power

Prior Research

- Prosocial Behavior and MCO
  - MCO
    - Psychological Literature
      - Deci and Ryan (1985); Deci (1971)
    - Experimental Evidence
      - Deci, Koestner, and Ryan (1999)
    - Field work
      - Frey and Jegen, 2001
  - Prosocial behavior more generally
    - Meier (2006)
    - Bénabou and Tirole (2006)

Economic Model

$$\max v_z \cdot z_i + v_Y \cdot Y_i - p_i + x\left[\gamma_z E\left(v_z \middle| z_i, Y_i\right) - \gamma_Y E\left(v_Y \middle| z_i, Y_i\right)\right]$$

- Adapted from Bénabou and Tirole (2006)
- Where:

  z = public attributes (intrinsic motivation)

  Y = private attributes (extrinsic motivation)

  v_z, V_Y represent consumer preferences

  p = product price

  x = visibility of salience of the choice

Methods & Procedures

- Conjoint Analysis
  - Hypothetical market or stated preference
  - Meant to replicate purchase decision

	If you were shopping for a side-by-side refrigerator/freezer for your home and these were your only options, which would you choose?		
	❍	❍	❍
Brand	Frigidaire	GE	Amana
Size	21.7 cubic feet	25.3 cubic feet	23.9 cubic feet
Icemaker	Icemaker in freezer	Icemaker in freezer	In-door dispenser
Warranty	2 year warranty	2 year warranty	1 year warranty
Energy Usage	ENERGY STAR	Meets Federal Requirements	ENERGY STAR
Price	$1199	$1479	$1349

Methods & Procedures

- Additional Survey Questions
  - Debriefing
  - Attitudinal
  - Demographic
- Survey Implementation
  - Computerized
  - Online

Methods & Procedures

- Product Selection Criteria
  - Energy consumption
  - Familiarity, buying experience
  - Adequately described with limited number of attributes
  - Limited importance of aesthetic, visual qualities
  - Accessibility of product information

Methods & Procedures

- Refrigerator Attribute Identification and Selection
  - Price
  - Brand
  - Finish
  - Size
  - Through-the-door water/ice
  - Noise Control
  - Humidity Control
  - Drawers (number)
  - Shelving (type)
  - Water Filtration
  - Length of warranty

Methods & Procedures

- Environmental Labels (Survey Versions)
  - ENERGY STAR
    - High and low private benefit
  - Green Power Partners
  - "Energy Savers"

ENERGY STAR Example:
Another factor that you may consider is whether or not the refrigerator has been awarded an ENERGY STAR® label. All refrigerators sold in the US are required to meet federal guidelines limiting their energy consumption. To be awarded the ENERGY STAR label, the refrigerator must consume at least 20% less energy than the federal guidelines. As a result, an ENERGY STAR refrigerator will, on average, reduce a household's electricity bill by $14 per year and reduce the emission of carbon dioxide associated with energy production by about 195 pounds per year. Carbon dioxide is a greenhouse gas that contributes to global climate change.

Methods & Procedures

- Four different survey versions
- Tests of the MCO Hypothesis
  - Strong: WTP for Green Power Partners or Energy Saver > WTP for ENERGY STAR with high cost savings
  - Weak: WTP for Green Power Partners or Energy Saver > WTP for ENERGY STAR with low cost savings
- Concerns
  - Equivalence of public benefits

Methods & Procedures

- Focus Group Analysis
  - Product and non-environmental attribute selection
  - Environmental attributes
  - Survey instrument

Policy Implications

- Relevance of public and private dimensions of labeling programs
- Influence of other program characteristics on consumer response
- Influence of demographic, attitudinal and opinion factors on consumer response
- Usefulness of conjoint analysis in evaluating labeling programs/attributes
- Empirical test of the objection that market mechanisms will lead to “moral ambiguity”

Voluntary Information Programs and Environmental Regulation: Evidence from 'Spare the Air'

W. Bowman Cutter, UC-Riverside
Matthew Neidell, Columbia University

Introduction

- Voluntary programs and environmental quality
  - Community Right-to-Know Act
  - Climate Wise
- Mostly target firms, but could be profit maximizing
- Hinge on consumer altruism → voluntarily forgo consumption despite no direct incentive

"Spare the Air" and ozone regulation

- *ozone = f (NOx, VOC, weather, solar_radiation)*
- Automobile emissions are precursors to ozone
  - 49% of Bay Area, Sacramento Valley, and San Joaquin Valley NOx from on-road mobile sources
- AQS based on "3-year average of the fourth-highest daily maximum "
- Traditional regulation: shift entire distribution of NOx, VOC
- Alternative: focus on episodic conditions
  - If forecasted ozone exceeds AQS, issue STA to encourage trip reduction
    - Widely publicized
    - Free-fare on BART since 2004
  - Trip reductions:
    - Lower ozone precursors
    - Lower ozone levels
    - Increase AQS attainment

Goal of project

- Goal 1: Impact of STA on commuting behaviors
  - Test of altruism
  - Voluntary programs and environment
- Goal 2: Impact of STA on ozone
  - 8-hour standard contested
    - Increased marginal abatement costs
    - Natural variability
    - Climate change predicts ozone increases
  - Ozone outreach programs, such as STA, may be more efficient tool
    - Implemented in Sacramento, Atlanta, Charlotte, Houston, Pittsburgh, …

Economic theory

- Individuals receive value from contribution [warm-glow, existence value]
  - Value increases with pollution
- 3 choices: drive alone, public transit, no trip
- 2 types of trips: commuting, discretionary
- Fact: ozone peaks late afternoon
- Intuitive prediction except:
  - STA signal as health risk [Neidell]
    - Most exposure from public transit
  - Free-rider issue: reduce traffic and travel time

Economic theory

- Commuting trips
  - No option to cancel trip
  - Health effects minimal

  →Contribute if warm-glow outweighs reduced travel time
- Discretionary trips
  - Option to cancel trip
  - Health effects largest during mid-day

  →Cancel over drive alone if warm-glow outweighs reduced travel time

  →Public transit if warm-glow net of health effects outweighs reduced travel time
    - Increase in public transit least likely during peak ozone period

Methodology

- Endogeneity of STAs
- Solution: regression discontinuity design (RDD)
  - $oz^f_{rt} = f\,(oz_{rt-1}, weather^f_{rt}, solrad_t) \geq trg\}$
    $trg=.081\ ppm \geq 2003,\ trg=.084\ ppm \leq 2002$
    $STA_t = 1\{oz^f_t = \max_t\,(oz_{rt})\}$
  - If days above trigger ≈ days below, discontinuity in transportation = effect of STA
- $y_{kt} = \beta * STA_t + \delta_0 * oz^f_t + \delta_1 * X_t + \theta_k + \mu_t + \varepsilon_{kt}$
  if $trg-\Delta \leq oz^f_t \leq trg+\Delta;\ \Delta=.01$ or $.02$ ppm
- Also diff-in-diff using *SCAQMD*
- Overall and by time of day

Data

- STAs and ozone forecasts from BAAQMD
  - June 1 to October 15
  - 2001-2004
- Traffic data from Freeway Performance Measurement System (PeMS)
  - Real-time traffic flow at 92 monitors in BAAQMD; 50 in SCAQMD
  - Aggregate 5 minute intervals to 1 hour
- BART
  - Hourly entrances for all stations
  - Free fares in 2004
- Daily pollution from CARB
- Observed and forecasted weather from NCDC

Data

year	STA=1	All obs. STA=0	+/- .02 of trigger STA=0	+/- .01 of trigger STA=0
2001	4	130	23	7
2002	7	127	32	8
2003	9	125	63	21
2004	3	131	38	8
Total	23	513	156	44

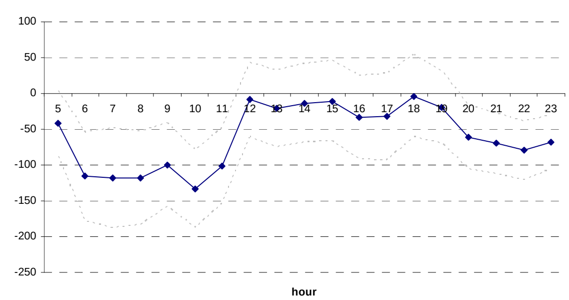
Covariate balance

	1 mean	2 All obs	3 +/- .02 of trigger	4 +/- .01 of trigger
precipitation	0.184	-0.069	0.024	0.023
max. temperature	81.92	2.115**	0.148	-0.255
precipitation (in.) (lag)	0.184	-0.096	-0.009	-0.006
max. temperature (lag)	82.015	1.733**	0.13	-0.082
forecast max. temp.	81.524	2.079**	0.286	0.262
forecast sunny	0.637	0.865**	-0.035	-0.257
forecast partly cloudy	0.326	-0.80**	0.036	0.268
holiday (lag)	0.024	0.13	0.221	-0.091
weekday	0.707	0.273	0.16	0.017

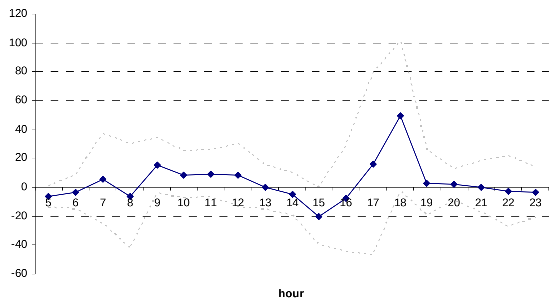
Effect of STA on all day traffic and BART

	1 all obs	2 +/- .02 of trigger	3 +/- .01 of trigger
A. Traffic			
monitor random effect	-1106.0	-2332.3**	-2001.0*
	-1.7%	-3.5%	-3.1%
monitor fixed effect	-995.2	-2111.7*	-1683.4
	-1.5%	-3.2%	-2.6%
Observations	70805	24073	8768
# of days	536	179	67
# of monitors	142	142	142
B. BART			
station random effect	34.6	40.3	29.4
	0.6%	0.7%	0.5%
station fixed effect	32.5	41.4	39.2
	0.5%	0.7%	0.6%
Observations	21391	7160	2520
# of days	536	179	67
# of stations	43	43	43

Effect of STA on Traffic by Hour (±.02 of trigger)



Effect of STA on BART by Hour (± .02 of trigger)



Effect of STA on 1-hour and 8-hour ozone

	1 all obs	2 +/- .02 of trigger	3 +/- .01 of trigger
A. 1-hour ozone			
monitor random effect	0.003*	-0.001	-0.001
	5.6%	-2.2%	-2.6%
monitor fixed effect	0.003*	-0.001	-0.002
	5.4%	-2.3%	-3.0%
Observations	6406	2139	777
# of days	536	179	65
# of monitors	12	12	12
B. 8-hour ozone			
monitor random effect	0.003*	-0.001	-0.002
	6.3%	-2.0%	-4.0%
monitor fixed effect	0.003*	-0.001	-0.002
	6.1%	-2.1%	-4.5%
Observations	6406	2139	777
# of days	536	179	67
# of monitors	12	12	12

Conclusion

- Individuals respond to STAs…
  …but not in sufficient volume
  - Impact of further outreach unclear because of counter-incentives
  - Free fare significant loss in gov't revenue, increase in complaints
  - If no effect in Bay Area, where could it work?
- Costs to consumer from switching unknown
- Generalize to other voluntary programs?

National-Scale Activity Survey (N-SAS)

Public awareness of and response to information on air pollution conveyed through the Air Quality Index (AQI)

Overview of Survey Design, Possible Uses of Data and Status/Timeline

Presented at the
EPA's Workshop on Environmental Behavior and Decision-Making (February 13-14, 2008 in New York City)

Presented by
Zachary Pekar and Susan Stone (EPA) and Carol Mansfield (RTI)

Overview of presentation

- Introduction to N-SAS
- Brief overview of past survey research with bearing on N-SAS (implications for N-SAS design)
- Overview of N-SAS
  - Design elements
  - Goals of the survey (types of information being collected)
- Potential uses of N-SAS results
- Survey timeline

2

Introduction to N-SAS

- OVERVIEW: N-SAS is a national-scale survey to collect variety of data related to the AQI and the public's awareness of and response to air pollution (including both averting and mitigating behavior).
- KEY DESIGN ELEMENTS:
  - Two survey designs will be used:
    - Cross-sectional survey (national-scale) measuring awareness, knowledge and stated responses to air quality warnings
    - Longitudinal survey (selected cities) collecting activity diary data to measure actual behavioral changes on poor air quality days.
  - Focus of initial N-SAS will be on the public's response to ozone pollution as conveyed through AQI alerts (later surveys may consider PM)
  - Initial N-SAS will focus on adults 55+ yrs of age (later surveys may consider additional age groups)
- STATUS: N-SAS is currently in the final planning stages and is targeted for summer 2008.

3

Brief overview of past survey research with bearing on N-SAS

- Roper Green Gauge Survey
- RTI/KN 2000 Health and Aging Survey
- 2006 BRFSS
  - module with four questions about awareness of the AQI and reported behavior change, 6 states administered it
- Individual metro areas conduct surveys
- Research linking air quality warnings to aggregate daily changes in attendance at outdoor events, hospital admissions, health outcomes and driving (for example, Neidell)
- Research on daily activities using diary studies

4

2002 STAR Grant and N-SAS Design

- **2002 STAR grant** (Mansfield, Van Houtven, Johnson, Pekar, Crawford-Brown)
- Epi and risk assessment see behavior change as a confounder – economists see behavior change as information about preferences and value
- Framework for cross-sectional and longitudinal N-SAS design
- Included questions on awareness, reported behavior, perceptions, health, neighborhood
- 6 daily activity diaries

5

2002 STAR Grant and N-SAS Design, con't

- Sample frame: Harris Interactive Online marketing panel, general and asthma panels
- Inclusion criteria:
  - 35 highest ozone MSA's
  - Child 2 to 12 years old
  - One stay-at-home parent to supervise child during July/August/September 2002

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2002 STAR Grant and N-SAS Design, con't

- Parents report relatively high level of ozone alert awareness, particularly if they have child with asthma
- High percentage of parents report reducing child's outdoor time on high ozone days, particularly parents of children with asthma
- Evidence of day-to-day behavioral adjustments w.r.t. high ozone conditions for asthmatics (based on daily diaries)

7

Goals of the N-SAS surveys – the types of information to be collected

- N-SAS will focus on measuring the following:
  - Public's awareness and knowledge of ozone pollution and the health threats posed by ozone (later surveys could include PM)
  - Public's awareness and knowledge of air quality warning systems such as AQI (including range of messages conveyed by these systems)
  - Exposure reduction behavior and emissions reduction behavior (both stated and actual)
  - Willingness to pay for information on air pollution conveyed through systems such as the AQI

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Design Elements – cross-sectional survey

- FOCUS: measure awareness, knowledge and risk perceptions related to air quality and reported behavioral changes (and differentiates these across socio-economic attributes), location (address or major intersection)
- SAMPLE:
  - Representative sample of older adults (55+ yrs) from MSA's that experienced at least one code orange day in the last 3 years
  - Sample size based on ability to compare responses to important subsamples of the population (e.g., stated awareness of AQI)
  - Survey conducted in English, but should Spanish speaking individuals be contacted, survey can be conducted in Spanish (potential for Spanish focus depending on funding)

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Design Elements – cross-sectional survey (continued)

- MODE OF ADMINISTRATION: telephone (RDD). Will include non-response follow-up studies.
- ADDITIONAL FACTOR: consider web-panel sample to improve compatibility with longitudinal activity diary survey and to research mode/sample selection issues in future surveys.

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Design Elements – Longitudinal survey

- FOCUS: collect seven 24-hr activity diaries for each member in a sampled group age 55+ years old. Allows actual changes in behavior (related to ozone exposure and emissions of ozone precursors) to be evaluated.
  - Respondents will also answer questions from the cross-sectional instrument in screening and debriefing surveys to allow stated behavior to be contrasted with actual behavior for this population
  - KN has addresses for geographic location

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Design Elements – Longitudinal survey (continued)

- SAMPLE:
  - Sample of older adults (55+ yrs) from 3-6 urban areas (selected to represent range of urban conditions in US)
  - Sampling frame will include individuals with respiratory and cardiovascular disease (i.e., sensitive subpopulations)
  - As with cross-sectional, will be conducted in English (not sure whether Spanish speakers will be covered at this point)
  - Sample size and number of diaries per individual based on ability to detect changes of a given size in time outdoors comparing days with high and low ozone pollution

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Design Elements – Longitudinal survey (continued)

- MODE OF ADMINISTRATION: Knowledge Networks web panel. Non-response follow-up study will be conducted.
  - Web-panel provides advantages over telephone, including the ability to collect more detailed information more frequently and the ability to collect diaries associated with high-ozone days.

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Goals of the Survey – Cross-sectional component

- Collect information on:
  - Respondent characteristics: health status, behavior (time outdoors)
  - Risk perception: perceived magnitude of air pollution problem and individual vulnerability
  - Averting and mitigating behavior (stated): possible actions taken, effectiveness of actions, frequency of action by individual.
  - Knowledge/Awareness of AQI
  - Valuation of air quality warnings (contingent valuation)
  - Geographic location

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Goals of the Survey – Longitudinal component

- Collect information on:
  - Daily activities (up to 7 days)
  - Continuous activity data for each diary day with details on type of activity, exertion level, and location (including model and duration of travel)
  - Respondent characteristics (including general health status and status on day of activity survey)
  - Geographic location
  - Stated activity (to support comparison against actual activity)
  - *Additional questions from cross-sectional survey*

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Possible Uses of N-SAS Results

- Accountability initiatives: Effectiveness of air pollution warnings at changing public's behavior.
- Enhance design of information outreach programs such as the AQI:
  - Provide insights into which populations are being reached by AQI (how this might be improved)
  - Provide a national benchmark against which state and regional programs can be compared and for evaluating improvements resulting from future enhancements to the AQI.
  - Insights into how other environmental health risk warning initiatives can be improved and enhanced.

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Possible Uses of N-SAS Results (continued)

- Improve exposure and risk modeling:
  - Data on averting and mitigating activity can increase representative of exposure and risk modeling (by potentially reducing exposure misclassification).
  - Detailed activity data for older population can enhance existing data in Comprehensive Human Activity Database (CHAD) used by EPA in micro-environmental exposure modeling.
- Improve economic benefits analysis:
  - Averting and mitigating activity reflects a cost to society. The presence of these activities in response to air pollution (and associated warning information) should be considered in assessing the benefits of air pollution reduction.

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N-SAS Timeline

- Pretesting instrument, January 2008
  - Cognitive interviews
  - Spanish language focus group
- Review, January 2008
  - Advisory panel
  - 2 -3 written peer reviews
- Submit ICR to OMB, February 2008
- Data collection, June to September 2008
- Report with basic data analysis, Fall/Winter 2008
- Peer review of report, Winter 2009
- Future waves of data collection?

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PURPOSE OF TRI:

- Annual reporting under EPCRA section 313 of toxic chemical releases and other waste management information

1) provides citizens with a useful picture of the total disposition of chemicals in their communities and

2) helps focus industry's attention on pollution prevention and source reduction opportunities.

There is a cost to society of these emissions. The more we know, the greater the pressure on industry to act.

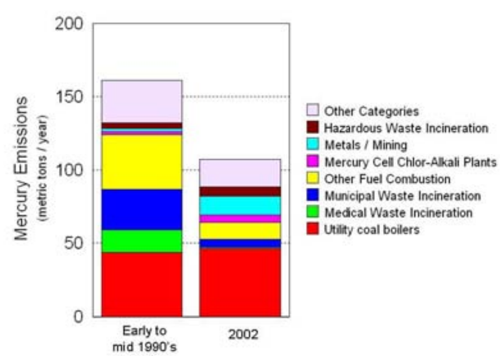
Evans et al

- Disclosure policy dilemma: how induce full disclosure, while also creating mechanism for internalization of social costs of emissions
- How much a firm decides to disclose depends on:
  – A tax on *disclosed* emissions as punishment for emitting
    - NY has such a tax on certain chemical emissions
  – A penalty on revealed *undisclosed* emissions
    - 2004 penalty for not reporting: $32.5K per chemical-year for major extent, minor $6448; adjusted annually by CPI
    - Facilities can reduce penalties through supplemental environmental projects (2006 cost: $1.18 M, or 27% total cost of EPA actions)
  – An imperfect audit by the regulator may reveal some (not necessarily all) *undisclosed* emissions
    - 2006: 308 inspections under EPCRA out of 20,000 reporting facilities = 1.5%, high estimate of *p*(getting caught)
- The model shows how the optimal policy balance depends on the relative costs of undisclosed vs. disclosed emissions, and the cost of enforcement

Bennear et al

- Hypothesis: Information disclosure requirements lead to *reductions* in emissions
- Compare emissions trends of newly reporting facilities to previously reporting facilities
  – 1995 new chemicals: limited (negative) effect
  – 2000 lower Mercury threshold: no effect
  – 2001 lower Lead threshold: positive effect
  – Other chemical emissions at newly reporting facilities: positive effect
- Explanation: something inherently different in previously reporting industries vs. newly reporting industries; need better industry effect variable?
- Other omitted variables? Break-down total releases, toxicity, strategic divestment from dirty facilities, other regulation/enforcement stringency, output/size, estimation methods, EPA training/CA

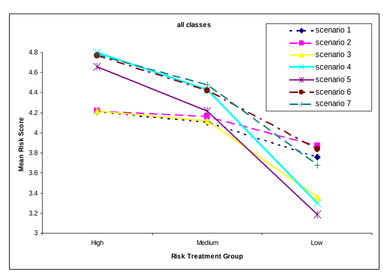
Estimated U.S. anthropogenic mercury emissions in the *early to mid 1990's* and *2002*.



Bui et al

- Assess 96% decrease in emissions from PCB industry, 1988-2003
  – Factors: voluntary program (33/50), CAA (non-attainment status & HAPs emissions), CWA, state-level regulations (TURA, P2 activities, community outreach)
- Significant explanatory factors: regulation, state actions, location in non-attainment county, dirty facility closure
- "TRI effect": Dirtier facilities located in attainment counties, all other things being equal, reduced their toxic releases more rapidly than non-attainment facilities such that by 2003, the facilities were not significantly different from one another.
- Caveat: A better understanding of the mechanism through which public disclosure affects firm behavior is extremely important if policy makers wish to rely upon it as a regulatory tool.

Do individuals understand the risks associated with toxic chemical emissions/use?



Speaker Papers

PRELIMINARY DRAFT
JANUARY 2008
NOT FOR CITATION
COMMENTS WELCOME

Regulatory Regime Changes Under Federalism: Do States Matter More?

Wayne B. Gray, Clark University and NBER
wgray@clarku.edu

and

Ronald J. Shadbegian, University of Massachusetts, Dartmouth
and US EPA, National Center for Environmental Economics
rshadbegian@umassd.edu

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1. INTRODUCTION

After the passage of the 1970 Clean Air Act Amendments and 1972 Clean Water Act Amendments the United States has been able to achieve substantial improvements in both air and water quality due in large part to increasing stringency of regulation, which has caused continuous declines in emissions from industrial sources. In the United States environmental policymaking is conducted via a federalist system with the federal U. S. Environmental Protection Agency (EPA) setting the stringency of regulation and states' implementing and enforcing the regulations. The ability of states to implement and enforce regulations provides them with a considerable amount of discretion (e.g. setting water permit discharge levels, number of plant inspections).

State discretion potentially has both pros and cons. First, this discretion allows each state to develop their own methods of regulating, thereby providing opportunities to develop more innovative policies, which can lead to more net benefits from regulation. However, there is potential for such discretion to be abused. For example, states may free ride on their neighbors by allowing plants located near state borders (border plants) to emit more pollution than non-border plants – Sigman (2005), Helland and Whitford (2003), and Gray and Shadbegian (2004) all find evidence of this behavior.[1] Finally, states may choose to be less rigorous in terms of enforcing regulations in an effort to attract new businesses to the state, resulting in a so-called "race to the bottom."[2,3]

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[1] In particular, Sigman finds that states allow plants to emit greater amounts of water pollution when that pollution crosses state borders via interstate rivers. Helland and Whitford, using annual (1987-1996) county-level TRI data, find that facilities located in counties on state borders (border counties) emit significantly more air and water toxics than facilities located in non-border counties. Gray and Shadbegian (2004) find that pulp and paper mills whose pollution impacts the population of neighboring states emit more pollution.

[2] See Sigman (2003) for more information on the discretionary powers of the states.

[3] There is a large literature examining the "race to the bottom"; see Oates (2001).

We would expect states to differ in their ability and/or desire to implement and enforce EPA regulations. Therefore, it is not clear whether making national regulations stricter in such a federal setting will increase or reduce differences across states in effective regulatory stringency. Stricter national rules may “raise the bar” and force less stringent states to make greater changes. On the other hand, since much of regulatory activity is done at the state level, stricter regulations at the national level may strengthen the bargaining power of regulators in more stringent states, enabling them to increase their stringency more than other states.

In 1998 the EPA promulgated the first integrated, multi-media regulation – known as the “cluster rule” (CR). The goal of the CR was to reduce the pulp and paper industry’s toxic releases into the air and water. By promulgating both air and water regulations at the same time EPA made it possible for pulp and paper mills to select the best combination of pollution prevention and control technologies, with the hope of reducing the regulatory burden.

We test the impact of the air and water regulations in the CR, using data from 1996-2005 for 150 pulp and paper mills, including information on both toxic and conventional pollutants. We include a wide range of control variables shown in previous research to affect plant environmental performance, including plant- and firm-level characteristics and regulatory activity. We find significant reductions in total toxics and air toxics around the time that the CR was implemented, though not for water toxics. However, plants identified as facing stricter CR rules do not generally show larger reductions in toxics. We find no evidence for large reductions in conventional pollutants around the CR implementation date, but do observe significant positive correlations in residuals across the different pollutants, suggesting the presence of unmeasured factors that may improve (or worsen) a plant’s performance across the board.

Finally, we find some evidence that the differences across states in regulatory stringency may have been lessened by EPA's adoption of the CR. Plants located in states with more political support for stringent regulation have lower toxic releases on average throughout the period, but they have a smaller decline in toxic releases over time, as shown by our 5-year-change analysis. This suggests that some of the reductions required by the CR had already been implemented in high-stringency states, so the CR had a greater impact on plants in lower-stringency states.

Section 2 provides background information on pollution from the pulp and paper industry and a brief history of the Cluster Rule. Section 3 reviews the relevant literature, while section 4 presents a model of the determinants of environmental performance. Section 5 discusses the data and empirical methodology. Section 6 presents the results, followed by concluding comments in section 7.

2. REGULATING THE PULP AND PAPER INDUSTRY

During the past 35 years environmental regulation on the U.S. manufacturing sector has become increasingly tougher in terms of both stringency, and enforcement and monitoring. Prior to the creation of the federal Environmental Protection Agency (EPA) in the early 1970's environmental rules were predominantly enacted at the state level, and were not rigorously enforced. Since the early 1970's the federal government has been the principal player in developing stricter regulations and promoting a greater emphasis on enforcement, much of which is still performed by state regulatory agencies under varying degrees of federal supervision.

The evolving stringency of environmental regulation has imposed large costs on traditional 'smokestack' industries, like the pulp and paper industry, which is one of the most highly regulated industries due to the large volumes of both air and water pollution it generates.

Although these regulatory efforts have proven costly to the pulp and paper industry they have also been successful in reducing the emissions of conventional air and water pollutants with the advent of secondary wastewater treatment, electrostatic precipitators, and scrubbers. Furthermore, some mills have gone beyond these end-of-pipe control technologies, and have redesigned their production process, *e.g.* more closely monitoring material flows to further reduce emissions. In general these modifications have been much easier to achieve at newer plants, which were, at least to a certain extent, designed with pollution controls in mind – some old pulp mills were intentionally constructed over rivers, so that any spills or leaks could run through holes in the floor for 'easy disposal.' These rigidities can be partially or completely offset by the propensity for most regulations to incorporate grandfather clauses exempting existing plants from the most stringent requirements – for example, until more recent standards limited their NOx emissions, most small old boilers were exempt from air pollution regulations.

The entire pulp and paper industry faces significant levels of environmental regulation. However, plants within the industry face differential impacts from regulation, depending in part on their technology (pulp and integrated mills vs. non-integrated mills[4]), age, location, and the level of regulatory effort directed at the plant. Previous studies, including Gray and Shadbegian (2003), have shown that the most important determinant of the regulatory impact on a plant is whether or not the plant contains a pulping facility, since the pulping process (separating the fibers need to make paper from raw wood) is much more pollution intensive than the paper-making process.[5] Different pulping processes result in different types of pollution: mechanical pulping uses more energy, generating air pollution from a power boiler, while chemical pulping

[4] Integrated mills produce their own pulp and non-integrated mills purchase pulp or use recycled wastepaper.

[5] The two main environmental concerns during paper-making stage are air pollution if the mill has its own power plant and the residual water pollution generated during the drying process.

could generate water pollution from spent chemicals, some of them potentially toxic. In addition, if a white paper product is desired the pulp must be bleached. The Kraft chemical pulping process was originally considered to be relatively low-polluting in terms of conventional air and water pollution. Unfortunately, when combined with elemental chlorine bleaching, it can create chloroform, furan, and trace amounts of dioxin, raising concerns over toxic releases that contributed, at least indirectly, to the development of the Cluster Rule.

An incident in Times Beach, Missouri (located near St. Louis) helped raise concerns about toxic pollutants in general, and dioxin in particular. On December 5th, 1982 the Meramec River flooded Times Beach, contaminating nearly everything in the town with dioxin that had been deposited by dust spraying in the early 1970's. The Center for Disease Control concluded that the town was uninhabitable and in 1983 the US EPA bought Times Beach and relocated its residents, reinforcing in the public mind the dangers of dioxin.

In the aftermath of the Times Beach incident two influential environmental groups, the Environmental Defense Fund and the National Wildlife Federation, sued the EPA for not adequately protecting the U.S. public from the risks of dioxin. As part of a 1988 settlement with the environmental groups the EPA agreed to study the health risks of dioxin and to set regulations to reduce dioxin emissions. Ten years later, EPA implemented regulations that included dioxin reductions, as part of the Cluster Rule.

The Cluster Rule

In 1998 the EPA promulgated the first integrated, multi-media regulation – known as the "cluster rule" (CR) – to protect human health by reducing the pulp and paper industry's toxic releases into the air and water. The Cluster Rule was scheduled to take effect (for the most part) three years later, in April 2001. By promulgating both air and water regulations at the same time EPA allowed pulp and paper mills to consider multiple regulatory requirements at one time, hoping to reduce the aggregate regulatory burden on the mills. The more stringent (technology based) air regulations in the CR call for substantial reductions in hazardous air pollutants (reduce by 59%), sulfur (47%), volatile organic compounds (49%) and particulate matter (37%). The more stringent (technology based) water regulations in the CR call for a 96% reduction in dioxin and furan, and a 99% reduction in chloroform. EPA estimates that approximately 490 pulp and paper mills are subject to the new CR air regulations. Furthermore, any pulp and paper mill that has the potential to emit ten tons per year of any particular hazardous air pollutant (HAP) or an aggregate of 25 tons per year of all HAPs is subject to the even more stringent maximum achievable control technology (MACT) standards for HAPs, under the National Emission Standards for Hazardous Air Pollutants (NESHAP). EPA estimated that 155 of the 490 affected pulp and paper mills would be subject to the new MACT standards. Finally, pulp and paper mills that chemically pulp wood (96 of the 155) are also required to meet a new set of effluent standards, defined as best available technology economically achievable (BAT) standards. These effluent standards are to take effect when the plant's water pollution discharge permit is renewed, which spreads the effective date out over several years (since many water permits last for five years). Thus we have a set of regulations affecting multiple pollution media, with different sets of plants facing different stringency on the different media, with some of the stringency changes occurring at different times for different plants. This allows us multiple dimensions along which to test the impact of the Cluster Rule.

3. LITERATURE REVIEW

Much of the empirical research on the impact of environmental regulation has focused on the effect of reported pollution abatement costs on productivity.[6] However, there is a growing literature, including studies by Magat and Viscusi (1990), Gray and Deily (1996), Laplante and Rilstone (1996), Nadeau (1997), Shadbegian and Gray (2003,2006), Earnhart (2004a,2004b), Schimshack and Ward (2005), and Gray and Shadbegian (2005,2007), which examines the environmental performance of polluting plants with respect to conventional air and water pollutants. Some studies have focused on the effectiveness of enforcement activities (mainly carried out by the states) in terms of raising compliance rates or lowering emissions. Gray and Deily (1996) and Gray and Shadbegian (2005) find that plants that face greater levels of air enforcement activity by regulators have higher compliance rates, while Nadeau (1997) finds these plants spend less time in non-compliance. In terms of the impact of water regulations, Magat and Viscusi (1990) and Laplante and Rilstone (1996) find that greater levels of water pollution enforcement activity result in lower water discharges. Furthermore, Shimshack and Ward (2005) find that one additional fine in a state for violating a water standard leads to roughly a two-thirds reduction in the statewide violation rate in the following year, suggesting that the regulator's enhanced reputation has a general deterrence effect leading to increased environmental performance at other plants in the state as well as at the fined plant. Earnhart (2004a) analyzes the impact of EPA regulations on the level of environmental performance of municipal wastewater treatment facilities in Kansas finding that the *threat* of federal inspections and enforcement action and the *threat* of state enforcement action significantly increase environmental performance. In a second study, Earnhart (2004b) finds that both income of a

[6] Research on the productivity effects of environmental regulation include Denison (1979), Gollop and Roberts (1983), Barbera and McConnell (1986), Gray (1986, 1987), Boyd and McClelland (1999), Berman and Bui (2001), Gray and Shadbegian (2002, 2003), and Shadbegian and Gray (2005,2006).

community and its political activism tend to significantly reduce discharge rates of municipal wastewater treatment plants in Kansas.

Shadbegian and Gray (2003) perform a more detailed examination of the environmental performance of 68 pulp and paper mills, finding that air emissions are significantly lower at plants: which have a larger air pollution abatement capital stock; which face more stringent local regulation; and which have higher production efficiency. Furthermore, they find a negative residual correlation between emissions and efficiency, providing evidence that plants which are more efficient in production are also more efficient in pollution abatement.

Shadbegian and Gray (2006) examined the impact of regulatory stringency on plants in the pulp and paper, steel, and oil industries and find that plants facing more local regulatory stringency had better (air and water) environmental performance. Finally, Gray and Shadbegian (2007) examine spatial factors affecting environmental performance of polluting plants, measured by air emissions and regulatory compliance. They find that increased regulatory activity has significant effects for compliance, but for not emissions. In particular, they find that increased regulatory activity has the expected effect of increasing compliance with air regulations, both at the inspected plant and at neighboring plants, but only for plants operating in the same state, indicating the importance of jurisdictional boundaries.

In addition to the large literature that now exists on the impact of regulation on the environmental performance of polluting plants with respect to conventional pollutants there is a growing literature which examines the impact of different EPA programs and community characteristics on toxic emissions. For example, Khanna and Damon (1999) find evidence that participation in EPA's voluntary 33/50 Program (a program under which facilities volunteered to decrease a certain specified set of their toxic releases by 33% by 1992 and 50% by 1995 relative to their 1988 levels) led to a significant decline in these toxic releases over the period 1991-93. On the other hand, Bui (2005) examines whether or not TRI induced public disclosure contributed to the decline in reported toxic releases by oil refineries. Bui finds some evidence that the public disclosure provisions of TRI may very well have caused some reductions in reported TRI releases. However she also finds evidence that reductions in toxic releases are a byproduct of more traditional command and control regulation of emissions of *non*-toxic pollutants.

In two additional studies which belong to the so-called environmental justice (EJ) literature, Arora and Cason (1999) and Wolverton (2002) examine the impact of community characteristics on toxic emissions. Arora and Cason, analyzing 1993 TRI emissions, find evidence race is significantly positively related to TRI releases, but only in non-urban areas of the south. Wolverton (2002) finds larger TRI reductions in minority neighborhoods than in non-minority neighborhoods in Texas, precisely the opposite of the assertions of many earlier entries in the EJ literature.

4. DETERMINANTS OF ENVIRONMENTAL PERFORMANCE

An individual manufacturing plant faces costs and benefits from complying with environmental regulation, depending on characteristics of the plant, the firm which owns the plant, and the regulatory stringency it faces. Given these constraints, the firm operating the plant maximizes profits, choosing to comply if the benefits (lower penalties, better public image) outweigh the costs (investment in new pollution control equipment, managerial attention). Regulators, in turn, allocate enforcement activity to maximize their objective function (political support, compliance levels, emissions reductions), taking into account the expected reactions of the firms to that enforcement.

There are substantial differences in pollution problems across different manufacturing plants. Difficulties in compliance might be related to a plant's production technology at the plant (e.g. pulp mills versus plants which buy pulp) or the plant's age or size. Differences in compliance behavior might also be related to the plant's productivity (proxying for economic performance and management ability). The impact of most of these plant characteristics on environmental performance could go either way: older plants might find it harder to comply with new stricter standards, but could be grandfathered; larger plants might enjoy economies of scale in pollution abatement compliance, but could also have more places that something could go wrong.

The expected direct benefit the plant receives from compliance is the avoidance of penalties. Therefore a plant's decision to comply depends on both the magnitude of the penalty and the probability of being caught in noncompliance; the latter depends on the amount of enforcement activity faced by the plant.

Environmental performance may also depend on characteristics of the firm which owns the plant, such as its financial condition. Pollution abatement can involve sizable capital expenditures, which may be more easily raised by more profitable firms. Firms with reputational investments in the product market may face an additional incentive not to be caught violating environmental rules, if their customers would react badly to the news. Firms might also differ in the quality of the environmental support that they offer their plants. A large firm, specializing in one of the highly regulated industries, is likely to have economies of scale in learning about what regulations require, and may be in a better position to lobby regulators on behalf of their plants.

We cannot measure the strength of a company's environmental program, but may see some effect of firm size. In sum, a plant's compliance status depends on plant characteristics and firm characteristics, and the level and efficacy of enforcement activity directed towards it.

Based on the above discussion, we estimate a model of plant environmental performance:

$Z_{pkt} = f_k(CLUSTER_{pkt}, STATE_{jt}, CLUSTER_{pkt}*STATE_{jt}, X_{pt}, X_{ft}, YEAR_t, u_{pkt})$

Here Z_{pkt} measures the environmental performance of plant p at time t along dimension k, including emissions of different air and water pollutants, possibly conventional as well as toxic (note that in this context, higher values of Z would represent poorer performance, so we'd expect negative coefficients on terms that improve performance). $CLUSTER_{pkt}$ is a measure of the stringency of the Cluster Rule related regulations faced by different plants at different times, which is expected to raise environmental performance (in its simplest form, CLUSTER could be a time dummy, turned on in 2001). $STATE_{jt}$ is an index of how rigorously a state is expected to enforce environmental regulations, which is also expected to raise environmental performance. The CLUSTER*STATE interaction term allows us to test whether stricter state regulatory agencies have been differentially affected by the Cluster Rule. This effect could go either way. Plants in states with preferences for strong environmental regulation might have already implemented some of the Cluster Rule requirements, and would therefore show less of an impact from the Cluster Rule on their performance, and a positive coefficient on the interaction. Alternatively, if stricter states are always looking for ways to increase regulatory stringency, the requirements of the Cluster Rule might provide those states with further regulatory tools, allowing them to become even stricter and resulting in a negative coefficient on the interaction. The model also includes characteristics of the plant (X_p) and firm (X_f), year dummies ($YEAR_t$)

to allow for changes in environmental performance or its definition over time, and other unmeasured factors (u_{pkt}).

We supplement our basic analyses of the impact of the Cluster Rule on various measures of emissions, with a seemingly unrelated regression (SUR) model. This allows us to test for correlations between the unexplained variation in different environmental performance measures, particularly for correlations across pollution media: air and water pollutants, and toxic and conventional pollutants. We would generally expect to find positive correlations across pollutants, as unobserved factors (such as management ability or local regulatory pressures) lead a plant to do better (or worse) than expected on a wide range of pollutants, but it's possible that some plants are able to substitute one type of pollution abatement for another when redesigning their production process.

5. DATA AND EMPIRICAL METHODOLOGY

This study examines the impact of the Cluster Rule on pollution emissions for a wide range of pollutants, as well as testing whether the gap in environmental performance across plants regulated in different states has been shrinking or growing as a result of the Cluster Rule. We control for a number of other factors shown in previous research to affect plant environmental performance, including plant- and firm-level characteristics. We also include a number of other control variables designed to capture characteristics of the location of the mill that could influence the level of regulatory activity it faces.

In past studies we developed a comprehensive database of U.S. pulp and paper mills to study the impact of environmental regulation on plant-level productivity and investment. This database includes published plant-level data from the Lockwood Directory and other industry sources to identify each plant's production capacity (both pulp capacity and paper capacity), age, production technology, and corporate ownership. We add financial data taken from Compustat, identifying firm profitability and firm size.

Our pulp and paper mill data is merged with annual plant-level information on quantities of pollution for both air and water pollution and for conventional and toxic pollutants. The EPA's Toxic Release Inventory (TRI) database provides annual information on the amount and type of releases of a wide range of hazardous substances. Given that the Cluster Rule focuses on reducing toxics, we defined our sample of plants in large part as those appearing in 10 consecutive years of TRI data, from 1996 to 2005, providing us with 5 years before and 5 years after the Cluster Rule implementation in 2001. This requirement (and a few restrictions for availability of other key variables) results in a sample of 150 plants. We aggregate the TRI data to create four measures of toxic pollution: total on-site releases (including air, water, underground injection, and other land releases), air releases, water releases, and releases of chloroform.[7]

Our measures of conventional air and water pollutants come from other EPA databases. The EPA's Envirofacts and Integrated Data for Enforcement Analysis databases provide information on water pollution discharges for Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS), covering the period from 1996 to 2002. Air pollution emissions data for particulates (PM10), volatile organic compounds (VOCs), and sulfur dioxide (SO_2) come from the National Emissions Inventory for 1996-1999 and 2002. There is not perfect overlap between the set of plants we obtained from the TRI and these databases, so our measures of conventional pollutants are only available for a subsample of the data.

[7] Of the different chemicals targeted by the Cluster Rule, only chloroform has been recorded in the TRI for a sufficiently long time to be included in our analysis (dioxin and related compounds were not added to the TRI until 2000, by which time many plants had already achieved their reductions).

Testing for an impact of the Cluster Rule requires us to identify which plants are affected by which parts of the rule, and at what time. All of the plants in our analysis are covered by the most general part of the Cluster Rule, which calls for reductions in releases of air toxics, beginning in April 2001. EPA also published a list identifying the 155 plants with sufficiently large emissions of hazardous air pollutants to qualify for the MACT standards, and a list identifying the 96 of those plants that would face the BAT water standards. We linked those lists to the 150 plants in our database, identifying 105 MACT plants and 65 BAT plants. Because the stricter water regulations for a given BAT plant become effective when that plant renews its water discharge permit, we use water permit date information from the Envirofacts database to assign an effective date for each BAT plant (EFFECTIVE BAT). The requirements for MACT plants come into place in 2001, so the indicator for that regulation (EFFECTIVE MACT) is turned on in 2001.

We also need a measure of regulatory stringency at the state level, to test whether the Cluster Rule has tended to increase or decrease the differences in stringency across states. For this we rely on an index of the political support for environmental regulation within a state, based on the pro-environment voting of its Congressional delegation (GREEN VOTE). These data are collected and reported by the League of Conservation Voters. They provide considerable explanatory variation both across states and over time, and we have used this variable extensively in earlier research.

6. RESULTS

Table 1 presents descriptive statistics for our data. The average plant in our sample reports nearly a million pounds of toxic releases annually, of which the majority are air toxics. As noted earlier, most of the dioxin-related substances were not included in the TRI until 2000, so we focus on releases of chloroform as an indicator of activity that might generate dioxin.[8] Releases of chloroform are relatively rare, with only about one-fifth of the sample reporting any chloroform releases; this number shrank rapidly during the years between 1996 and 2005.

The 5-year-change versions of the dependent variables identify the growth (or decline) of toxic releases and other pollutants over a five-year period, designed to identify trends in pollution across the time when the cluster rule was implemented. Total toxic releases at the average plant declined by about 30 percent over five years, with air toxic releases declining by a somewhat larger amount and water toxic releases increasing. There was also a huge decrease in releases of chloroform, which was one of the targets of the Cluster Rule, as we observed earlier. In terms of conventional pollutants, we saw declines of about 20 percent for water pollutants, with larger declines for sulfur dioxide and increases for particulates and VOCs.

Our initial analysis of the toxic release data is presented in Table 2. Most of the variables in the model show significant effects and generally have the expected signs, although this is less often true for chloroform releases, which also has the lowest R-squared. A one standard deviation change in our measure of state-level political support for regulatory stringency, GREEN VOTE, is associated with a 20 percent decline in toxic releases, and about twice as large a decline in chloroform. Plant characteristics are significant, as expected, with larger pulping plants and kraft mills having more toxic releases. On the firm side, more profitable firms show generally lower releases, although larger firms do not have lower releases, as we might have expected if larger firms provide more compliance assistance to individual plants. Plants located within 50 miles of a state border have higher air and total releases, while plants located in a non-

[8] Chlorinated toxic pollutants including dioxins, chloroform, and furans are byproducts of the elemental chlorine bleaching process, being created when elemental chlorine and hypochlorite react with the lignin in wood.

attainment county (with respect to ambient particulates) have lower releases. Plants located in poor neighborhoods tend to have more releases, while those in highly-educated neighborhoods have fewer releases.

Our focus in Table 2 is on the pattern of the year dummies, to see whether toxic releases in the years <u>after</u> the cluster rule is implemented appear significantly different (and lower) from toxic releases in the years <u>before</u> implementation. Of all the toxic measures, the air toxic model comes the closest to this pattern; the results for the total toxic model are similar, not surprising since air toxics are the largest component of total toxics in our sample. We observe a large drop in releases in 2001 relative to 2000, with relatively little variation on either side of the implementation point. What variation there is fits a relatively quick adjustment period - a bit of a downturn starting in 2000 and continuing into 2002. A statistical test for coefficient equality shows essentially no difference for the coefficients within each period, and a noticeably larger difference across the periods (marginally significant for total emissions). By contrast, the chloroform releases show a substantial downward trend from the start of the pre-cluster period, with a leveling-out (at much lower levels) in the post-cluster period. We find significant differences within the pre-cluster period and between the periods, but not within the post-cluster period. This is consistent with paper manufacturers taking steps during the 1990s to phase out their use of chlorine bleaching, even before the cluster rule took effect.

Table 3 presents the results of an analysis with a more nuanced model of the impacts of the cluster rule on toxic releases (we omit a discussion of the coefficients on the control variables, which are similar to those seen in Table 2). Although we anticipate a general increase in regulatory stringency around the implementation date, different plants face different degrees of stringency, and there is some variation in the timing. Along the stringency dimension, we have some plants facing MACT air standards and/or BAT water standards, while others do not. Along the timing dimension, the more stringent water standards were to be implemented when a plant renewed its water discharge permits. Identifying the impacts of these regulatory differences is complicated, because the regulatory stringency depends on the level of releases from the plant, with the more stringent MACT rules applying to plants emitting relatively large amounts of toxics. We therefore include dummy variables indicating a plant's eligibility for the MACT or BAT rules in all the years of the data analysis, along with dummy variables (EFFECTIVE-MACT and EFFECTIVE-BAT) indicating when that part of the cluster rules became effective for that plant.

The pattern of year dummies is similar to that found in Table 2. Since we are controlling separately for the MACT and BAT standards, this indicates that other plants in the paper industry, not affected by MACT or BAT also made considerable reductions in air, chloroform, and total releases over this time period. As expected, the MACT and BAT dummies are significantly positive in the air and water toxic equations, reflecting the targeting of those additional requirements towards the largest sources within the industry. The measures of the impact of additional regulatory stringency, EFFECTIVE MACT and EFFECTIVE BAT, show weaker results. The EFFECTIVE MACT measure actually shows an increase in toxics following the implementation date. The EFFECTIVE BAT measure does show a decrease of about 30 percent in water toxics, but this is not significant.

An alternative approach to measuring the impact of the implementation is shown in Table 4, where we move to an analysis of 5-year-changes in toxic releases. Here we calculate the change in log releases over a five-year period, hopefully smoothing out some of the year-to-year fluctuations in releases and concentrating on medium-run changes that reflect improvements in plant operating procedures or investments in pollution abatement activity. The analysis includes five observations per plant for the 2001-2005 releases, each measured relative to the releases from five years earlier, 1996-2000. The intercept terms reflect the declines over the period in all the releases (except water releases). Again, we see an unexpected positive sign for plants covered by the MACT air regulation, suggesting that they are reducing their air toxic releases by less than other, non-MACT plants. The BAT water regulations are associated with a greater reduction in water toxics than that achieved by plants facing less stringent regulation.

Another coefficient of interest in Table 4 is GREEN VOTE, reflecting differences in the amount of toxic reductions achieved by plants in states with different political support for stringent regulations. This coefficient is positive in all models, and significant for air and total toxics. The coefficient found on GREEN VOTE for air toxics here (+0.012) is comparable in magnitude to that found in Table 1 (-0.015). Taken together, these results suggest that plants located in states with more political support for strict environmental regulations achieved lower levels of toxic releases in the years before the cluster rule was implemented, but that plants located in other, less stringent states, have tended to catch up, at least in part, after the cluster rule was implemented.

In Tables 5 and 6 we turn our attention to discharges of conventional air and water pollutants, considering three air pollutants (PM10, SO2, and VOC) and two water pollutants (BOD and TSS). While conventional pollutants are not directly addressed by the cluster rule, EPA had suggested that the steps taken under the cluster rule to reduce air toxic releases could also lead to some reductions in other air pollutants, most notably particulates and VOCs. We defined our dataset based on having complete toxic release data, not complete air and water pollution data, so the analyses here are being done on subsamples of our plants. We have 144 plants with a total of 599 plant-years of air pollution data and 107 plants with 749 plant-years of water pollution data; the water pollution data came with complete 1996-2002 data for each plant, while the air pollution data came in two sets, one for 1996-1999 and the other for 2002, with incomplete overlaps between them, so that we can calculate long changes in the air pollution measures for only 104 plants.

The various control variables in Table 5 show impacts that are broadly similar to those found earlier for toxic releases. Both air and water pollution levels are significantly lower in states with more support for regulatory stringency, as measured by GREEN VOTE: a one standard deviation higher GREEN VOTE value is associated with 20-50 percent lower levels of emissions. Plant characteristics are again significant, with larger pulp mills showing higher pollution levels. Firm characteristics are less significant, and the plant location and demographics variables for water pollution are more consistent with those found for toxics, with plants near state borders and in poor or less well-educated neighborhoods having higher pollution levels.

Turning to the impact of the cluster rule, in Table 5 we apply an analysis similar to that used in Table 3, although our ability to measure any effects is hampered by limited data in the post-cluster period - a single year (2002) for air pollution and only two years (2001-2002) for water pollution. In addition to year dummies, we also include the detailed measures of which plants were affected by different regulatory stringencies under the cluster rule and at different times. Unlike the results we found for toxic releases, there are no significantly negative year dummies for any of the air or water pollutants. In fact, the water pollutants seem to be decreasing over the years while the air pollutants are staying the same or increasing, the opposite of what we found for toxics.

Looking at the more detailed measures, MACT and BAT plants have higher emissions of conventional pollutants to go with their higher emissions of toxic pollutants. This relationship is strongest for particulates and VOCs in MACT plants, which provides indirect support for EPA's suggestion of where to look for a toxic-conventional link. In fact, we have some direct evidence of an effect in this area with the negative coefficients on EFFECTIVE MACT, although these effects are not significant. For water pollutants, the corresponding coefficients are positive, though again not significant.

These indications of a connection between the cluster rule and reductions in conventional pollutants do not carry over to the analysis of long differences in air and water pollution presented in Table 6. Here all of the detailed regulatory stringency measures have positive coefficients. Few of the other coefficients are significant, although the reduction in air pollutants seems to be smaller at plants in states that have more political support for regulation, again suggesting that further reductions may be more difficult to achieve in those states.

Finally, we examine the relationship between different pollutants at the same plant, both in terms of levels and changes over time. Table 7 shows the results of a seemingly unrelated regression analysis focusing on the toxic release data for air, water, and chloroform. We see a significant set of correlations across the residuals from the different equations. This suggests the presence of unmeasured factors influencing the different pollutants in the same direction, perhaps including the quality of plant management or local pressures from regulators and plant neighbors. When we turn to the changes in air, water, and chloroform releases over a five-year period, we continue to find a significant positive correlation between unexplained changes in air and water releases (and a significant overall correlation among the residuals), but changes in chloroform releases are no longer strongly related to air and water changes.

Because our data for conventional air and water pollutants is only available for a subsample of our plants, we chose to maintain our sample size by estimating each model independently of the others, calculating the residual, and then looking for correlations across the residuals for different pollutants at the same plant. Table 8 shows the correlations for the levels of toxic and conventional pollutants. We find consistently positive, and generally significant, correlations across all the pollutants. The results for the changes, in Table 9, are somewhat weaker, but still show positive relationships in most cases. This suggests that plants with greater than expected reductions in one pollutant also have unexpected reductions in other pollutants.

7. CONCLUDING REMARKS

In this paper we examine the impact of the Cluster Rule on the environmental performance of plants in the pulp and paper industry. This was EPA's first integrated, multi-media regulation, announced in 1997, promulgated in 1999, and effective in 2001 (with some variation in effective date, as described above). Using a sample of 150 pulp and paper mills, we test for changes in emissions of toxic pollutants. We find significant reductions in total toxics and air toxics around the time that the CR was implemented, though not for water toxics. These reductions in air and total toxics are highly concentrated around the time of implementation, with little evidence of anticipation or delay in responding to the implementation date. By contrast, the very large reduction in chloroform releases begins well before the CR effective date, indicating some anticipation of the new rules, possibly triggered by non-regulatory factors affecting the industry, such as pressure from customers and environmental organizations to reduce dioxin.

When we examine the plant's CR status in more detail, plants identified as facing stricter CR rules, on either the air (MACT) or water (BAT) side, do not show consistently greater reductions in those toxic releases. We find no evidence for large reductions in conventional pollutants around the CR implementation date, but do observe significant positive correlations in residuals across the different pollutants, suggesting the presence of unmeasured factors that may improve (or worsen) a plant's environmental performance across the board.

Finally, we find some evidence that the differences across states in regulatory stringency may have been lessened by EPA's adoption of the CR. Plants located in states with more political support for stringent regulation have lower toxic releases on average throughout the period, but they have a smaller decline in toxic releases over time, as shown by our 5-year-change analysis. This suggests that some of the reductions required by the CR had already been implemented in high-stringency states, so the CR had a greater impact on plants in lower-stringency states.

These results should be recognized as preliminary, based in part on the limitations of the datasets being used here. We intend to expand the years of data on conventional air and water pollutants incorporated in the analysis, to get a stronger test for reductions in those pollutants after the CR was implemented. We also intend to test alternative measures of state regulatory stringency, to get a better handle on how a regulatory structure under federalism responds to changes in centrally-mandated stringency as new regulations are introduced. Finally, an innovative provision in the CR is the ability of plants to opt into the Voluntary Advanced Technology Incentives Program (VATIP), agreeing to further reductions (beyond those required by the CR) in the future, but extending their effective compliance date beyond April 15th, 2001. We have not yet located a list of plants that joined the VATIP (despite several contacts with EPA), but hope to add this information to the analysis, so we can get a more precise estimate of the effective date of the CR for all affected plants.

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TABLE 1

DESCRIPTIVE STATISTICS
(N=1500 unless otherwise noted)

VARIABLE	MEAN (STD DEV)	{log mean,std}	5-YEAR-CHANGE
DEPENDENT VARIABLES			
TOTAL AIR EMISSIONS[a] Total toxic air emissions (in pounds)	761863.4 (851008.4)	{12.35,2.57}	{-0.379,1.6}
TOTAL WATER EMISSIONS[a] Total toxic air emissions (in pounds)	57229.2 (149833.0)	{8.15,4.06}	{0.383,2.5}
CHLOROFORM[a] Total Chloroform emissions (in pounds)	67861.8 (69465.7)	{2.26,4.39}	{-2.648,4.7}
TOTAL TRI EMISSIONS[a] Total toxic emissions (in pounds)	914882.9 (984479.9)	{12.71,2.12}	{-0.287,1.3}
PM10 (N=599)[a] Tons of particulate emissions per year	488.3 (625.8)	{5.20,1.85}	{0.147,1.2}
SO_2 (N=599)[a] Tons of sulfur dioxide emissions per year	2409.7 (3905.8)	{6.49,2.24}	{-0.321,1.8}
VOCS (N=599)[a] Tons of volatile organic compound emissions per year	686.8 (879.6)	{5.66,1.60}	{0.366,1.7}
BOD (N=749)[a] Biological oxygen demand discharged	4784.8 (5007.7)	{7.86,1.31}	{-0.193,0.8}
TSS (N=749)[a] Total suspended solids discharged	7308.1 (8813.6)	{8.22,1.36}	{-0.191,1.0}
EXPLANATORY VARIABLES			
MACT Dummy variable =1 for plants which must install maximum available control technology to abate toxic air emissions	0.7 (0.5)		
EFFECTIVE-MACT Dummy variable =1 for MACT plants after 2000	0.35 (0.5)		
BAT Dummy variable =1 for plants which must install best available technology to abate toxic water releases	0.43 (0.5)		
EFFECTIVE-BAT Dummy variable =1 for BAT plants with timing based on date of plant's water permit	0.25 (0.4)		

TABLE I (cont)

GREEN VOTE State pro-environment Congressional voting (League of Conservation Voters)	43.12 (22.05)	
KRAFT Dummy variable =1 for plants which use the kraft pulping process	0.59 (0.49)	
PULP CAPACITY[a] Plant capacity - tons of pulp per day	761.4 (724.4)	(4.92,3.04)
PAPER CAPACITY[a] Plant capacity - tons of paper per day	831.9 (724.6)	(5.40,2.71)
OLD PLANT Dummy variable =1 for plants opened before 1960	0.63 (0.48)	
RETURN ON ASSETS Firm’s rate of return on assets (Compustat)	0.81 (2.61)	
EMPLOYMENT Firm’s number of employees in 1000’s (Compustat)	20.74 (31.97)	
BORDER PLANT Dummy =1 for plants located within 50 miles of a state border	0.27 (0.44)	
POOR Fraction of the population within 50 miles of the plant living below the poverty line	0.16 (0.06)	
COLLEGE Fraction of the population within 50 miles of the plant who graduated from college	0.16 (0.04)	
NONTSP Dummy variable =1 for plants located in non-attainment area for TSP	0.23 (0.42)	

a = measured in logs in the regressions; in some analyses measured in 5-year-changes

TABLE 2
BASIC TRI MODELS (N=1500)

DEPVAR	TOTAL AIR EMISSIONS	TOTAL WATER EMISSIONS	CHLOROFORM EMISSIONS	TOTAL TRI EMISSIONS
CONSTANT	11.107 (22.66)	3.872 (4.79)	6.320 (6.61)	11.281 (29.49)
GREEN VOTE	-0.015 (-4.80)	-0.009 (-1.71)	-0.024 (-3.87)	-0.010 (-4.12)
PLANT CHARACTERISTICS				
KRAFT	1.136 (6.84)	0.574 (2.09)	0.057 (0.18)	0.957 (7.39)
PULP CAPACITY	0.226 (8.25)	0.503 (11.08)	0.203 (3.79)	0.229 (10.71)
PAPER CAPACITY	0.069 (2.97)	-0.269 (-7.03)	-0.357 (-7.91)	0.007 (0.37)
OLD PLANT	0.130 (1.09)	-0.333 (-1.70)	0.854 (3.68)	-0.128 (-1.38)
FIRM CHARACTERISTICS				
RETURN ON ASSETS	-0.031 (-1.39)	-0.10 (-2.69)	0.10 (2.28)	-0.042 (-2.42)
EMPLOYMENT	0.151 (2.20)	0.271 (2.39)	-0.704 (-5.26)	0.128 (2.39)
PLANT LOCATION AND DEMOGRAPHICS				
BORDER STATE	0.569 (4.68)	0.194 (0.96)	-0.103 (-0.44)	0.420 (4.43)
POOR	1.677 (1.24)	13.267 (6.02)	2.732 (1.04)	2.550 (2.42)
COLLEGE	-4.916 (-3.56)	3.222 (1.41)	4.484 (1.66)	-2.267 (-2.10)
NONTSP	-0.340 (-2.54)		1.753 (6.72)	-0.498 (-4.78)
PRE-CLUSTER RULE				
y1997	-0.035 (-0.15)	0.412 (1.06)	-0.190 (-0.41)	0.109 (0.59)
y1998	-0.060 (-0.25)	0.803 (2.06)	-0.340 (-0.74)	0.084 (0.46)
y1999	-0.067 (-0.28)	0.775 (1.99)	-0.698 (-1.52)	0.048 (0.26)
y2000	-0.20 (-0.85)	0.630 (1.61)	-1.419 (-3.09)	-0.027 (-0.15)

TABLE 2 (cont.)

POST-CLUSTER RULE

y2001	-0.424	0.722	-2.578	-0.240
	(-1.78)	(1.83)	(-5.53)	(-1.29)
y2002	-0.464	0.815	-2.835	-0.275
	(-1.96)	(2.08)	(-6.13)	(-1.49)
y2003	-0.502	0.996	-2.982	-0.303
	(-2.12)	(2.54)	(-6.46)	(-1.64)
y2004	-0.419	1.103	-3.139	-0.223
	(-1.77)	(2.82)	(-6.80)	(-1.21)
y2005	-0.488	1.015	-3.287	-0.280
	(-2.06)	(2.59)	(-7.12)	(-1.52)
R^2	0.387	0.327	0.203	0.452
F-TEST I	0.21	1.43	2.95	0.19
F-TEST II	0.05	0.33	0.72	0.06
F-TEST III	0.12	1.35	16.89	1.65

NOTES:
(t-statistics in parentheses)
All models include a dummy variable MISSFIRM=1 for firms with missing Compustat data.
F-TEST I tests for the equality of y1996-y2000
F-TEST II tests for the equality of y2001-y2005
F-TEST III tests for the equality of y1996-y2005

TABLE 3
EXENDED TRI MODELS (N=1500)

DEPVAR	TOTAL AIR EMISSIONS	TOTAL WATER EMISSIONS	CHLOROFORM EMISSIONS	TOTAL TRI EMISSIONS
CONSTANT	10.194 (21.15)	3.305 (4.08)	5.198 (5.53)	10.536 (28.16)
MACT	1.585 (8.71)		-0.632 (-1.61)	1.334 (8.56)
EFFECTIVE MACT	0.365 (1.68)		-0.596 (-1.27)	0.350 (1.87)
BAT		1.192 (4.41)	3.823 (11.30)	-0.016 (-0.12)
EFFECTIVE BAT		-0.327 (-1.02)	-3.390 (-8.42)	-0.097 (-0.60)
GREEN VOTE	-0.009 (-2.83)	-0.008 (-1.47)	-0.024 (-4.08)	-0.005 (-1.97)
PLANT CHARACTERISTICS				
KRAFT	0.754 (4.67)	0.50 (1.83)	0.221 (0.70)	0.640 (5.11)
PULP CAPACITY	0.109 (3.89)	0.429 (9.07)	0.118 (2.14)	0.134 (6.09)
PAPER CAPACITY	0.087 (3.95)	-0.234 (-6.04)	-0.310 (-7.07)	0.020 (1.12)
OLD PLANT	0.001 (0.01)	-0.391 (-2.00)	0.805 (3.63)	-0.235 (-2.66)
FIRM CHARACTERISTICS				
RETURN ON ASSETS	-0.049 (-2.29)	-0.104 (-2.84)	0.091 (2.18)	-0.058 (-3.48)
EMPLOYMENT	0.079 (1.20)	0.260 (2.31)	-0.721 (-5.63)	0.066 (1.29)
PLANT LOCATION AND DEMOGRAPHICS				
BORDER PLANT	0.812 (6.91)	0.340 (1.69)	0.016 (0.07)	0.616 (6.74)
POOR	3.262 (2.52)	14.109 (6.44)	2.817 (1.12)	3.832 (3.81)
COLLEGE	-3.826 (-2.90)	3.614 (1.59)	4.543 (1.77)	-1.369 (-1.34)
NONTSP	-0.239 (-1.87)		1.536 (6.15)	-0.410 (-4.13)

TABLE 3 (cont.)

PRE-CLUSTER RULE				
y1997	-0.076	0.403	-0.199	0.074
	(-0.34)	(1.04)	(-0.46)	(0.43)
y1998	-0.144	0.776	-0.201	0.020
	(-0.64)	(2.00)	(-0.46)	(0.12)
y1999	-0.122	0.765	-0.422	0.013
	(-0.54)	(1.97)	(-0.96)	(0.07)
y2000	-0.260	0.650	-0.825	-0.058
	(-1.16)	(1.66)	(-1.86)	(-0.33)
POST-CLUSTER RULE				
y2001	-0.774	0.798	-0.922	-0.526
	(-2.82)	(1.94)	(-1.73)	(-2.47)
y2002	-0.798	0.910	-1.017	-0.543
	(-2.93)	(2.21)	(-1.91)	(-2.57)
y2003	-0.831	1.092	-1.162	-0.567
	(-3.05)	(2.65)	(-2.19)	(-2.68)
y2004	-0.752	1.198	-1.319	-0.490
	(-2.76)	(2.91)	(-2.48)	(-2.32)
y2005	-0.818	1.110	-1.467	-0.544
	(-3.00)	(2.70)	(-2.76)	(-2.57)
R^2	0.443	0.339	0.28	0.509

NOTES: see Table 2

TABLE 4
TRI MODELS IN 5-YEAR-CHANGE FORM (N=750)

DEPVAR	TOTAL AIR EMISSIONS	TOTAL WATER EMISSIONS	CHLOROFORM EMISSIONS	TOTAL TRI EMISSIONS
CONSTANT	-1.933 (-3.71)	0.760 (0.94)	-2.367 (-1.70)	-1.693 (-3.91)
EFFECTIVE MACT	0.376 (2.29)		1.086 (2.24)	0.213 (1.42)
EFFECTIVE BAT		-0.353 (-1.74)	-4.510 (-11.94)	-0.040 (-0.34)
GREEN VOTE	0.012 (3.81)	0.001 (0.14)	0.011 (1.33)	0.010 (3.84)
PLANT CHARACTERISTICS				
KRAFT	-0.249 (-1.37)	-0.429 (-1.52)	0.082 (0.17)	-0.168 (-1.11)
PULP CAPACITY	0.034 (1.10)	-0.057 (-1.17)	-0.216 (-2.54)	0.056 (2.13)
PAPER CAPACITY	-0.054 (-2.16)	0.038 (0.96)	0.207 (3.06)	-0.059 (-2.80)
OLD PLANT	0.375 (2.94)	0.213 (1.07)	-0.551 (-1.62)	0.213 (2.01)
FIRM CHARACTERISTICS				
RETURN ON ASSETS	-0.121 (-4.03)	-0.111 (-2.35)	0.176 (2.19)	-0.104 (-4.17)
EMPLOYMENT	0.090 (1.24)	-0.257 (-2.24)	0.313 (1.61)	0.083 (1.37)
PLANT LOCATION AND DEMOGRAPHICS				
BORDER PLANT	0.420 (3.21)	0.424 (2.06)	0.522 (1.49)	0.291 (2.66)
POOR	5.467 (3.83)	6.288 (2.85)	-8.029 (-2.10)	4.856 (4.09)
COLLEGE	-2.799 (-1.88)	1.033 (0.44)	2.795 (0.70)	-0.871 (-0.70)
NONTSP	-0.664 (-4.67)		-1.509 (-3.95)	-0.578 (-4.86)
POST-CLUSTER RULE				
y2002	0.083 (0.47)	-0.387 (-1.39)	0.339 (0.72)	-0.106 (-0.72)
y2003	0.130 (0.73)	-0.314 (-1.12)	0.506 (1.06)	-0.059 (-0.40)

TABLE 4 (cont)

y2004	0.189 (1.07)	-0.114 (-0.40)	0.616 (1.30)	0.053 (0.36)
y2005	0.256 (1.44)	-0.113 (-0.40)	1.286 (2.71)	0.064 (0.43)
R^2	0.126	0.059	0.275	0.134

NOTES: see Table 2;
5-YEAR-CHANGE calculated as $\log(Y_t) - \log(Y_{t-5})$,
so only post-CR years 2001-2005 are included in the regression.

TABLE 5
CONVENTIONAL AIR/WATER POLLUTION EMISSION MODELS

DEPVAR	PM10	SO_2	VOCS	BOD	TSS
CONSTANT	4.383 (7.34)	8.059 (10.52)	5.395 (9.45)	8.069 (23.24)	8.192 (21.88)
MACT	0.775 (3.91)	0.202 (0.79)	0.656 (3.46)		
EFFECTIVE MACT	-0.481 (-1.45)	0.132 (0.31)	-0.520 (-1.64)		
BAT				0.176 (1.77)	0.228 (2.12)
EFFECTIVE BAT				0.139 (1.03)	0.098 (0.67)
GREEN VOTE	-0.018 (-4.30)	-0.023 (-4.28)	-0.020 (-5.04)	-0.016 (-6.63)	-0.011 (-4.31)
PLANT CHARACTERISTICS					
KRAFT	0.415 (2.24)	0.582 (2.45)	0.499 (2.82)	-0.246 (-2.19)	-0.254 (-2.09)
PULP CAPACITY	0.211 (6.16)	0.30 (6.80)	0.065 (1.98)	0.204 (10.71)	0.227 (11.08)
PAPER CAPACITY	-0.071 (-2.52)	0.006 (0.16)	0.016 (0.59)	-0.099 (-6.05)	-0.110 (-6.27)
OLD PLANT	0.114 (0.81)	0.540 (3.00)	-0.032 (-0.24)	0.076 (0.91)	-0.038 (-0.42)
FIRM CHARACTERISTICS					
RETURN ON ASSETS	-0.001 (-0.04)	0.050 (1.71)	0.006 (0.28)	0.007 (0.45)	0.008 (0.44)
EMPLOYMENT	0.097 (1.17)	0.192 (1.80)	0.031 (0.39)	0.148 (2.90)	0.125 (2.28)
PLANT LOCATION AND DEMOGRAPHICS					
BORDER PLANT	0.145 (0.98)	-0.050 (-0.26)	0.151 (1.07)	0.233 (2.65)	0.336 (3.55)
POOR	-0.957 (-0.62)	-12.629 (-6.41)	-1.318 (-0.90)	1.478 (1.62)	1.540 (1.56)
COLLEGE	-0.903 (-0.56)	-10.445 (-5.01)	-0.780 (-0.50)	-4.011 (-3.92)	-3.419 (-3.10)
NONTSP	-0.503 (-3.07)	-0.113 (-0.54)	0.169 (1.08)		

TABLE 5 (cont.)

PRE-CLUSTER RULE					
y1997	0.036 (0.19)	0.10 (0.40)	0.072 (0.39)	0.066 (0.48)	-0.003 (-0.02)
y1998	0.078 (0.40)	0.108 (0.43)	0.093 (0.50)	0.055 (0.40)	-0.017 (-0.11)
y1999	0.058 (0.30)	0.029 (0.11)	0.062 (0.33)	-0.003 (-0.02)	-0.067 (-0.45)
y2000				-0.054 (-0.38)	-0.129 (-0.85)
POST-CLUSTER RULE					
y2001				-0.103 (-0.69)	-0.125 (-0.77)
y2002	0.527 (1.70)	-0.189 (-0.47)	0.791 (2.67)	-0.148 (-0.98)	-0.205 (-1.26)
R^2	0.39	0.319	0.259	0.425	0.384
OBS	599	599	599	749	749

NOTES: see Table 2

TABLE 6
CONVENTIONAL AIR/WATER POLLUTION EMISSION MODELS
IN 5-YEAR-CHANGE FORM

DEPVAR	**PM10**	**SO_2**	**VOCS**	**BOD**	**TSS**
CONSTANT	-1.384 (-0.95)	-2.742 (-1.56)	-1.398 (-0.81)	-1.170 (-2.33)	-1.436 (-2.36)
EFFECTIVE MACT	0.051 (0.11)	1.332 (2.40)	0.056 (0.10)		
EFFECTIVE BAT				0.161 (1.29)	0.208 (1.38)
GREEN VOTE	0.010 (1.07)	0.031 (2.76)	0.020 (1.83)	-0.001 (-0.43)	-0.002 (-0.40)
PLANT CHARACTERISTICS					
KRAFT	-0.032 (-0.07)	0.338 (0.64)	-0.109 (-0.21)	-0.191 (-1.10)	0.077 (0.36)
PULP CAPACITY	-0.154 (-1.90)	-0.176 (-1.80)	-0.047 (-0.49)	0.032 (1.11)	-0.003 (-0.08)
PAPER CAPACITY	0.116 (1.69)	0.128 (1.54)	0.033 (0.40)	0.006 (0.26)	0.033 (1.12)
OLD PLANT	-0.236 (-0.71)	-0.159 (-0.40)	0.279 (0.70)	0.032 (0.25)	-0.10 (-0.66)
FIRM CHARACTERISTICS					
RETURN ON ASSETS	-0.092 (-1.04)	-0.091 (-0.85)	0.029 (0.27)	0.013 (0.39)	0.040 (0.96)
EMPLOYMENT	0.074 (0.38)	-0.138 (-0.58)	-0.039 (-0.17)	0.190 (2.49)	0.212 (2.28)
PLANT LOCATION AND DEMOGRAPHICS					
BORDER PLANT	0.713 (1.94)	0.262 (0.59)	-0.253 (-0.58)	0.093 (0.71)	0.287 (1.80)
POOR	4.713 (1.31)	6.817 (1.57)	6.809 (1.59)	0.743 (0.54)	0.096 (0.06)
COLLEGE	2.569 (0.63)	-1.198 (-0.24)	0.497 (0.10)	0.867 (0.56)	1.948 (1.04)
NONTSP	0.321 (0.81)	-0.597 (-1.24)	0.148 (0.31)		
y2002				-0.034 (-0.30)	-0.043 (-0.31)
R^2	0.139	0.186	0.079	0.083	0.093
OBS	104	104	104	214	214

NOTES: see Table 2, 4

TABLE 7
SEEMINGLY UNRELATED REGRESSION MODELS: TRI
(CORRELATIONS OF RESIDUALS)

PANEL A: LEVELS

	AIR	WATER
WATER	0.1592	
CHLOROFORM	0.1480	0.0492

Breusch-Pagan test of independence: chi2(3) = 74.526, Pr = 0.0000

PANEL B: 5-YEAR-CHANGE FORM

Correlation matrix of residuals:

	AIR	WATER
WATER	0.2246	
CHLOROFORM	0.0075	-0.0263

Breusch-Pagan test of independence: chi2(3) = 38.404, Pr = 0.0000

TABLE 8
CORRELATIONS OF RESIDUALS: LEVELS

	TRI AIR	TRI WATER	CHLOROFORM	PM10	SO_2	VOCS	BOD
TRI WATER	0.1592*						
CHLOROFORM	0.1480*	0.0492					
PM10	0.3378*	0.1277*	0.0199				
SO_2	0.0821*	0.1441*	0.0053	0.4055*			
VOCS	0.3086*	0.0490	0.0956*	0.3128*	0.1520*		
BOD	0.2825*	0.2192*	0.1043*	0.2633*	0.0893	0.2381*	
TSS	0.2533*	0.2293*	0.0010	0.2938*	0.1143*	0.1425*	0.8872*

* = significant at the 5% level or better

TABLE 9
CORRELATIONS OF RESIDUALS: 5-YEAR-CHANGE FORM

	TRI AIR	TRI WATER	CHLOROFORM	PM10	SO_2	VOCS	BOD
TRI WATER	0.2246*						
CHLOROFORM	0.0075	-0.0263					
PM10	0.1352	0.3606*	0.0449				
SO_2	0.2757*	0.3913*	-0.1650	0.3235*			
VOCS	0.1858	0.2020*	0.1389	0.4416*	0.4632*		
BOD	-0.0135	0.0557	0.2396*	0.3231*	0.0244	0.1472	
TSS	-0.0222	0.0016	0.2231*	0.1639	0.0080	-0.0143	0.8785*

* = significant at the 5% level or better

The Persistence of Economic Factors in Shaping Regulation and Environmental Performance: The Limits of Regulation and Social License Pressures.

Dorothy Thornton, University of California, Berkeley
Robert A. Kagan, University of California, Berkeley
Neil Gunningham, Australian National University

This paper draws on a research project that explores the regulation of air pollution from heavy-duty diesel trucks, addressing two puzzles in the study of regulation:

(1) what factors affect the basic *design* of regulatory laws and programs?

(2) what accounts for *variation across individual firms* in environmental performance?

I. Why Trucks?

In explaining how regulatory programs are designed, one kind of theory, formalized by Chicago School economists such as George Stigler (1971), is that regulatory laws are shaped by well-organized business interests who use government regulation to limit competition and capture economic rents at the expense of diffuse, unorganized interests. Some political scientists have challenged that notion. They have shown that the political influences on regulatory policy design are more variable. Not infrequently, for example, regulatory laws are shaped by ideologically-motivated *policy entrepreneurs* who mobilize diffuse interests (Wilson, 1980), or who capitalize on the political opportunities that arise in the wake of widely publicized disasters, scandals, or frightening research findings (Bardach & Kagan, 2002: 22-25; D. Vogel, 2004; Levine, 2006: 217-223).

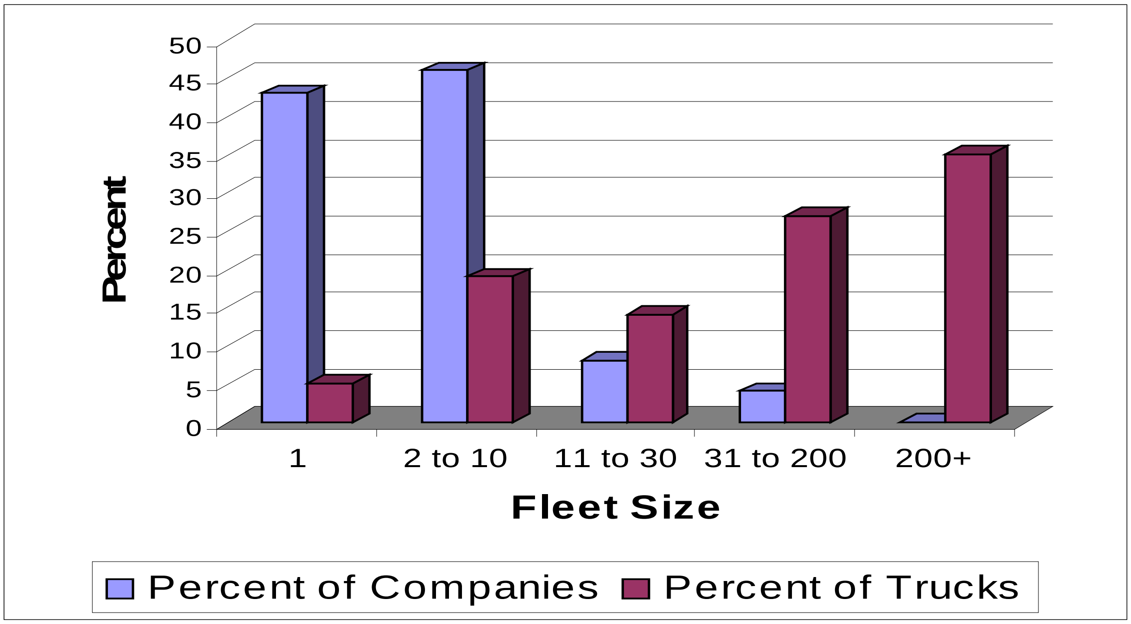
At the level of individual firm behavior, the traditional economic theory has been that business firms are “amoral calculators.’ They spend time and money on complying with regulations only to the extent the threat of costly legal sanctions, discounted by the probability of detection and punishment, outweigh the costs of compliance. And the implication of this theory is that regulated firms will not spend money on achieving regulatory goals, such as environmental protection, that are not required by law at all.

Sociolegal studies of regulation and compliance, on the other hand, have complicated the "criminology of the corporation" (Kagan & Scholz, 1984), showing that compliance efforts are not driven entirely by the risk of detection and punishment (Thornton, et al 2005), and indeed is common even when enforcement risk is fairly remote. Many firms spend money on "beyond compliance" environmental measures (Gunningham et al, 2003). To explain this, sociolegal scholars have pointed to the role of social norms (Vandenbergh, 2003) and of "social license" pressures – that is, pressures from employees, neighbors, activist organizations, and the news media (Gunningham et al, 2005). Many managers, these and other studies have shown (May,2004), are concerned about their own and their firms' reputation for law-abidingness, or being a good environmental citizen.

This research project was designed to explore the *limits* of such "social license" pressures in shaping firm behavior. Our own previous research concentrated on highly visible, closely-regulated industries – like large pulp and paper mills, and chemical companies – that have been subject of a great deal of regulatory attention. We conjectured, however, that social license pressures and corporate environmental management style (which we had found to be significant variables) might be less important in settings involving smaller firms, with less economic resources, and which receive less direct regulatory attention and social scrutiny. Those same factors, we hypothesized, would provide new insight into economic and political theories of regulatory design.

To explore those ideas, we focused on the regulation of emissions from heavy-duty diesel-powered trucks in the United States, and did so for several reasons. First, the trucking industry constitutes a big, tough, and environmentally important regulatory target. Collectively, the industry operates a huge, ubiquitous, fleet of mobile sources of pollution, and collectively, their emissions are huge and particularly hazardous. Second, a large portion of the trucking market is served by thousands of small trucking firms. We found, as shown in Figure 1, that in 2005, there were 336,000 heavy duty diesel trucks registered in the state of Texas; 38% of them belonged to firms with no more than 30 trucks, and 24% were owned by 32,000 small companies with 10 or fewer trucks. Many of these firms operate on small margins. Finally, trucking companies, especially small trucking companies, have not been a major target of environmental regulation or of environmental activist groups, so that social license pressures presumably would be less salient.

Figure 1: Texas Fleet Size Distribution (2005)



II. Research Design

Our basic research design was first, to use archival sources to trace the political evolution of federal and state regulatory programs for diesel emissions. At the state level, we decided to concentrate on two – Texas and California – both large states with seaports, and lots of truck traffic, but with contrasting political climates, especially with respect to environmental policy in general and vehicular air pollution in particular. We also gathered statewide data on state programs and age of registered vehicles that enable us to compare overall progress in California and Texas in reducing emissions from heavy duty diesel vehicles.

To study variation in firm level environmental performance, we conducted intensive case studies of 16 small or medium sized trucking companies, 8 in Texas, 8 in California, interviewing company officials in their primary places of business about their operations, motivations, and attitudes.

III. Regulatory Context and Regulatory Design

There are approximately 3 million heavy duty diesel trucks in the US involved in interstate commerce, and far more in intra-state commerce. They are the workhorses of the economy. Diesel engines are powerful and very durable. A new heavy duty diesel truck today costs in the neighborhood of $150,000, but a driver can buy an old one for $20,000 or less and start his own business. Barriers to entry into the market, therefore, are very low. This generates the economic contours of the regulatory context: a market for a vital service, but a market that comes very close to perfect competition, with many small firms, intense price competition, and low profit margins.

Then there are the environmental features of the regulatory context. The more diesel emissions are studied, the more dangerous they turn out to be. California regulators found that fine *particulate matter* (PM) in diesel emissions posed the highest risk of any air contaminant they had examined. A study of post-menopausal women found that living in areas with high levels of fine particulates had very substantial risk of death from cardiovascular problems. [1]Reviewing the evidence, the California Air Resources Board (CARB) estimated that PM and

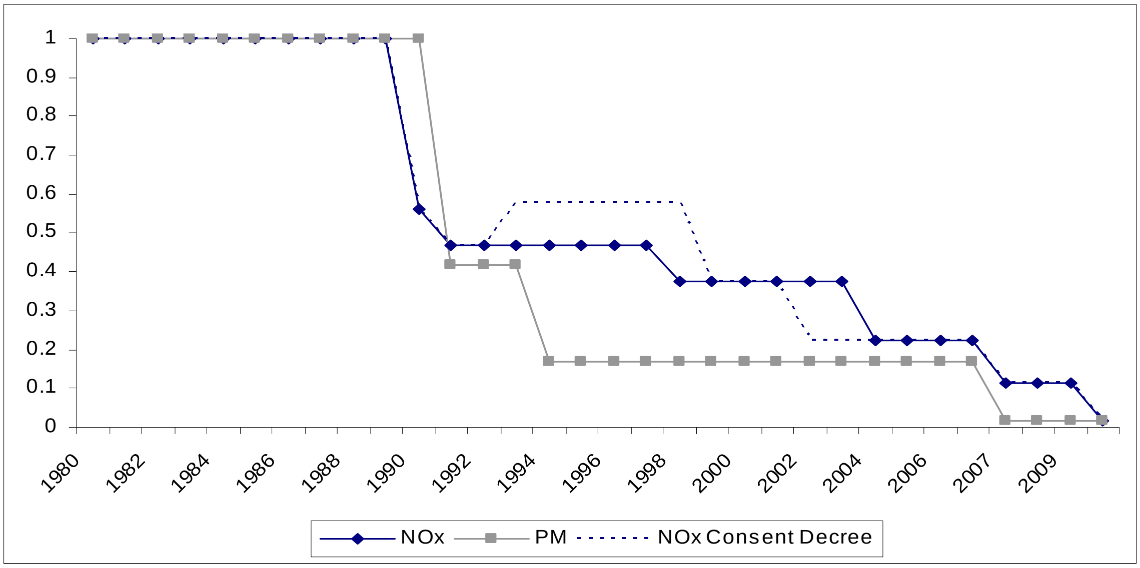
[1] Miller et al, 2007 found that in 2000, levels of PM2.5 exposure varied from 3.4 to 28.3 μg per cubic meter (mean, 13.5). Each increase of 10 μg per cubic meter was associated with a 24% increase in the risk of a cardiovascular event and a 76% increase in the risk of death from cardiovascular disease. UCLA researchers found "Children and adults who suffer from asthma and live near heavy vehicular traffic are nearly three times more likely to visit the emergency department or be hospitalized for their condition than those who live near low traffic density. For adults with asthma, medium to high traffic exposure increases the likelihood of chronic symptoms by approximately 40% to 80%. Moreover, living in areas of heavy traffic is a burden borne disproportionately by asthma sufferers who are ethnic/racial minorities or from low-income households. The issue is more pronounced among children than adults with asthma." (Meng et al, 2006)

another diesel engine pollutant -- NOx – are responsible for an average of 2,880 premature deaths per year in California alone.

A. Federal Regulation

Faced with this regulatory task environment, what have Congress and the EPA done? First, they imposed technology-forcing emissions-reduction standards on diesel engine *manufacturers*. The Clean Air Act Amendments of 1990 instructed U.S. EPA to set maximum emissions for heavy duty diesel engines Accordingly, as illustrated by Figure 2, EPA has periodically ratcheted down the maximum NOx and dPM standards for *new* heavy-duty diesel engines. For instance, 1992 models had to have maximum particulate emissions that were 50% below the level of engines produced in the 1980s; 1994 model years had to be still lower. 2007 model year engines had to cut emission from 1980 levels by over 95%. To achieve the 2007 model year standard, a new cleaner-burning diesel fuel was required, so EPA regulated oil refineries, compelling to make that kind of fuel available by 2005.

Figure 2: Proportional Declines in Federal NOx and PM Diesel Engine Emissions Limits (1980-2010) [2]



On the other hand, neither Congress nor EPA has required *owners and operators* of heavy-duty diesel trucks to scrap their old engines and *use* this gradually improving "best available control technology." In effect, older, dirtier trucks are "grandfathered in." And remember, diesel trucks last a long time. So while some companies will buy the greener new model year trucks, there is no restriction on their selling the older trucks to other truckers, who can sell their still older trucks to other trucking companies. Nor are operators of older engines subjected to any legal incentives to scrap them, such as sharply higher annual license fees or taxes.

[2] NOx emissions in 1993 – 1998 model years are shown 24% higher than the legal emissions limit, because most truck manufacturers used software in the electronic engine control module of the truck engine to switch to a more fuel-efficient (but higher NOx) driving mode when the truck was not being operated under federal test conditions. This resulted in a lawsuit charging the manufacturers of using "defeat devices." The dispute was settled and manufacturers in the resulting consent decree agreed to introduce engines meeting the 2004 standard in 2002.

The federal regulations, in short, don't deal with the obvious, hard problem – getting the old, dirtier trucks off the road. How can we explain this obvious gap in the federal regulatory scheme?

The Economic Problem. The standard "polluter pays" regulatory design is based on the theory that the costs of engineering, purchasing and using best available technologies will be passed on to the ultimate users of the products or service in question. Prices will then reflect *all* the costs of production, including the internalization of environmental harm. But trucking companies operate in a market that comes very close to perfect competition – profit margins are very thin; firms are small, numerous, have little pricing power, and can't coordinate price increases; and hence can't pass on the cost of new environmental control technology – new engines – to their customers. And a large proportion of firms simply cannot come up with the capital costs for the best available control technology (a new truck). The general lesson for policymakers is that perfect competition of that kind jeopardizes the traditional "polluter pays" regulatory strategy, especially in the face of expensive control technology.

The Political Problem. Consequently, banning old, heavily-polluting trucks (or accomplishing the same through high fees or taxes) would destroy tens of thousands of small businesses, in effect confiscating their sole business assets (on which many of them owe money). It might also result in consolidation of ownership into a smaller number of trucking firms who *could* finance the new trucks, and result in higher rates and shipping costs – precisely what the deregulation of trucking in 1980 was designed to stop. Hence neither Congress nor the EPA was close to being willing to face the political storm that would come from mandatory, rapid phasing-out of older, more polluting trucks. That was the case even though, by our rough calculations, the aggregate national cost of replacing the diesel fleet – which would run into the billions of dollars – is still less than the aggregate monetary benefits of lives saved by reduction of the dangerous emissions.[3]

Contrary to standard theory, therefore, in terms of the politics of regulatory design, the best-organized industries, with small numbers of very large corporations – motor vehicle engine manufacturers and petroleum refiners – were subjected to demanding technology-forcing regulations, and a diffuse industry with many very small firms was *not* forced to bear the regulatory costs. Even the policy entrepreneurs on the environmental side did not seem to want to go after them, because the political risks of driving many small entrepreneurs out of business seemed too high. The sheer economic cost of compelling them to upgrade, it seems, was the controlling factor -- an economic explanation, to be sure, but not the traditional economic theory.

One might imagine that *large* trucking firms would comprise a powerful political lobby for regulatory mandates requiring rapid phase-out of old trucks, since big firms would be better able to afford the new trucks and raise rates as thousands of small firms dropped out of the industry. As best as we can tell, such a lobby has not materialized because many large trucking firms rely

[3] Here are our estimates for California:

Deaths per year	Number of years	Cost of premature death	Total Cost
3,000	10	$2,000,000	$60,000,000,000
Trucks in California		Cost to replace a truck	Total Cost
250,000		$150,000	$37,500,000,000

If a new best-pollution technology model currently costs approximately $150,000, replacing the approximately 3 million heavy-duty diesel trucks nationally would cost $450 billion.

primarily on subcontracts with small truckers – and those large firms' costs could be expected to increase sharply if their subcontractors were required to buy new green trucks (and their ranks were sharply depleted). Put another way, the American Trucking Association, dominated by large firms, was divided between members who profited from the intense competition among smaller trucking firms with cheaper, older trucks, and those that didn't.[4]

B. Delegating the Problem to the States

Faced with the economic and political problems discussed above, what *did* the federal government do to accelerate the phasing-out of old trucks?. First and foremost, it passed the problem on to state governments. In 2002, after much political contention and litigation, EPA sharply tightened National Ambient Air Quality Standards (NAAQS) for ozone and fine particulates. NOx, a precursor of ground-level ozone, is one of the major emissions of diesel engines, and diesel trucks are a major source of NOx and particulates. Pursuant to the Clean Air Act, state governments must file with EPA state implementation plans (SIPs), showing how they will attain the NAAQS. After the new standards were promulgated, therefore, EPA could pressure state governments that couldn't meet the new PM and ozone standards to do more to phase out the older, more polluting diesel engines. EPA's regulatory stick in that regard is its legal authority to cut off federal highway funds to states that don't meet their SIP air quality goals.[5]

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[4] See generally Levine (2006) (noting that deregulation typically makes firms in an industry more *diverse*, and hence likely to have different policy goals).

[5] The threat is real enough that in states with "non-attainment areas," state bureaucrats work hard to achieve what is called "transportation conformity," constantly estimating total emissions from transportation sources and searching for regulations that will reduce those total vehicle-generated emissions.

Additionally, the federal government offered carrots rather than sticks. States were offered federal funding for carefully formulated plans that would provide substantial financial *subsidies* for vehicle owners who purchased new cleaner vehicles (either new diesel engines or alternative fueled vehicles) and retired (not re-sell) the old dirty ones.

C. State Programs: Texas and California.

So what did the states do? We looked at policy-design in Texas and in California. Texas did comparatively little, partly because, unlike California, it has few "non-attainment areas." As of the end of 2006, there was still nothing in Texas SIPs or new regulations that apply directly to trucking companies. Texas *did* establish a substantial *subsidy program*, however, using state as well as federal funds.

California has been more aggressive. As in the case of automobile emissions, strong demand for lower emissions from Los Angeles and Riverside Counties have driven state policy, since populous southern California is so powerful in Sacramento. Thus California adopted its own progressively tighter standards for new diesel *engines*, paralleling and occasionally leading federal regulations. California regulations require truck fleet owners to perform annual tests on their own vehicles (to prevent extra emissions due to poor maintenance) and state officials periodically inspect fleets to see that this is done. The California Air Resources Board (CARB) deploys roadside "strike teams" of inspectors who move from locality to locality to pull over diesel-powered trucks to check for excessive smoke. California also raised annual registration fees for all motor vehicles to help pay for subsidies for the purchase of new, lower-polluting vehicles, although officials directed these subsidies mostly to operators of school and urban transit bus fleets.

Moreover, after declaring diesel emissions a toxic air pollutant under state law, (CARB) imposed restrictions on idling of heavy-duty diesel vehicles, first for school buses, and in 2005 for commercial trucks. CARB also promulgated regulations requiring companies to, in effect, phase-in a ban of older trucks. CARB required this first in vehicles that operate in residential neighborhoods - urban transit buses and garbage trucks – then in October 2006 for publicly-owned diesel truck fleets (with first actions required by December 2008), and then in December 2007 for port drayage fleets. CARB's drayage truck rule was designed to bolster a phased-in ban of older diesel vehicles by the Ports of Los Angeles and Long Beach. In conjunction with the ban, the Ports imposed fees on the beneficial cargo owner of containers moving in and out of the ports, beginning January 1, 2008, and the fees are to be used to subsidize the purchase of new trucks by private drayage companies. Exactly how the subsidy/financing program will work has yet to be decided. And at best, the plan is expected to drive hundreds of small owner-operators out of business, which raises questions about its ultimate viability. Port action has been driven by local communities' ability to prevent any further port expansion unless environmental health concerns are addressed (a good example of social license pressures at work), as well as by the Ports' distinctive ability to regulate access and to impose higher fees on shippers and their customers.

Nevertheless, California has only *proposed* phase-out controls on the *major* source of diesel emissions from heavy-duty trucks– the thousands of over-the-road private diesel truck companies who operate older trucks in the state.

D. Consequences.

Due to its subsidy programs and fleet average improvement regulations, California has made considerable progress in reducing diesel emissions from urban bus fleets.[6] But for trucking firms, which are much more numerous, there are no fleet emissions reduction regulations in California or Texas. And because of the huge economic costs of improvement in that sector, government subsidies have amounted to little more than a drop in the bucket. We found that Texas, for example, has spent $57 million in subsidies. But that has replaced only 1,300 trucks. Yet in 2006, there were approximately still 38,000 trucks in Texas with 1990 or earlier model year engines. If we extrapolate the average subsidy cost per new green truck in Texas – $44,000 – to all the 38,000 pre-1990 trucks, it would cost $1.7 billion in subsidies to get them off the road. And that is just Texas!

The first conclusion of our project, therefore, is that in highly competitive, populous and unprofitable markets, like trucking, *economic variables* are *primary* in structuring the politics that shape regulatory laws and programs. In this case, the sheer enormity of the economic cost of "greening" the national fleet of heavy-duty diesel vehicles has limited the coerciveness of direct regulation of vehicle owners and operators. BAT regulations would drive too many firms out of business to be politically feasible. Only when there have been countervailing economic pressures

[6] According to 2004 data, alternative fuel vehicles constituted 43% of the 10,000+ urban bus fleet in California, and 17% of the entire *diesel* bus fleet has had a particulate emissions control system installed.

(such as port communities' threat to limit port expansion) have these politically difficult steps been taken. And that same economic factor – the enormous cost of upgrading a huge fleet of vehicles – has dwarfed the reach and effectiveness of the governmental subsidy programs.

IV. Company-Level Variation in Environmental Performance

Progress in reducing harmful emissions from heavy-duty diesel-powered trucks ultimately depends on the behavior of the thousands of companies that purchase and operate the vehicles. Yet as we have seen, those companies are not legally *obligated* to buy the newest, "greenest" engines. With rare exceptions, trucking firms are not obligated to reduce idling or adopt other measures (including fuel-efficiency measures) that incrementally reduce emissions. Any rapid improvement of air quality in this sector, therefore, depends on individual firms' willingness to engage in what regulatory scholars have labeled "beyond compliance" behavior. Another, and major, part of our research, accordingly, focused on trucking companies. We sought to determine why some firms, but not others, had purchased newer, less-polluting engines and why some, but not others, had adopted day-to-day operating practices that reduce emissions (such as introducing controls on driving speeds and idling time, or superior engine maintenance).

A. Framework for Analyzing Company-Level Variation

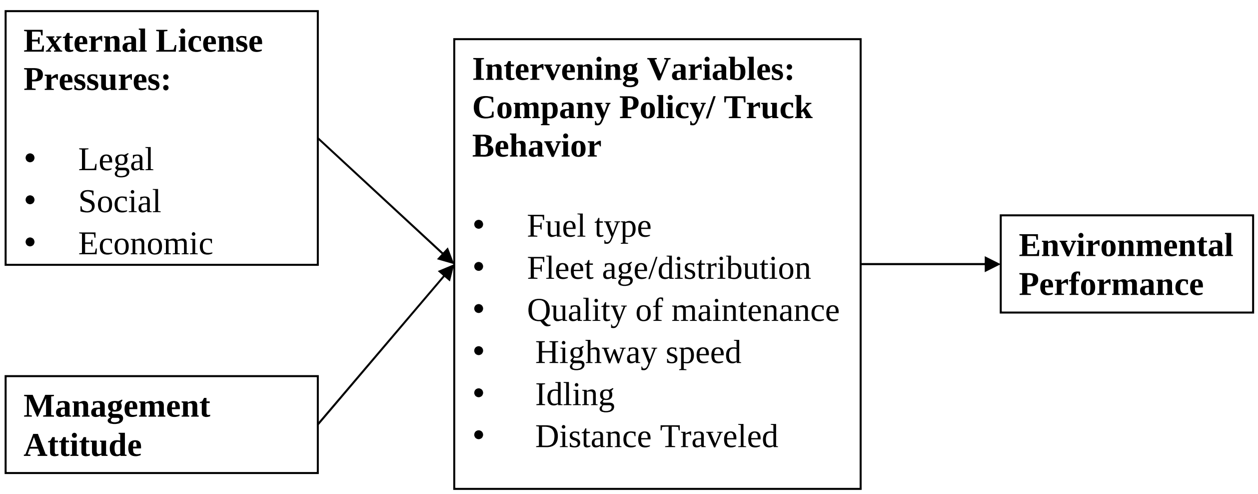
We approached the problem of explaining company-level variation in environmental performance by using a conceptual framework that was derived from our previous research. We viewed facility-level environmental performance as shaped first of all by the interaction of a firm' environment – the terms of (1) their *economic license* (that is, the market-based imperatives and constraints they face; (2) their regulatory license (that is, legal obligations and threats); and (3) their social license (that is, pressures from communities, advocacy groups, employees, newsmedia). But our prior research provided clear evidence that these external license pressures are interpreted, filtered, and negotiated by *management attitudes and commitments,* which vary from indifference or resistance to environmental concerns to higher levels of environmental awareness and engagement. Firms' environmental management styles, we found, had significant effects on the environmental performance of individual facilities, reinterpreting, amplifying or dampening the impact of the economic, regulatory and social license factors the facility encountered.

Applying this framework to trucking firms, we soon found, is complicated by the number and technical factors that affect each truck's (or fleet of trucks') environmental performance. Emissions of NOx and PM from a particular diesel engine can vary dramatically depending on the model year of the vehicle, the ambient temperature and humidity, the altitude and incline at which the truck is being driven, the speed and load of the vehicle, and the kind of fuel it is burning, and the amount of time the vehicle idles.[7] Regulators' models of environmental performance posit that in broad terms, a trucking company's environmental performance is determined by six basic factors: (1) the type of fuel used (diesel versus natural gas), as well as the formulation of the diesel fuel it regularly has access to; (2) the age-distribution of the fleet, qualified by deterioration in its trucks' emissions systems over time; (3) the quality of its maintenance program; (4) the average speed at which its trucks travel, as affected by the average time its fleet spends cruising the highway versus battling traffic on city streets; (5) the amount of time its trucks, on average, spend idling; and (6) the number of miles its trucks travel.[8]

[7] When one reads estimates of 'grams per mile' for a given vehicle's emissions, they are actually estimates of emissions over average driving conditions and loads.
[8] The relationships among these factors are complex. For example, for some model years, a cruising speed of 65 miles per hour will result in increased NOx emissions, and for other model years, a decrease.

All of these factors can be affected, of course, by a firm's economic license, by regulation, and by company policy. Thus we conceptualized the six technical or operating factors as intervening variables, between the external license factors and management attitudes, on the one hand, and firm environmental performance on the other, as indicated graphically in Figure 3.

Figure 3 : The Relationship Between External License Pressures, Management Attitude and Environmental Performance is Determined by a Series of Intervening Variables Amenable to Regulatory and/or Company Policy



B. The Sample

We conducted a series of 16 case studies of small and medium-small trucking companies, focusing closely in each case on the relationship between the external factors and the six intervening variables. We conducted in-depth interviews 8 firms in California, 8 in Texas. As in our pulp mill study, we used this small-n sample because of the gaps and bluntness of most official sources of aggregate compliance-related data, and because of the inability of large-n research to plumb the attitudes and motives of company officials. The remedy, we believe, is *in-depth* interviews and *detailed firm-specific* environmental performance data. That is a very labor intensive research strategy, however, ,as is the process of contacting prospective respondents and inducing them to participate in the study. Hence only a 16 firm sample seemed feasible, given budget constraints.

We devised a stratified sampling framework to assure that we would get some medium-sized and some very small trucking firms. And within those categories, in order to assure we had some variability, we used state data that provided some indication of which firms had good environmental performance (e.g. average age of trucks) and which were average or poor, and sampled within those. We interviewed company owners or operations managers at their primary place of business, obtaining technical information about their operations (including their relative performance on the six intervening variables, their economic license, and management policies and attitudes. [9]

C. Findings

Our most important finding is that in an extremely competitive market like trucking, dominated numerically by small companies with low social visibility and few direct pressures from environmental regulators, *social license pressures are weak and managers' environmental consciousness is minimal*. Company-level variation in environmental performance does exist, but it flows primarily from *economic* variables.

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[9] More specifically, we asked participants to describe specific policies or practices they had put in place in order to improve fuel economy; criteria they considered in making truck purchases; what they saw as the industry's environmental and health impacts; which government regulations had the biggest impact on their company; what role (if any) government subsidies had played in their company; and what role environmental agencies, community groups, and environmental groups had played in the life of the company. We obtained data on the age distribution of their truck fleet, fuel used (diesel vs. alternative), maintenance practices, amount of time their trucks idled, policies to decrease idling times, miles per year their trucks traveled, the speed at which their trucks were governed (or other policies the company had in place to influence truck speed), and the fuel economy of the fleet. We also asked companies to rate their own environmental and economic performance on a scale of 1 (worse than average) to 5 (excellent). We asked companies about their prior experience with environmental and safety regulators. We asked for relatively detailed information about the maintenance practices at the company, and technologies the company had considered and/or adopted that would impact fuel efficiency and idling.

Economic license pressures on trucking companies operate on three levels: (a) *the general market* – how well the economy is doing, the price of fuel, the price of labor where the company operates (California generally has more expensive fuel, labor, worker's compensation and other costs.); (b) the particular firm's *market niche* – the kinds of goods are being hauled, how far they are being hauled, day-to-day decisions designed to decrease costs and meet specific customer demands; and (c) company-level *financial condition*. The choices made by a company regarding determinants of environmental performance reflect a mixture of these elements, but certain choices tend to be dominated by one particular level. Figure 4 summarizes the impact of economic license pressures on company-level fleet characteristics that determine fleet emissions. It shows clearly that most economic factors have both positive and negative effects on emissions. Unfortunately the *net effect* of each economic factor is difficult to predict.

Figure 4: The Impact of Economic License Pressures on Company-Level Fleet Characteristics that Determine Truck Fleet Emissions

Economic Factors		Effect of Economic Factors on the Determinants of Environmental Performance	
		Better Emissions	**Worse Emissions**
General Economy	Expanding Economy → higher revenues, More capital*	• Younger fleet (more capital) within niche limits*	• More miles***
	More Expensive Diesel Fuel → Incentive for fuel cost controls** Less capital**	• Less idling • Better maintenance • Better logistics (fewer miles for same deliveries) • Lower highway speed	• Older fleet (higher costs, less capital)
	More Expensive Labor, Workers' Compensation, etc. → Less available capital*, more incentive for fuel cost controls**	Fuel cost controls viz.: • Less idling • Better maintenance • Better logistics (fewer miles for same deliveries) • Lower highway speed	• Older fleet
Market Niche	Long Trips → need for more reliable trucks**	• Younger fleet • Better maintenance	• More idling • More miles
	Sensitive goods More reliable trucks**	• Younger fleet • Better maintenance	
	Customers demand speedy delivery More reliable trucks**	• Newer fleet • Better maintenance	• Faster highway speeds
Company Financial Condition	Company doing well (more capital)**	• Better maintenance • Newer fleet within niche limits • Able to install idling-control equipment	

* based on inference; ** based on interview evidence; *** based on literature

We measured company-level environmental performance in a variety of ways, since no single summary measure captures it. We estimated each firm's NOx and PM emissions per truck and per mile, relying both on formulas created by the California Air Resources Board and on information provided by each company – the age distribution of their fleet of trucks, average miles driven per year per truck, the quality of the firms' maintenance practices, average highway speed of operation (which may be mechanically governed), and the intensity of the company's controls on idling time. We then ranked the 16 firms on each measure, and averaged the company's environmental performance rankings across all measures.

Using this summary measure, we find that no single explanatory or intermediate factor dominates. Some companies that report their financial conditions as "excellent" are only middling environmental performers. The same is true for companies in market niches that encourage younger fleets and better maintenance. Texas and California differ in terms of the general economy factor (with higher labor costs in California, for example), but within each state some companies are excellent environmental performers and others are weak. Similarly, competition and high fuel prices impel many of the companies we studied, particularly those based on California, to emphasize fuel economy in their operations – and fuel economy tends to reduce harmful emissions. But some of our California companies worked on fuel economy more intensively than others, and hence had better environmental performance. But as noted above, they did so not to reduce emissions but in order to control fuel costs.

To state our findings more generally, trucking companies that had better environmental performance most often did so as a byproduct of actions undertaken primarily for economic reasons, such as avoiding the cost of external repair services, late delivery penalties, customer complaints about reliability, and rising prices for fuel.

We also found that medium-sized companies – those with more than 100 vehicles – had a higher proportion of newer trucks (2003 or later model year), and they were much more likely than smaller truck companies to say they were 'doing well' economically. That indicates that size and profitability also are important factors in enabling companies to acquire the capital necessary to turn over their fleets – and thereby reduce emissions.

V. Conclusion

In sum, in the regulation of emissions from heavy-duty diesel trucks in the United States, economic factors have been the dominant factors shaping both company-level environmental performance and the substance of regulatory laws and regulations. More specifically, in an extremely competitive market like trucking, dominated numerically by small companies with low social and regulatory visibility, social license pressures are weak and environmental consciousness is minimal. Company-level variation in environmental performance flows primarily from economic variables – which induce technological investments and management practices designed to reduce costs – and may reduce emissions as a side effect.

At the aggregate level, even in a 'green' state like California, regulators and politicians have only recently begun to consider direct regulations requiring private trucking companies -- by far the largest source of harmful NOx and PM emissions -- to rapidly phase out older, more polluting diesel trucks or engines. The reason, we speculate, again is an economic one: the staggering cost of retrofitting or replacing large portions of the entire diesel fleet, destroying the residual economic value of old trucks. That is why, we believe, both federal and state regulators have focused on new vehicle emissions standards while ignoring how long diesel trucks are kept in operation; why they have shied away from requiring trucking companies (by direct regulation or by fees) to install best available control technologies and scrap older polluting vehicles; and why they have focused on subsidy programs that are too small to have more than a marginal impact on the dangerous emissions of older diesel trucks.

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Adoption of Pollution Prevention Techniques: The Role of Management Systems and Regulatory Pressures

Madhu Khanna*
Dept. of Agricultural and Consumer Economics
University of Illinois
1301 W. Gregory Drive
Urbana, IL 61801
Tel: 217-333-5176
khanna1@uiuc.edu

George Deltas
Department of Economics
University of Illinois
1206 S. Sixth Street
Champaign, IL 61820
Tel: 217-333-4586
deltas@uiuc.edu

Donna R. Harrington
Department of Agricultural Economics and Business
J.D. Maclachlan Building
University of Guelph
Guelph, Ontario, Canada N1G 2W1
Tel: (519) 824-4120 Ext. 53855
dramirez@uoguelph.ca

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*Corresponding Author.
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Adoption of Pollution Prevention Techniques: The Role of Management Systems and Regulatory Pressures

This paper investigates the extent to which firm level technological change that reduces unregulated emissions is driven by existing and anticipated regulatory pressures, and technological and organizational capabilities of firms. Using a treatment effects model with panel data for a sample of S&P 500 firms over the period 1994-96, we find that organizational change in the form of Total Quality Environmental Management leads firms to adopt techniques that prevent pollution even after we control for the effects of various types of regulatory pressures and firm-specific characteristics. Moreover, we find that the presence of 'complementary assets', in the form of technical capability of the firm, is important for creating an internal capacity to undertake incremental adoption of pollution prevention techniques.

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Adoption of Pollution Prevention Techniques: The Role of Management Systems and Regulatory Pressures

1. Introduction

Command and control environmental regulations in the U.S. have typically sought to control pollution after it has been generated. The steeply rising costs of these regulations (these costs increased by more than 50% between 1990-2000)[1] and their negative impact on the productivity of regulated firms (see survey in Gray and Shadbegian, 1994) have shifted the attention of environmental regulators and firms towards flexible environmental strategies that target the reduction of pollution at source. The U.S. National Pollution Prevention Act of 1990 emphasizes pollution prevention rather than end-of-pipe pollution control as the preferred method of pollution reduction. However, it does not mandate adoption of pollution prevention technologies. Instead, the USEPA has sought to induce voluntary adoption of such technologies through the promotion of environmental management systems that induce firms to take a holistic view of pollution control and reduce waste generation at source (Crow, 2000; USEPA, 1997, 1998; USGAO, 1994). This paper investigates the influence of a firm's environmental management system and other internal and external factors on the extent to which the firm adopts pollution prevention technologies.

An environmental management system typically embodies the concept of Total Quality Management which emphasizes prevention over detection, continuous progress in product quality by minimizing defects, and quality improvement across all aspects of the industrial process. Application of these principles to environmental management, referred to as Total Quality Environmental Management (TQEM),[2] can lead firms to apply the same systems perspective to prevent pollution problems. Under TQEM, pollution is viewed as a quality defect to be continuously reduced through the development of products and processes that minimize waste generation at source. Case studies of leading firms, such as Kodak, Polaroid, Xerox and L'Oreal show how TQEM principles and tools led them to implement techniques that reduce waste and improve the quality and environmental friendliness of their processes and products (Ploch and Wlodarcyzk, 2000; Breeden et al., 1994; Wever and Vorhauer, 1993; McGee and Bhushan, 1993; Nash et al., 1992). An in-depth study of firms led the President's Commission on Environmental Quality (1993) to conclude that quality management principles and pollution prevention are complementary concepts; a finding reinforced by subsequent surveys of firms which show that firms that adopted pollution prevention practices were more likely to be those practicing TQEM.[3] However, there has been no systematic empirical determination of a link between TQEM and the adoption of new pollution prevention technologies. Moreover, while TQEM can provide a framework that encourages pollution prevention, it does not guarantee that firms will choose to do so. Firms may instead resort to other ways to control pollution such as recycling or reusing waste. Alternatively, firms may adopt TQEM simply to convey a visible signal of an environmentally responsible firm and gain legitimacy among external stakeholders (Shaw and Epstein, 2000).[4]

In addition to the firm's management system, its technical capabilities can also influence the extent to which it adopts pollution prevention technologies. This is based on the premise that even though generic knowledge about ways to prevent pollution already exists, strategies to prevent pollution need to be customized to the particular production processes and products of the adopting firm. Therefore, pollution prevention is likely to require technical expertise and related experience.[5] Indeed, surveys of firms suggest that adopters of pollution prevention techniques are more innovative in general, with higher R&D intensity and a history of more frequent new product introductions and product design changes (Florida and Jenkins, 1996). This suggests that proactive efforts at reducing pollution do not occur in a vacuum. Instead, they are associated with broader and previous efforts of a firm to be innovative.

Furthermore, external pressure from mandatory regulations could have an impact on the environmental innovativeness of firms. While these regulations do not directly require firms to adopt pollution prevention technologies, they can create incentives to adopt such technologies if these technologies have synergistic effects on reducing emissions of regulated pollutants and thereby reducing current or anticipated costs of compliance. Several authors have also suggested that regulators are responsive to good faith efforts put forth by firms to reduce releases of pollutants not currently regulated or to limit releases of pollutants beyond what is required by statute or permit (Hemphil, 1993/1994; Cothran, 1993). This may create incentives for firms to voluntarily adopt pollution prevention technologies to serve as a signal of environmentally responsibility and reduce regulatory scrutiny and the stringency with which environmental regulations are enforced.

We conduct this analysis using an unbalanced panel of 167 firms from the S&P 500 list which reported to the Toxics Release Inventory (TRI) and responded to the survey on adoption of environmental management practices conducted by the Investor Research Responsibility Center over the period 1994-96. Our study controls for the heterogeneity among firms in a broad range of characteristics while analyzing the impact of technological capabilities, regulatory pressures and TQEM on the adoption of pollution prevention technologies.

Previous studies have used conceptual analysis and case studies in management and organizational theory to show that organizational structure of the firm can affect its speed in adopting productivity enhancing innovations and its ability to realize the benefits of technology adoption. In particular, an effective management system with clear policies, organizational structure, tracking and reporting mechanisms and performance measures is needed to induce environmental innovations (DeCanio et al., 2000; Breeden et al., 1994). Several empirical studies find that environmental regulatory pressures led to environmental innovation (Lanjouw and Mody, 1996; Jaffe and Palmer, 1997; Gray and Shadbegian, 1998; Brunnermeier and Cohen, 2003; Pickman, 1998). These studies use either industry expenditures on R&D or aggregate number of patents as a proxy for innovation and industry pollution abatement costs as a measure of regulatory pressures (with the exception of Gray and Shadbegian (1998) who use plant level data). A related study by Cleff and Rennings (1999) examines the perceived importance of various types of environmental policy instruments on the discrete self-classification of firms as being environmentally innovative and finds that firms perceived voluntary programs (eco-labels and voluntary commitments) to be important in encouraging product and process innovation.

Studies of environmental management systems (survey in Khanna, 2001) have examined the motivations for adopting an environmental plan (Henriques and Sadorsky, 1996), seeking ISO certification (Anderson et al., 1999; Dasgupta et al., 2000; King and Lenox, 2001; Nakamura et al., 2001), adopting a more comprehensive environmental management system (Khanna and Anton, 2002 a, b; Anton et al., 2004) and participating in the Responsible Care Program (King and Lenox, 2000).[6] Another related set of studies has examined the implications of such initiatives by firms for their environmental performance, measured by toxic releases (King and Lenox, 2000; Anton et al., 2004) or by compliance status (Dasgupta et al. 2000). More recently, Arimura et al (2007) and Frondel et al (2007) examine the impact of management systems on the environmental innovation behavior of facilities in various OECD countries. The former study uses R&D expenditure as a proxy for environmental innovation and finds that management systems did not lead to more environmental R&D. The latter study uses a multinomial logit model to examine whether a facility adopted an end-of-pipe technology or a cleaner production technology and finds that management systems motivated adoption of both types of technologies. Both these studies, however, do not control for the endogeneity of the management system adoption decision, which may be determined simultaneously with its environmental innovativeness.

This paper makes several contributions to the literature on the determinants of environmental innovations. Unlike the previous literature which has used either aggregate and broad measures of innovation such as industry expenditures and patent counts or has used discrete indicators of technology adoption, we use detailed micro data on a specific type of environmental innovation, namely count of adoption of 43 types of pollution prevention techniques adopted by firms to reduce their toxic releases as reported annually to the USEPA's Toxics Releases Inventory (TRI). These pollution prevention practices include product and process changes, raw material substitutions and good operating practices. Moreover, we analyze the effects of organizational structure on environmental innovation using a treatment effects model that allows us to control for the endogeneity of the TQEM adoption decision. We also analyze the impact of various types of environmental regulations, both existing and anticipated, on pollution prevention.

2. Conceptual Framework

We consider profit maximizing firms that are emitting toxic releases which are not directly subject to any penalties or other regulations. Despite the absence of regulation, firms may have several motivations to reduce the releases of these pollutants voluntarily. These motivations could be internal, that is, generated by the firm's management philosophy and technical capacity, or external, that is, arising from the firm's interaction with external stakeholders, including environmental regulators, environmental interest groups and consumer groups. These stakeholders have the potential to take actions that affect the costs of compliance, market share, reputation and image of firms. All of these developments have increased the incentives for firms to make proactive efforts to reduce their unregulated toxic releases. In the absence of any mandated technology standards, firms have flexibility in choosing either pollution prevention or end-of-pipe technologies for controlling such releases.

Interest in pollution prevention has grown among firms with the passage of the Pollution Prevention Act and due to increasing costs of end-of-pipe disposal. Underlying the concept of pollution prevention is the premise that pollution is caused by a wasteful use of resources; thus, a reduction in these wastes through changes in production methods that increase production efficiency can lead to input cost-savings, higher productivity, lower costs of pollution control and disposal and lower risk of environmental liabilities relative to using end-of-pipe technologies (Porter and van der Linde, 1995; Florida, 1996). The adoption of pollution prevention activities could also confer a second benefit to firms seeking to improve their environmental image. While emissions reductions from some unobserved counterfactual level may be sometimes hard to ascertain, pollution prevention activities provide tangible evidence to the public and to regulators that the firm is proactively engaged in abatement using methods not mandated by law. Although, recognition of the net benefits of adopting pollution prevention technologies is likely to have been increasing among all firms, we expect these benefits to differ across heterogeneous firms. We next discuss our measure of adoption of pollution prevention techniques.

Our dependent variable is the count of new pollution prevention techniques adopted by a firm during a year. Since pollution prevention is popularly referred to as P2, we call this variable *New P2*. Each facility of a firm is required to report new adoption of any of 43 different activities to prevent pollution for each toxic chemical to TRI in a given year. These activities are broadly categorized into changes in operating practices, materials and inventory control, spill and leak prevention, raw material modifications, equipment and process modifications, rinsing and draining equipment design and maintenance, cleaning and finishing practices, and product modifications. Each facility can report up to four different P2 activities adopted for controlling the level of releases of each chemical.

We use several different methods for aggregating the number of P2 practices across categories of practices, across chemicals, and across facilities belonging to the same parent company. First, we simply aggregate the number of all P2 practices adopted in a year across all chemicals for each facility and then across all facilities belonging to a parent company to obtain *New P2* at the firm-level for that year.[7] Second, we consider the count of chemicals for which a facility had undertaken any P2 activity and aggregate these across chemicals and across facilities belonging to a parent company to obtain *Chem-Count P2* at the firm-level for that year. Third, we weight each facility's P2 activities (summed over chemicals as under the first method above) by its share in the five-year lagged toxic releases of the parent company and obtained a *Weighted Sum of New P2* at the firm level. Facilities with fewer P2 activities per chemical, fewer number of chemicals and a smaller share in lagged toxic releases of the firm would contribute less to this measure of firm level *Weighted Sum of New P2*. The hypotheses and the discussion below are framed in terms of the determinants of *New P2*, for ease of presentation, but apply as well to the alternative aggregations of P2 discussed above. We now discuss the specific factors, first the external and internal factors and then the management system that can explain environmental innovativeness of firms.

Profit maximizing firms can be expected to adopt the lowest cost methods to comply with existing and anticipated regulations. Existing regulations, that are primarily in the form of end-of-pipe technology standards, may create disincentives for voluntary adoption of pollution prevention technologies. Theoretical studies by Downing and White (1986) and Milliman and Prince (1989) show that the incentive to innovate is stronger under market-based systems (e.g. emission fees or permits) than under command and control regulations because the gains through lower costs of compliance with innovation are much higher with market based policies. Additionally, by diverting resources towards compliance with technology standards and promoting a reactive approach to compliance, command and control regulations can reduce incentives to be innovative. However, these studies ignore the potential for firms to influence the stringency with which regulations are enforced, to preempt future regulations or to indirectly lower costs of compliance through synergistic reductions in related pollutants.

Existing mandatory regulations could lead firms to adopt pollution prevention technologies that might be directly targeted at reducing (unregulated) toxic releases but could indirectly lower the costs of regulatory compliance through at least two different channels. First, efforts to prevent toxic releases could reduce the compliance costs for regulated pollutants (if regulated pollutants and toxic releases are complementary by-products of the production process). Surveys find that firms are proactively adopting P2 and seeking to eliminate harmful emissions to avoid complex, inflexible and costly regulatory processes and legal liabilities (Rondinelli and Berry, 2000; Florida and Davison, 2001).

Second, frequent inspections and penalties associated with enforcement of mandatory regulations are not only costly for firms but they can also have a negative impact on a firm's reputation. Empirical studies show that firms that had lower toxic releases were less likely to be subject to inspections and enforcement actions. Such firms were also subject to fewer delays in obtaining environmental permits (Decker, 2003; 2004). Sam and Innes (forthcoming) find that participation in USEPA's voluntary 33/50 program led to a significant decline in the frequency with which firms were inspected. To the extent that adoption of P2 practices can signal good faith efforts by firms to be environmentally responsible and reduce compliance costs, there would be incentives for firms to adopt such practices. We expect both of these channels to create incentives for firms that face greater enforcement pressure in the form of more frequent inspections and a larger number of penalties to adopt more *New P2* not only to reduce pollution at source but also to earn goodwill with regulators and possibly reduce the frequency of future inspections and severity of penalties.

Furthermore, future regulations, particularly if targeted at toxic releases, can also impact adoption of pollution prevention technologies. Anticipation of stringent environmental regulations for reducing currently unregulated pollutants could induce technological innovation by firms to reduce pollution at source (Porter and van der Linde, 1995).[8] By taking actions to control pollution ahead of time through product and process modifications, firms may be able to lower costs of compliance as compared to the costs of retrofitting abatement technologies in the future (Christmann, 2000). Firms may also adopt pollution prevention technologies to reduce the potential for environmental contamination and avoid future liabilities. The anticipation of future stringent environmental regulations may also induce firms to be innovative to gain a competitive advantage by establishing industry standards and creating potential barriers to entry for other competitors (Dean and Brown, 1995; Barrett, 1992; Chynoweth and Kirschner, 1993).

This suggests the following:

Hypothesis 1: The higher the costs of compliance with existing and anticipated mandatory regulations, the greater the incentives to adopt pollution prevention techniques.

As proxies for the costs of existing regulations, we include the variable, *Inspections*, defined as the number of times a firm was inspected by state and federal environmental agencies to monitor compliance with mandatory regulations.[9] We also include *Civil Penalties* received for noncompliance with environmental statutes, such as the Clean Air Act, the Clean Water Act, Toxic Substances Control Act and the Resource Conservation and Recovery Act.

Additionally, as a measure of the stringency of the existing regulatory climate of the county, we construct a measure based on the non-attainment status of all counties in the US. As per the 1977 Clean Air Act Amendments, every county in the US is designated annually as being in attainment or out of attainment (non-attainment) with national air quality standards in regards to six criteria air pollutants: carbon monoxide, sulfur dioxide, total suspended particulates, ozone, nitrogen oxide and particulate matter. Regulatory requirements are commonly understood to be more lax in attainment counties compared to non-attainment counties. These amendments, therefore, led to significant spatial differentials in air quality regulation across counties within states. Within any of the six criteria air pollutant categories, county status may range from attainment of the primary standard to non-attainment. Because a county can be out of attainment in several air pollutant categories, and many heavy polluters emit numerous pollutants, we construct a dummy variable for each of the six pollutants for each facility based on its location: for each pollutant a value of 1 is given to facilities located in a non-attainment county for that pollutant and 0 otherwise. Each of the six dummy variables is summed up for all the facilities of each parent company and the resulting counts are then summed up over the six pollutants to derive the *Non-attainment* variable (as in List, 2000). Higher values indicate that a larger number of the facilities of a parent company are located in counties with non-attainment status for a larger number of pollutants.

A few states have also initiated mandatory P2 programs since 1988 to encourage source reduction of toxic emissions. These programs impose mandatory reporting requirements for P2 activities adopted, similar to the federal TRI, and provide technical assistance to firms in the state. Six states have numerical goals for P2 adoption, while two states provide financial assistance to firms.[10] We hypothesize that facilities located in states with mandatory P2 programs are more likely to adopt *New P2* activities. We include a dummy equal to one if a facility is located in a state with a mandatory P2 program and zero otherwise. These dummies are then summed over the facilities of a firm to obtain the *Mandatory P2 Policy* variable, which provides a measure of the extent to which a firm is facing regulatory pressure to report/adopt P2 activities.

We include another variable, the *Number of Superfund Sites* for which a firm has been listed as a potentially responsible party under the provisions of the Comprehensive Environmental Response, Compensation and Liability Act. This provides a measure of the potential threat of liabilities for harmful contamination caused by disposal of pollution (as in Khanna and Damon 1999; Videras and Alberini 2000). As a proxy for anticipated costs of compliance, we include the volume of *Hazardous Air Pollutants* (*HAP*) consisting of 189 toxic chemicals listed in Title III of the 1990 Clean Air Act Amendments. These were expected to be regulated under New Emissions Standards for HAP from 2000 onwards. We expect that firms with a larger *HAP* face a greater threat of anticipated regulations and are more likely to adopt pollution prevention technologies to obtain strategic advantages over competitors by reducing HAP emissions ahead of time.

In addition to external pressures to adopt P2 activities, two internal factors may also play an important role by influencing a firm's ability to identify profitable techniques and its learning costs of adoption. The first of these is the firm's technological capabilities. These are also referred to as "complementary internal expertise/assets" or "absorptive capacity" (Cohen and Levinthal, 1994). These capabilities depend on the level of in-house technical sophistication.[11] Several scholars have demonstrated the relationship between the knowledge resources and capabilities/competencies of a firm and its innovativeness (Teece, Pisano and Shuen, 1997; Cohen and Levinthal, 1994, 1989).[12] Based on this literature we hypothesize that:

Hypothesis 2: Firms that have stronger technical capabilities are likely to adopt more pollution prevention techniques.

We measure a firm's absorptive capacity by its *R&D Intensity*, defined as the ratio of its annual R&D expenditures over its annual sales. Cohen and Levinthal (1989) contend that R&D expenditures not only generate new information but also enhance the firm's ability to assimilate and exploit existing information, that is, a firm's 'learning' or 'absorptive' capacity.

The second internal factor that could influence the adoption of pollution prevention technologies is the organizational structure of the firm. The managerial literature argues that organizational systems are critical to the innovativeness of firms because they condition firm responses to challenges and ability to realize the full benefits of cost-reducing or productivity enhancing technologies (Teece and Pisano, 1994; DeCanio et al., 2000). In particular, TQEM creates an organizational framework that encourages continuous improvement in efficiency and product quality through systematic analysis of processes to identify opportunities for reducing waste in the form of pollution. The TQEM tool-kit of senior management commitment, team-work, empowerment of employees at all levels, and techniques such as process mapping, root cause analysis and environmental accounting can enable the firm to become aware of inefficiencies that were not recognized previously and to find new ways to increase efficiency and reduce the costs of pollution control (Wlodarczyk et al., 2000). This may lead the firm to see the value of developing products and processes that minimize waste from "cradle to grave" rather than focusing only on end-of-pipe pollution control. The conceptual relationship between TQEM and pollution prevention suggests:

Hypothesis 3: Firms which adopt TQEM will adopt more pollution prevention techniques.

We define *TQEM* as a dummy variable equal to 1 if a firm adopted TQEM in a particular year and zero otherwise. In testing Hypothesis 3, it is important to recognize that *TQEM* could be an endogenous variable. For example, (unobserved) managerial preferences could influence the adoption of both *TQEM* and pollution prevention techniques. We discuss this issue and our methods for accounting for it in the next section.

While testing the above three hypotheses we control for other factors that could also influence the adoption rates of pollution prevention practices. In addition to regulatory pressures, market pressures from consumers and environmental organizations could also lead firms to undertake pollution prevention.[13] Several studies have shown that consumer willingness to pay premiums for environmentally friendly products and the desire to relax price competition can lead some firms to produce higher quality environmental products to differentiate themselves from other firms (Arora and Gangopadhyay, 1995). For example, Starbucks consumers pressured the coffee chain to purchase only from suppliers who grow coffee beans in a bird-friendly-fashion (GreenBiz News, 2004). We extend the demand-side pressures to include the demand for innovation by other stakeholders, such as environmental and citizen groups. These groups can express their preferences through boycotts and adverse publicity which can affect the reputation of a firm.

We proxy consumer pressure by a dummy variable, *Final Good*, which is equal to one for firms that produce final goods and zero for those that produce intermediate goods.[14] We measure pressure by environmental groups through an explanatory variable, *Environmental Activism*, which is defined as the ratio of per capita membership in environmental organizations in a state relative to that in the entire U.S. We obtain a measure of environmental activism for each parent company by averaging the values for all its facilities located in different states.[15] Higher values of this variable indicate that a firm has its facilities in states with relatively high per capita membership in environmental organizations.

Additionally, we recognize that the costs of adopting pollution prevention practices and the effectiveness of pollution prevention as a strategy for reducing emissions may vary with the scale of toxic releases. If larger toxic polluters face larger (smaller) costs of abatement using pollution prevention methods, then one would observe a negative (positive) association between the emissions reported to the TRI and pollution prevention activities. Since current emissions are endogenous, as they are affected by the level of pollution prevention activities, we use lagged *Toxic Releases* (choosing a five year lag to ensure that endogeneity is not an issue even in the presence of serial correlation). In some specifications, of which we report one, we replace lagged

Toxic Releases by current *Toxic Releases* as an explanatory variable. We avoid endogeneity bias from doing so by using lagged *Toxic Releases* as an instrument for current *Toxic Releases*. It is also possible that firms emitting releases with a higher toxicity index may be more concerned about regulatory or public scrutiny and potential liabilities. Such firms may have greater incentives to adopt P2 techniques. We, therefore, also include the lagged *Toxicity-Weighted Releases* as an explanatory variable in one model.

We control for the number of pollution reduction opportunities a firm has by including the *Number of Chemicals* emitted as an explanaotry variable. This variable is the count of chemicals reported by the firm which is obtained by summing up the chemicals reported by each facility over all facilites of that firm. This controls for the possibility that firms emitting a larger number of chemicals or having a larger number of facilities may adopt more pollution prevention practices simply because they have more opportunities to do so.

We also include the *Age of Assets* of a firm, its *Market Share of Sales* and its *Sales* as explanatory variables. *Age of Assets*, measured by the ratio of total assets to gross assets (as in Khanna and Damon, 1999), indicates how depreciated a company's assets are and is thus a proxy for the cost of replacement of equipment. Higher values of this variable indicate newer assets. The newer the equipment, the more costly it would be to replace it, which may be a barrier to innovative activities to prevent pollution. Newer equipment may also be more efficient and less polluting; there may, therefore, be less of a need for making the modifications needed to prevent pollution. We, therefore, expect that firms with older assets may be more likely to adopt more *New P2*.[16]

We include the *Market Share* of a firm in terms of industry sales as an explanatory variable to control for any effects of industry leadership on the incentives for innovation. There is a considerably large theoretical and empirical literature analyzing these effects and yielding ambiguous predictions (see survey by Cohen and Levin 1989). Some have supported the Schumpeterian argument that monopolists or market leaders can more easily appropriate the returns from innovative activity. Others argue that insulation from competitive pressures breeds bureaucratic inertia and discourages innovation.[17] Market share can also be a proxy for a firm's innovativeness and technical capabilities as innovative and technically capable firms tend to dominate their markets. Finally, we include the *Sales* of a firm as a measure of firm size. Larger firms may have more resources to adopt pollution prevention practices. They are also likely to be more visible and thus targets of social pressure by stakeholders because they may be held to higher standards. Such firms may also be more vulnerable to adverse effects of a tarnished reputation.[18]

3. Empirical Model

Our empirical model consists of a *New P2* adoption equation (1) which relates the number of *New P2* techniques Y_{it}, adopted by the i^{th} firm at time t to a vector of observed exogenous variables, X_{it}, the *TQEM* adoption decision, T_{it} , and unobserved factors, ε_{1it}.

$$Y_{it} = \alpha X_{it} + \beta T_{it} + \varepsilon_{1it} \qquad (1)$$

Contemporaneous values of explanatory variables X_{it} are used to explain *New P2* in equation (1), except for five-year lagged values of toxic releases and *HAP*, because emissions might be jointly determined with the *New P2* adoption decisions; unobserved factors influencing *New P2* adoption are likely to influence current emissions. However, our results are robust to using current emissions as a regressor with past emissions as an instrument. Since the distribution of *HAP*, *Toxic Releases* and *Toxicity-Weighted Releases* in our sample is highly skewed to the right and to allow for diminishing marginal effects these variables on *New P2*, we include the square roots of these variables as explanatory variables. We also estimated models using levels of these variables and found that the signs and significances of these and other explanatory variables were unaffected. Because we have multiple years of observations, the error terms may be serially correlated. We allow for serial correlation of the form $\varepsilon_{1it} = \rho_1 \varepsilon_{1it-1} + u_{it}$ where $E(u_{it}) = 0$, $E(u_{it}^2) = \sigma_u^2$ and $Cov(u_{it}, u_{is}) = 0$ if $t \neq s$ and estimate all models using the Prais and Winsten (1954) algorithm.[19]

The coefficient of *TQEM* represents the average treatment effect of *TQEM* adoption on *New P2* adoption levels. We recognize that the *TQEM* adoption decision, T_{it}, may be endogenous because the unobserved variables that influence *TQEM* may be correlated with the unobserved variables that influence *New P2* equation. For example, one such unobserved variable could be the 'green' preferences of the current management which would affect both the decision to undertake *TQEM* and undertake more *New P2* even after conditioning for observed variables. The bias on β in (1) could be positive if *TQEM* is more likely to be adopted by such firms. However, the bias could be negative if firms with an inherently low scope for pollution prevention activities find the adoption cost of *TQEM* not worthwhile. A test for the endogeneity of *TQEM* (Wooldridge, 2002) rejects the null hypothesis that it is an exogenous variable at the 1% significance level. To deal with this endogeneity problem, we can use a two-stage least squares method to estimate the effect of T_{it} on Y_{it} consistently if the following conditions are satisfied (Wooldridge 2002): the error term has zero conditional mean; the variance of the error is constant; the standard rank condition is satisfied; and the TQEM adoption is adequately described by a probit model (Wooldridge 2002). The optimal instrumental variable for *TQEM* in such a model is the predicted probability of *TQEM*, $\hat{T}_{it}$, which we obtain by estimating the *TQEM* adoption equation using a probit model with a vector of explanatory variables, W_{it-5} (that capture the factors that influence the benefits and costs of adopting TQEM). In particular, we posit the following selection equation based on the latent variable T_{it}* which measures the net benefits from adoption of TQEM.

$$T_{it}{}^* = \gamma_1 W_{it-5} + \varepsilon_{2it} \qquad (2)$$

The indicator variable for *TQEM* is $T_{it} = 1$ if $T_{it}{}^* > 0$ and 0 otherwise. Some of the variables included in W_{it-5} are likely to be also included in X_{it}. The *i.i.d.* error component ε_{2it} is assumed to be normally distributed with mean zero and variance $\sigma^2_{\varepsilon 2}$. We estimate the probit model pooling all observations from the three year panel. The parameter estimates obtained thereby are consistent but the standard errors are incorrect because they ignore the panel nature of the data. We correct for the standard errors by allowing for correlation in the disturbance of the latent variable across time for the same firm.

The explanatory variables included as instruments for TQEM in estimating equation (2) are based on the findings about the determinants of TQEM adoption described in Harrington et al. (forthcoming). They hypothesize that the incentives for firms to adopt TQEM depend on external stakeholder pressures from environmentally aware consumers and public interest groups, regulatory pressures from environmental agencies, and internal factors which depend on the production related benefits and costs of making such organizational changes and the capabilities of firms to make them. The internal production-related benefits arise because TQEM focuses on process improvement to reduce input waste, which is seen as the cause of pollution, and input use while increasing productivity and value-added activities. The adoption of TQEM may also impose production-related and managerial costs due to a need for process and product modifications.[20] We include lagged values of *Civil Penalties*, *Inspections*, *Superfund sites* and *HAP* as proxies for regulatory pressures. We include *Final Good* as a measure of consumer pressure and lagged *Sales* as a measure of visibility to the public. *Sales* is also a proxy for the economies of scale and firm size could influence the firm's ability to bear the fixed costs of adoption. We include lagged *Toxic Releases* reported to the TRI as a measure of the scale of the environmental problem. Additionally, lagged *R&D Intensity* and *Number of Facilities* could influence the net benefits of adopting TQEM. *R&D Intensity* is a proxy for the technical capacity of firms. The *Number of Facilities* of a firm could influence the firm's visibility to the public, the costs of coordinating a common management system within the corporation and the gains from implementing a uniform approach towards environmental management. In equation (2) all time dependent explanatory variables (other than *Number of Facilities*) are measured with a five-year lag (for the years 1989-91) to avoid possible endogeneity bias since the year that a firm adopts TQEM for the first time is not known. However, adoption may have occurred during or after 1991, since TQEM was first introduced by the Global Environmental Management Facility that was formed in April 1990. The use of five-year lagged explanatory variables avoids the possibility that TQEM adoption in the past could have influenced any of the explanatory variables included above. While *Number of Facilities* is expected to influence the adoption of TQEM, it is not expected to influence the adoption of P2 activities by a firm after we have controlled for the *Number of Chemicals* emitted by the firm aggregated over facilities. The exclusion of this variable from equation (1) enables identification of its parameters.

4. Data Description

The sample consists of S&P 500 firms which responded to the Investor Research Responsibility Center (IRRC) survey on corporate environmental management practices adopted by them and whose facilities reported to the TRI at least once over the period 1994-1996 or 1989-1991 (since we are using five-year lagged values of toxic releases as explanatory variables). The IRRC data provides information about the adoption of TQEM by parent companies. The TRI contains facility-level information on releases of chemical-specific toxic pollutants and on the pollution prevention activities adopted by firms since 1991. It also provides data on *HAP* and the *Toxicity-Weighted Releases*.[21] To match the TRI dataset with the IRRC, we construct unique parent company identifiers for each facility in the TRI database, and then aggregate all chemical and facility level data to obtain parent company level data.[22] We dropped the chemicals which had been added or deleted over the period 1989-1996 due to changes in the reporting requirements by the USEPA. This ensures that the change in toxic releases in our sample over time is not due to differences in the chemicals that were required to be reported. Of the S&P 500 firms, only 254 firms reported to the TRI at least once during the period 1989-1996. Of these firms, an unbalanced panel of 184 firms responded to the survey by the IRRC in at least one of the three years. Restricting our sample to the firms for which complete data for estimating equations (1)-(2) were available resulted in 463 observations belonging to 174 firms for estimating equation (1) and 422 observations belonging to 167 firms for estimating equation

(2). Summary statistics for the variables used here are presented in Table 1.

The TRI instructs firms to report the new P2 activities adopted by them in that year. However, it is possible that some firms might be reporting all (cumulative) P2 activities adopted by them instead of only the incremental ones. To check if this was the case we examined the annually reported P2 counts by each facility belonging to S&P 500 firms and reporting to TRI, for each chemical for the period 1992-1996 and compared it with their reports for the previous period (1991-1995). We then derived the change in the reported *New P2* count for a total of 74,780 instances at the chemical-facility level. If firms were inadvertently reporting all P2 activities adopted instead of New P2 activities, we would expect that the annual count of P2 reported would be increasing or stay constant over time for all years. Our investigation focused at the facility level on the premise that any misinterpretation of the instructions in the TRI would be at the facility rather than chemical level. In particular, we have calculated the number of facilities for which the reported P2 counts were non-decreasing for all chemicals. We found that this was the case for only 236 facilities (5.68% of all S&P facilities reporting to TRI) and represents only 0.67% of the chemical-facility pairs (because these facilities have a much lower than average number of chemicals). Therefore, even if there was any misinterpretation of the survey question, it impacted at most a small fraction of the data. [23]

The number of environmental *Civil Penalties* and the number of *Inspections* are derived from USEPA's Integrated Data for Enforcement Analysis (IDEA) database. Since these data are reported at the sub-facility level, inspections and penalties of all sub-facilities of each parent company are added up to get parent company level data. The number of *Superfund Sites* is derived from the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) of the USEPA. Superfund data are at the facility level and were aggregated to the parent company level.

The S&P 500 Compustat database, now known as Research Insight, is the source of parent-company level financial data on net sales, total assets, gross assets and R&D expenditures. *Market share* data are obtained from Ward's Business Directory using parent company names. The *Final Good* dummy is constructed based on the firm's four-digit SIC code (as described in Harrington et al., 2005). The primary SIC code of a parent company is that reported in the Research Insight database. If that was missing, then we use the SIC code in Ward's Business Directory to construct the *Final Good* dummy.

The *Non-attainment* status of counties is obtained from the USEPA Greenbook.[24] These data are matched with the TRI using the location information of each facility. The data on *Environmental Activism* are obtained at the state level for 1993 from Wikle (1995).[25] Data on state P2 policies are obtained from the National Pollution Prevention Roundtable.[26]

5. Results

We estimated three alternative first-stage probit models to explain TQEM adoption (Table 2). In Model I-A the explanatory variables are measured in levels while in Model I-B they are measured in square roots (except for *Number of Facilities*). The Schwarz Information Criterion and Akaike Information Criterion indicate that explanatory variables measured in square-roots provide a better fit to the data on *TQEM*. We then estimate Model II, which is a parsimonious version of Model I-B and includes only the variables that have a statistically significant effect on *TQEM*. We find that firms that have larger *R&D intensity*, larger *Sales*, larger *Toxic releases* and a fewer *Number of Facilities* are more likely to adopt TQEM. Consumer pressure, proxied by *Final Good*, and regulatory pressure proxied by *Number of Superfund Sites*, *HAP*, *Civil Penalties* and *Inspections*, is not found to have any effect on TQEM adoption. These results are consistent with those reported in Harrington et al. (forthcoming) which find that internal considerations were more important in motivating adoption of TQEM than external factors.

We estimate several different models to examine the determinants of *New P2* adoption. All linear models are estimated assuming an AR1 error process. The estimates of ρ_1, the autocorrelation parameter, in all models strongly support the validity of assuming an AR1 error process against the alternative of an *i.i.d.* error distribution. Since the dependent variable is a count variable, we also estimate a negative binomial model. The dispersion parameter of the negative binomial is statistically significant, indicating the validity of using this model instead of a Poisson model. The standard errors of the negative binomial models allow for correlation in the disturbance of the latent variable across time for the same firm.

We first examine the results of models that include only the exogenous explanatory variables and exclude *TQEM*. Model III-A (Table 3) examines the determinants of *New P2*. Model III-B is a negative binomial version of Model III-A. Model IV A includes the square root of *Toxicity-Weighted Releases* as an additional explanatory variable. Model V and Model VI have *Chem-Count P2* and *Weighted P2* as dependent variables, respectively. These models examine only hypotheses I and II. The coefficients of all variables will also include any indirect effects the associated factors will have through their influence on TQEM adoption. We then estimate and report results of the full structural system which includes the TQEM variable, appropriately instrumented.

Results from the linear regressions consistently support Hypothesis 1 and show that current and anticipated regulatory pressures, as proxied by *Penalties, Inspection, HAP and Non-Attainment*, had a statistically significant positive impact on *New P2* and *Chem-Count P2* adoption. In the negative binomial model, however, only the regulatory pressure proxied by *Non-Attainment* had a statistically significant impact on *New P2*. Surprisingly, we find that the effect of *Superfund Sites* is negative and statistically significant across all models, suggesting that firms that were responsible for fewer *Superfund Sites* were more likely to adopt *New P2* and *Chem-Count P2*. This could be because firms that are potentially responsible for a larger number of *Superfund Sites* are those that typically dispose large amounts of waste off-site. An effective way to manage their environmental impacts may be through end-of-pipe treatment rather than pollution prevention. It could also be that such firms are expecting to incur a substantial financial burden to address current liabilities and have fewer resources to invest in pollution prevention technologies.

Model VI shows that existing mandatory regulations did not have a statistically significant impact on the *Weighted P2* measure of adoption of pollution prevention techniques. Recall that *Weighted P2* differs from *New P2* in that it attaches a higher weight to P2 adoption by facilities with a higher share of toxic emissions within the firm. Therefore, the finding that regulatory pressures influence *New P2* adoption but not *Weighted P2* adoption suggests that existing regulations primarily impact the P2 activities of those facilities that have a smaller share of the firm's toxic releases. Existing regulations do not appear to have motivated the relatively pollution intensive facilities within the firm to undertake more P2 activities, possibly because the costs of undertaking P2 may have been much higher for these facilities. Anticipated HAP regulations, however, did motivate a higher level of *Weighted P2* adoption in addition to a higher level of *New P2* adoption. This indicates that regulations targeted at toxic releases were more effective in motivating P2 adoption by the pollution intensive facilities within firms as compared to command and control regulations aimed at other pollutants. We also find robust support for Hypotheses 2 in the linear and negative binomial model and across alternative measures of P2 activity. All models in Table 3 show the positive effects of technological capabilities, as proxied by *R&D Intensity* on *New P2*.

In Table 4, we present the results of models that include the impact of TQEM adoption on P2 activity. Model VII-A estimates an OLS model that disregards the endogeneity of the TQEM adoption decision. Model VII-B examines the impact of TQEM on *New P2* using the predicted probability of TQEM estimated from Model II as an instrument for TQEM. Model VII-C uses the variables from Model II directly as instruments for TQEM (except *Number of facilities* which is included to explain *TQEM* but is not expected to influence *New P2* and hence excluded from that equation). We find that the conclusions of our paper regarding the determinants of *New P2* techniques do not depend materially on whether the parsimonious or larger specification of the first stage models is used. Model VII-D includes current toxic releases as an explanatory variable and lagged toxic releases as an instrument, while Model VII-E includes toxicity-weighted releases as an explanatory variable. Model VII-F estimates a two-step negative binomial model.

Model VII-A which is estimated without correcting for the endogeneity of *TQEM* shows that the effect of *TQEM* on *New P2* is positive but small and statistically insignificant. The other Models VII B-E, however, consistently support Hypothesis 3 and show that *TQEM* has a positive and statistically significant impact on *New P2*. The coefficient of *TQEM* in the models that instrument for *TQEM* is much larger than in Model VII-A, indicating the presence of a negative selection bias in its estimation, i.e., that TQEM adopters are firms with lower than average *unobserved* propensity to adopt pollution prevention activities. The two-step negative binomial in Model VII-F is implemented using the predicted value of *TQEM* as an explanatory variable. Since we are using a generated regressor, the standard errors are corrected using the Murphy-Topel method.

The magnitude of the *TQEM* coefficient in the base models (VII-B and VII-C) suggests that the average effect of TQEM adoption on the annual count of *NewP2* practices is equal to approximately 18 practices. In our sample, the average annual count of pollution prevention practices by adopters of TQEM is equal to 27. This suggests that if these firms had not adopted TQEM, their average annual count would be only about 9. The non-adopters of *TQEM* average about 16 *New P2* practices per year in our sample. The fact that adopters would have introduced fewer pollution prevention practices per year in the absence of *TQEM* is consistent with our finding that there is negative selection into the adoption of TQEM (though this simple difference in means is partially due to differences in observable firm characteristics). In comparing the results of Table 4 with those of Table 3, the most important observation is that with the inclusion of TQEM as a variable, the magnitude of the coefficient of *R&D Intensity* and its statistical significance diminishes. This suggests that *R&D intensity* has an indirect effect on the adoption of *New P2* through the adoption of TQEM and after accounting for that, its direct effect is smaller. On the other hand, the effects of variables proxying for regulatory pressure appear to be primarily direct effects on *New P2*. This is consistent with the results obtained in Table 2 which show that R&D intensity has a significant influence on TQEM adoption while regulatory pressures do not.

In Table 5, we examine the effect of *TQEM* on alternative measures of pollution prevention. Models VIII-A and VIII-C use predicted probability of *TQEM* as an instrument while Models VIII-B and VIII-D use lagged variables as instruments. We find that *TQEM* has a statistically significant and positive effect on *Weighted P2* and on *Chem-Count P2*, while the effects of other variables remain as discussed above. These results suggest that *TQEM* leads even the more pollution intensive facilities within firms to adopt more pollution prevention activities.

Among the other firm characteristics, *Market Share*, and *Number of Chemicals*, have a statistically significant effect on P2 adoption. The effect of *Number of Chemicals* was as expected; the more opportunities a firm has to adopt pollution prevention technologies the more such technologies it will adopt. We find a fairly robust negative and statistically significant sign for *Toxic Releases* (whether lagged or not) suggesting that firms that were relatively small toxic polluters had lower costs of abatement of toxic releases using pollution prevention technologies. After controlling for the effects of the volume of toxic releases, we find that *Toxicity-weighted releases* had a positive and significant impact on *New P2*. The effects of other firm characteristics, such as *Sales* and *Age of Assets*, are not robustly significant across all the models. The effects of other external pressures from environmental groups, communities or consumers on adoption of pollution prevention techniques, as proxied by *Environmental Activism* and *Final Good*, are also not statistically significant. The effects of firm characteristics and the magnitudes of their coefficients are very similar in models that include *TQEM* and those that exclude *TQEM* as a variable.

6. Conclusions

The objective of this paper is to study the factors that influence the voluntary adoption of technologies that reduce toxic pollution at source in a sample of S&P 500 firms. Particular attention is devoted to examining the impact of a firm's management system and of external regulatory pressures on the adoption of pollution prevention technologies. In addition, we investigate the role played by internal capabilities in influencing incremental adoption of these technologies. More generally, our study makes a contribution to the broader literature that studies the determinants of environmental innovation by firms.

Our main econometric findings are as follows. First, regulatory pressure from current and anticipated regulations plays an important role in motivating voluntary environmental innovation. In contrast, market pressures are found to have an insignificant effect on firm behavior. Pressure from existing regulations is found to be more important in motivating the relatively cleaner facilities within firms to adopt pollution prevention technologies. Second, adoption of TQEM does indeed motivate the adoption of more pollution prevention technologies. Thus, managerial innovations, such as adoption of TQEM, lead firms to be innovative in their approaches towards environmental management. Third, technological capability is an important determinant of a firm's adoption of pollution prevention technologies. Fourth, firms with a relatively smaller volume of toxic releases face higher costs of abatement using pollution prevention technologies. To the extent that this is also the case for facilities within firms, it would explain the finding above that regulatory pressures were more likely to motivate the less toxic release intensive facilities to undertake pollution prevention. High toxicity-weighted releases in the past do, however, motivate more pollution prevention activities by firms. This suggests that firms perceive the benefits from preventing such pollution and reducing potential liabilities and public concern.

These results indicate that firms' adoption of TQEM is not simply a 'greenwash' or done only to achieve social legitimacy. Such firms are indeed changing their operations to make them more environmentally friendly. While our study cannot shed light on whether strategies to induce voluntary adoption of pollution prevention techniques are sufficient (or more effective than mandatory approaches requiring pollution prevention) for achieving the goals of the Pollution Prevention Act, they do show that efforts to encourage voluntary changes in a firm's management system while maintaining a strong regulatory framework and a credible threat of mandatory regulations can be effective in moving firms towards those goals.

This analysis has several policy implications. It shows the extent to which policy makers can rely on environmental management systems to induce voluntary pollution prevention. It also shows the role that regulations can play in motivating innovative methods for pollution control. By distinguishing between different types of regulatory pressures, this analysis shows that regulatory pressures targeted towards hazardous toxic releases are more effective than others in inducing the pollution intensive firms and facilities within firms to adopt pollution prevention practices. The results obtained here also highlight the importance of providing technical assistance to firms that may not have the capacity to undertake innovative pollution prevention activities. Lastly, by identifying the types of firms less likely to be self-motivated to voluntarily adopt pollution prevention practices, this analysis has implications for the design and targeting of policy initiatives that seek to encourage greater pollution prevention.

[1]http://yosemite1.epa.gov/ee/epalib/ord1.nsf/77e34926d19d5664852565a500501ed6/335eadf8201059108 52565d00067efc6!OpenDocument

[2] The Global Environmental Management Initiative (GEMI) is recognized as the creator of total quality environmental management (TQEM) which embodies four key principles: customer identification, continuous improvement, doing the job right first time, and a systems approach (http://www.bsdglobal.com/tools/ systems_TQEM.asp).

[3] A survey of U.S. manufacturing firms in 1995 by Florida (1996) found that 60% of respondents considered pollution prevention to be very important to corporate performance and two-thirds of them had also adopted TQEM. Of the 40% firms that considered pollution prevention to be only moderately important, only 25% had adopted TQEM. A survey of U.S. manufacturing plants in 1998 found that among the pollution prevention adopters, the percentage of firms practicing TQM was twice that for other plants (Florida, 2001). A survey of Japanese manufacturing firms found that plants adopting a green design were more likely to be involved in TQM than other plants (Florida and Jenkins, 1996).

[4] For example, Howard et. al (2000) found that Responsible Care participants were more likely to implement practices visible to external constituencies but they varied a great deal in implementation of practices such as pollution prevention and process safety that were visible only internally. Shaw and Epstein (2000) argue that firms adopt popular management practices, such as total quality management, to gain legitimacy and find that implementation of such practices leads to gains in external reputation regardless of whether there is an improvement in the firm's financial performance.

[5] More generally, prior research suggests that firms cannot costlessly exploit external knowledge, but must develop their own capacity to do so, through the pursuit of related R&D activities and cumulative learning experience (Cohen and Levinthal, 1989; 1994).

[6] Several studies also investigate the motivations for firms to participate in public voluntary programs such as EPA's 33/50 program, Waste Wise and Green Lights (for a survey of those studies see Khanna, 2001).

[7] It is extremely rare in our sample that a firm reports four P2 activities for a particular chemical. Thus, censoring through top coding is not a concern in our data.

[8] Several theoretical studies show that the threat of mandatory regulations can induce voluntary environmental activities to preempt or shape future regulations (see survey in Khanna, 2001). Empirical analyses show that regulatory pressures (Henriques and Sadorsky, 1996; Dasgupta, et al., 2000), threat of liabilities and high costs of compliance with anticipated regulations for hazardous air pollutants (Anton et al., 2004; Khanna and Anton, 2002) did motivate adoption of environmental management practices, but their direct effect on environmental technology adoption has not been examined.

[9] Information about the pollution prevention practices adopted by firms is available to regulators only with a lag of one or two years. Hence we do not expect current inspections and penalties to be influenced by current pollution prevention decisions.

[10] Mandatory P2 programs started in 1988 with Washington, followed by Massachusetts and Oregon in 1989. Four states adopted them in 1990 (Maine, Minnesota, Mississippi, and Vermont) while three adopted them in 1991 (Arizona, New Jersey, and Texas). Arizona, Massachusetts, Maine, Mississippi, New Jersey and Washington have set numerical goals for P2 activities; while Arizona and Minnesota provide financial assistance to firms.

[11] These capabilities or specialized assets are firm-specific. They are acquired over time, are non-substitutable and imperfectly imitable, such as firm-specific human capital, R&D capability, brand loyalty. They can enable firms to adopt new technologies at lower cost (Dierickx and Cool, 1989).

[12] Blundell et. al. (1995) find that the stock of innovations accumulated in the past was significant in explaining current innovations. Christmann (2000) finds that complementary assets in the form of R&D intensity of the firm determine the competitive advantage that a firm receives from adopting P2 strategies.

[13] Consumer preferences for green products may manifest themselves through movements in demand and relative prices in the product markets. This parallels the argument put forth by Schmookler (1962) and

Grilliches (1957) that demand-pull can explain innovative activity by firms as they strive to deliver the preferred goods in the market (Dosi, 1982).

[14] Empirical evidence does suggest that firms that produce final goods and that were larger toxic polluters in the past were more likely to participate in voluntary environmental programs and adopt EMSs (see survey in Khanna, 2001; Anton et al., 2004).

[15] Studies also show that community characteristics can influence the level of public pressures for reducing pollution (Arora and Cason, 1999; Hamilton, 1999). Pressure from environmental groups, proxied by membership in environmental organizations, was found to influence participation in voluntary programs (Welch et al., 1999; Karamanos, 2000) and reduction in intensity of use of certain toxic chemicals (Maxwell et al., 2000). Using this measure of environmental activism, Welch et al. (1999) find that firms headquartered in states with greater environmentalism were more likely to participate in the voluntary Climate Challenge program.

[16] Studies find that firms with older assets were more likely to participate in voluntary environmental programs (Khanna and Damon, 1999) and adopt a more comprehensive environmental management system (Khanna and Anton, 2002).

[17] In the context of quality provision, Spence (1975) shows that this depends on the relationship between the marginal value of quality and the average value of quality to the firm while Donnefeld and White (1988) show that it depends on the differences in the absolute and marginal willingness to pay for quality.

[18] Larger firms have been found to be more likely to participate in the chemical industry's Responsible Care Program (King and Lenox, 2000), Green Lights, Waste Wise, and 33/50 programs (Videras and Alberini, 2000) and in Climate Challenge (Karamanos, 2000).

[19] A fixed effects model could not be estimated because we have several regressors that are time-invariant. A random effects model failed to converge and hence could not be estimated.

[20] Empirical studies show that regulatory pressures, threat of liabilities and high costs of compliance with existing and anticipated regulations motivated the adoption of environmental practices. (Henriques and Sadorsky, 1996; Dasgupta, et al., 2000; Anton et al., 2004; Khanna and Anton, 2002a). They also find that firms that were large toxic polluters and likely to face greater public scrutiny, that were in closer contact with consumers and were more visible to the public were also motivated to adopt EMSs (Anton et al., 2004; Khanna and Anton, 2002; King and Lenox, 2000). Some empirical studies have found a positive significant effect of R&D on the adoption of EMSs (Khanna and Anton, 2002), on participation in the 33/50 program (Arora and Cason, 1996) and in Waste Wise (Videras and Alberini, 2000). In contrast, Khanna and Damon (1999) and Videras and Alberini (2000) did not find the R&D level to significantly influence participation in 33/50 and Green Lights.

[21] We construct toxicity weighted releases using toxicity weights defined by the Threshold Limit Values (TLV) for each toxic chemical. TLVs are set by the American Conference of Governmental and Industrial Hygienists (ACGIH, 2003) as the maximum average air concentration of a substance to which workers can be exposed without adverse health effects during an 8-hour work shift, day after day. The TLV index is calculated by multiplying the quantity of emissions of each toxic chemical with the inverse of the TLV of the chemical and then summing across all chemical releases by the firm.

[22] To match the facilities with their parent companies, a combination of the Dun and Bradstreet number, facility name, location, and SIC code were used (these additional identifiers were used for some facilities when the Dun and Bradstreet number was missing). The ticker symbol, which identifies the parent companies in the Research Insight database, was used to match the IRRC data with financial data from Research Insight. Since some parent company names have changed over our study period, Market Insight, a database tool linked with Research Insight was used to trace the parent company's history. The historical information included mergers, acquisitions, changes in names, SIC codes and ticker symbols.

[23] These 236 facilities consistently reported P2 counts that were the same or higher than in preceding year(s) for all their chemicals, and they comprise 5.68% of all unique 4155 facilities that belonged to S&P 500 firms and reported to the TRI. They can be suspected of incorrectly reporting their P2 activities (though an equally likely possibility is that the P2 count was indeed non-decreasing for all the chemicals

and time periods for these facilities). In terms of total sample, this translates to 502 out of 74,780 chemical-facility pairs. Additionally, these 236 facilities belong to 113 different parent companies. Hence, we can rule out systemic and large scale misinterpretation of TRI instructions at the parent company level. Even if it occurred at the facility level, the number of facilities and the number of P2 activities affected by it is negligible.

[24] Can be found at http://www.epa.gov/oar/oaqps/greenbk/anay.html.

[25] It is based on data on membership in 10 environmental organizations, namely African Wildlife Foundation, American Birding Association, The Nature Conservancy, World Wildlife Fund, Zero Population Growth, American Rivers, Bat Conservation International, Natural Resources Defense Council, Rainforest Action Network, and Sea Shepherd Conservation Society.

[26] http://www.p2.org/inforesources/nppr_leg.html.

Table 1. Descriptive Statistics (1994-96).

Variable	Mean	Std. Dev.	Minimum	Maximum
TQEM	0.68	0.47	0.00	1.00
New P2	23.40	37.13	0.00	284.00
Chem-Count P2	14.65	23.28	0.00	173.00
Weighted Sum of New P2	2.49	4.16	0.00	28.93
R&D Intensity	0.03	0.04	0.00	0.24
Final Good	0.56	0.50	0.00	1.00
Environmental Activism	0.90	0.28	0.26	2.43
Lagged Toxic Releases (Millions of pounds)	14.87	42.34	0.00	382.88
Current Toxic Releases (Millions of pounds)	31.88	69.85	0.00	519.18
Superfund Sites	66.32	173.28	0.00	1376.00
Lagged HAP (Million of pounds)	3.05	6.86	0.00	57.97
Penalties	1.49	3.43	0.00	33.00
Inspections	50.66	82.79	0.00	491.00
Non-attainment	12.24	16.87	0.00	96.00
Mandatory P2 Policy	1.69	2.87	0.00	18.00
Market Share of Sales	0.26	0.22	0.00	0.98
Net Sales ($ Billion)	12.96	22.40	0.18	165.37
Age of Assets	0.75	0.10	0.46	0.93
Number of chemicals	80.69	113.86	1.00	625.00
Number of Facilities	17.64	20.73	1.00	111.00

Summary statistics are presented for N=422.

Table 2: Determinants of TQEM Adoption

Explanatory Variables	Model I-A	Model I-B	Model II
Constant	0.207 (0.188)	-0.446* (0.259)	-0.391 (0.248)
R&D Intensity	2.328 (2.365)	1.797** (0.880)	1.818** (0.881)
Final Good	0.042 (0.201)	0.032 (0.209)	
Toxic Releases	0.005 (0.003)	0.063 (0.040)	0.115*** (0.040)
Superfund	0.0004 (0.001)	0.011 (0.032)	
HAP	0.008 (0.016)	0.012 (0.110)	
Penalties	0.053* (0.064)	0.108 (0.129)	
Inspections	0.002 (0.002)	0.042 (0.042)	
Sales	0.0001 (0.0001)	0.006* (0.003)	0.007** (0.003)
Number of Facilities	-0.014** (0.006)	-0.017** (0.007)	-0.011** (0.005)
Schwarz I.C.	611.86	586.83	561.82
Akaike I.C.	1.23	1.18	1.17

N= 463 in all these regressions. Values in parentheses are standard errors.
All models allow for correlation of disturbances across time for each firm:
*significant at 10%, **significant at 5%, ***significant at 1%. All variables in Model I-A are in linear terms. All variables in Model I-B and II are in square root with the exception of Number of Facilities.

Table 3: Determinants of the Adoption of Pollution Prevention Techniques

Explanatory Variables	MODEL III-A New P2: OLS	Model III-B New P2: Negative Binomial	Model IV New P2: OLS	MODEL V Chem-Count P2: OLS	MODEL VI Weighted P2: OLS
Constant	12.349 (9.640)	-0.832** (0.383)	10.763 (9.678)	5.655 (5.525)	5.110*** (1.687)
Innovative Capabilities					
R&D Intensity	67.584** (28.455)	2.772* (1.528)	66.438** (28.419)	43.416*** (4.984)	15.998*** (16.329)
Regulatory Pressures					
Superfund	-0.025*** (0.009)	-0.080* (0.045)	-0.025*** (0.009)	-0.010* (0.005)	-0.001 (0.001)
HAP	4.038*** (1.524)	-0.158 (0.129)	4.506*** (1.550)	1.580* (0.876)	1.168*** (0.267)
Penalties	0.639* (0.358)	-0.076 (0.068)	0.562 (0.361)	0.578*** (0.207)	0.073 (0.063)
Inspections	0.047** (0.021)	0.054 (0.071)	0.046** (0.021)	0.031** (0.012)	0.004 (0.004)
Non-attainment	0.391*** (0.093)	0.161** (0.078)	0.404*** (0.093)	0.161*** (0.053)	0.030* (0.016)
Mandatory P2Policy	-0.581 (0.562)	-0.147 (0.089)	-0.422 (0.571)	0.062 (0.322)	-0.243** (0.098)
Other Firm Characteristics					
Final good	0.194 (2.367)	-0.255* (0.152)	0.632 (2.379)	-0.269 (1.362)	0.408 (0.416)
Environmental Activism	2.589 (3.493)	0.066 (0.232)	2.751 (3.486)	-0.570 (2.018)	2.162*** (0.616)
Toxic Releases	-0.816* (0.426)	0.099 (0.068)	-1.288** (0.520)	-0.410* (0.248)	0.061 (0.076)
Toxicity Weighted Releases			0.347+ (0.221)		
Market share	16.359*** (5.029)	0.090+ (0.058)	15.050*** (5.091)	7.854*** (2.892)	1.988** (0.883)
Net Sales	-0.012 (0.074)	0.094 (0.079)	-0.009 (0.074)	0.035 (0.042)	0.026** (0.013)
Age of Assets	-24.720** (12.028)	-0.488 (0.558)	-23.180* (12.047)	-9.630 (6.907)	-8.801*** (2.108)
Number of Chemicals	0.186*** (0.027)	0.900*** (0.110)	0.184*** (0.027)	0.124*** (0.016)	-0.009** (0.005)
Year	-1.140 (0.965)	-0.130** (0.052)	-1.161 (0.962)	-0.843 (0.563)	-0.245 (0.171)
Log- Likelihood	-1886.65	-1424.55		1643.47	-1143.69
ρ_1	0.597*** (0.039)			0.565*** (0.0401)	0.569*** (0.040)

N=422. Values in parentheses are standard errors. * Significant at 10%, ** Significant at 5%, *** Significant at 1%.
+ Significant at 15% level. Dispersion parameter for Negative Binomial is 0.533 and statistically significant at 5%.

Table 4: Impact of TQEM Pollution Prevention (New P2) Adoption

Variables	Model VII-A OLS	Model VII-B 2SLS: Predicted probability as IV	Model VII-C 2SLS: Variables as IV	Model VII-D 2SLS: Predicted probability and lagged releases as IV	Model VII-E 2SLS: Predicted probability as IV	Model VII-F Two-Step Negative Binomial
Constant	12.586 (9.672)	-2.346 (11.107)	-2.242 (11.618)	3.775 (11.015)	-3.223 (11.140)	1.546* (0.903)
Internal Managerial and Innovative Capabilities						
TQEM	0.197 (2.058)	17.496*** (6.679)	18.519*** (6.674)	22.507*** (7.426)	16.656** (6.634)	1.786** (0.830)
R&D Intensity	70.292** (28.036)	46.928 (29.284)	48.924* (29.849)	40.143 (29.543)	47.810* (29.170)	-2.289 (2.009)
Regulatory Pressures						
Superfund	- (0.009)	-0.029*** (0.009)	-0.029*** (0.009)	-0.027*** (0.009)	0.029*** (0.009)	-0.001** (0.000)
HAP	3.953*** (1.506)	3.648** (1.520)	3.034* (1.637)	4.333*** (1.604)	4.300*** (1.543)	0.108 (0.110)
Penalties	0.634* (0.342)	0.750** (0.361)	0.762** (0.368)	1.139*** (0.404)	0.671* (0.363)	0.032 (0.020)
Inspections	0.045** (0.021)	0.051** (0.021)	0.052** (0.022)	0.068*** (0.023)	0.049** (0.021)	0.000 (0.001)
Non-attainment	0.401*** (0.090)	0.418*** (0.092)	0.405*** (0.094)	0.402*** (0.094)	0.423*** (0.093)	0.032*** (0.007)
Mandatory P2 Policy	-0.643 (0.549)	-0.378 (0.561)	-0.150 (0.576)	-0.378 (0.559)	-0.225 (0.570)	-0.047 (0.034)
Other Firm Characteristics						
Final good	0.029 (2.336)	-0.747 (2.375)	-0.521 (2.446)	-1.627 (2.404)	-0.114 (2.381)	-0.391** (0.182)
Environmental Activism	2.681 (3.389)	3.614 (3.505)	3.125 (3.901)	2.440 (3.541)	3.748 (3.500)	-0.382 (0.381)
Toxic Releases	-0.708* (0.401)	-1.148** (0.447)	-1.205*** (0.456)	-2.373** (0.932)	-1.738*** (0.554)	0.070* (0.041)
Toxicity-Weighted Releases					0.432* (0.224)	
Market share	16.703** (4.899)	10.890** (5.385)	12.651** (5.491)	7.814[+] (5.601)	9.727* (5.465)	0.701* (0.380)
Net Sales	-0.014 (0.074)	-0.029 (0.074)	-0.022 (0.076)	-0.108 (0.082)	-0.263 (0.074)	-0.005 (0.007)
Age of Assets	- (11.829)	-18.897 (12.149)	-19.832 (12.754)	-22.254* (12.201)	-17.795 (12.167)	-0.398 (0.959)
Number of chemicals	0.188*** (0.027)	0.182*** (0.027)	0.181*** (0.028)	0.214*** (0.032)	0.179*** (0.271)	0.003* (0.002)
Year	-1.078 (0.945)	-0.521 (0.998)	-0.453 (1.046)	-1.587* (0.939)	-0.579 (0.994)	-0.084 (0.055)
Log – likelihood	1931.45	1935.43	1861.03	-1955.08		-1535.25
ρ_1	0.598*** (0.0386)	0.569*** (0.400)	0.561*** (0.041)	0.545*** (0.0408)		

Values in parentheses are standard errors. * Significant at 10%, ** Significant at 5%, *** Significant at 1%. [a/] Model VII-D has current toxic releases as explanatory variable with lagged releases as an instrument. All other models use lagged toxic releases.

Table 5: Determinants of Adoption of Alternative Measures of Pollution Prevention

Variables	Model VIII-A Chem-Count P2 2SLS: Predicted probability as IV	Model VIII-B Chem-Count P2 2SLS: Variables as IV	Model VIII-C Weighted P2: 2SLS: Predicted probability as IV	Model VIII-D Weighted P2: 2SLS: Variables as IV
Constant	-3.946 (6.368)	-3.039 (6.334)	2.578 (1.949)	1.170 (1.912)
Internal Managerial and Innovative Capabilities				
TQEM	11.362*** (3.834)	10.451*** (3.801)	2.908** (1.175)	4.573*** (1.148)
R&D Intensity	30.069* (16.773)	31.758* (16.732)	12.673** (5.128)	11.025** (5.038)
Regulatory Pressure				
Superfund	-0.012** (0.005)	-0.012** (0.005)	-0.002 (0.001)	-0.002 (0.001)
HAP	1.334^{+} (0.871)	1.286^{+} (0.875)	1.113*** (0.266)	1.054*** (0.264)
Penalties	0.659*** (0.208)	0.642*** (0.207)	0.092 (0.064)	0.100 (0.063)
Inspections	0.032*** (0.012)	0.031** (0.012)	0.004 (0.004)	0.004 (0.004)
Non-attainment	0.176*** (0.053)	0.164*** (0.053)	0.034** (0.016)	0.033** (0.016)
Mandatory P2 Policy	0.187 (0.321)	0.199 (0.323)	-0.214** (0.098)	-0.186* (0.097)
Other Firm Characteristics				
Final good	-0.842 (1.362)	-0.650 (1.358)	0.288 (0.417)	0.280 (0.410)
Environmental Activism	0.089 (2.014)	-0.014 (2.014)	2.329*** (0.618)	2.401*** (0.612)
Toxic Releases	-0.634** (0.258)	-0.645** (0.261)	0.006 (0.080)	-0.038 (0.080)
Market share	4.430 (3.086)	4.651 (3.095)	1.048 (0.944)	0.486 (0.933)
Net Sales	0.022 (0.042)	0.021 (0.042)	0.023* (0.013)	0.020 (0.013)
Age of Assets	-5.822 (6.963)	-6.139 (6.970)	-7.745*** (2.130)	-7.124*** (2.102)
Number of chemicals	0.123*** (0.016)	0.125*** (0.016)	-0.010** (0.005)	-0.009** (0.005)
Year	-0.444 (0.576)	-0.501 (0.574)	-0.140 (0.178)	-0.089 (0.177)
Log Likelihood	-1700.81	-1706.43	-1172.63	-1221.88
ρ_1	0.554*** (0.0406)	0.556*** (0.405)	0.534*** (0.0411)	0.512*** (0.0419)

N=422. Values in parentheses are standard errors. * Significant at 10%, ** Significant at 5%, *** Significant at 1%.
$^{+}$ Significant at 15% level.

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GREEN MANAGEMENT AND THE NATURE OF TECHNICAL INNOVATION

George Deltas
Associate Professor
Department of Economics

University of Illinois
1206 S. Sixth Street
Champaign, IL 61820
United States
Tel: 217-333-4678
deltas@uiuc.edu

Donna Ramirez Harrington
Assistant Professor
Department of Economics

University of Vermont
Old Mill Building
Burlington, VT 05405
United States
Tel: (802) 656-0964
djramire@uvm,edu

Madhu Khanna
Professor
Department of Agricultural and Consumer Economics
University of Illinois
1301 W. Gregory Drive
Urbana, IL 61801
United States
Tel: 217-333-5176
khanna1@uiuc.edu

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Abstract

The types and nature of a firm's innovative activities are influenced by a firm's organizational structure. We develop an empirical framework to examine the effect of Total Quality Environmental Management (TQEM) on the adoption of 43 types of innovative pollution prevention activities over the period 1992-1996, and to determine whether the effect of this management system differs systematically across innovation types. We differentiate innovations according to (i) their functional characteristics: whether they involve procedural changes, equipment modifications, material modifications or other unclassified/customized changes; (ii) their visibility to consumers and, (iii) their ability to enhance efficiency. We find that the effect of TQEM on pollution prevention is non-uniform and provides stronger support for the adoption of practices that involve procedural changes or have unclassified/customized attributes. We also find that the visibility to consumers or efficiency enhancement does not incrementally contribute to the effect of TQEM on the adoption of pollution prevention practices. These findings are robust to controlling for the timing of TQEM adoption and any type-specific trends in the adoption of pollution prevention activities. Because the pollution prevention activities most strongly affected by TQEM are generally more prevalent in the petroleum refining and chemical manufacturing, our simulations show that these sectors experience the largest impact from the adoption of TQEM on the rate of pollution prevention innovation.

Key words: pollution prevention, TQEM, technical innovation, organizational structure
JEL Code: Q55, L20, M14

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1. Introduction

Innovation is a key component of a firm's strategy to improve market competitiveness and operational efficiency as well as to respond effectively to changing consumer preferences and regulations. Innovations differ in the extent to which they involve changes in products, processes or practices and lead to gains in efficiency or brand image. We postulate that the extent and nature of innovation undertaken by a firm depends on its management system which influences the firm's organizational structure, the extent of employee involvement in decision making and the internal communication channels for information sharing. The management system, therefore, has an impact on the incentives and ability to improve a firm's technology. We develop an empirical framework to examine how the effect of a management system differs across different types of innovations and draw implications from the nature of this differential impact on the channels through which a management system affects a firm's operations. Our framework can also be used to evaluate the effect of adoption of the management system on firms with different pre-adoption innovation profiles.

We apply this framework to investigate the effect of total quality management (TQM), one of the single most influential managerial systems developed in the last twenty five years, on technical innovations that reduce the generation of pollution. TQM is an integrated management philosophy that emphasizes customer satisfaction through continuous progress in preventing defects and seeks to achieve gains in efficiency using a systems-wide approach to process management (Powell, 1995). Expansion of the notion of product quality to include the environmental impact of production systems and products, and the belief that pollution is equivalent to a waste of resources, has led firms to apply the systems-based approach of TQM to the management of their environmental impacts. This is referred to as Total Quality

Environmental Management (TQEM).[1] It involves changing the organizational culture of the firm and using quality management tools to encourage prevention of pollution upstream (at source) as a way to increase efficiency rather than controlling pollution after it is generated (DiPeso, 2000; Klassen and MaLaughlin, 1993). Pollution can be reduced at source through a variety of different practices. We examine the types of pollution prevention activities that are more responsive to TQEM systems, and the implications of such differential response on the channels through which TQEM in particular influences innovation and technology adoption.

We use a very detailed dataset that catalogues the rate of technical innovation in pollution prevention to reduce toxic releases by a sample of S&P 500 firms over the five year period 1992-1996. This dataset is a particularly well suited one to demonstrate our approach for a number of reasons. First, it forms a rich five year panel of pollution prevention innovations that firms have undertaken in 43 different categories. Second, a number of firms have chosen to apply TQM for environmental management during this period. Third, the description of adopted pollution prevention practices is very detailed and allows us to classify them on the basis of their functional characteristics, their potential for improving production efficiency and possibly yielding auxiliary cost benefits, and their visibility to consumers. In particular, we partition the practices according to four mutually exclusive functional characteristics: whether the practice requires physical change in equipment, a change in materials usage, a change in operating procedures, or other modifications. This last category includes practices that the firms have been unable to assign to one of the established types of pollution prevention categories as defined by the EPA. Some of these unclassified/customized practices are likely to be newly innovated practices that modify the firm's operations and, therefore, cannot be classified generically. In

[1] The Global Environmental Management Initiative is recognized as the creator of *TQEM* which embodies four key principles: customer identification, continuous improvement, doing the job right first time, and a systems approach

addition to this multinomial classification of practices on the basis of their functional characteristics, we also include binary attributes that reflect the presence of efficiency gains and visibility to consumers.

The waste prevention-oriented philosophy of TQEM suggests an inherent complementarity between TQEM systems and pollution prevention. One would expect the adoption of all types of pollution prevention practices to be higher among TQEM firms than among otherwise identical firms that are not practicing TQEM. However, the TQEM tools used for identifying and evaluating opportunities for waste reduction and the measures for assessing performance may be more conducive to the adoption of some types of practices than others. We use count models to examine how the effect of TQEM adoption differs across practices of different types and to what extent any such differences may lead the pollution prevention activities of some industries to be more sensitive to TQEM than those of other industries. In addition to the role of organizational structure and practice attributes, our analysis recognizes that the net benefits of adopting pollution prevention practices are also likely to be influenced by firm-specific technical and economic factors. These include the suitability/effectiveness of those practices for a firm's production system (or the inherent propensity of a firm to adopt certain types of pollution prevention practices), the costs of learning about new technologies, the potential for diminishing returns associated with incremental adoption, and other unobserved slowly evolving factors.[2]

In particular, our analysis can be summarized as follows. We first define a set of binary variables that take the value of 1 if the pollution prevention activity possesses a particular attribute and 0 otherwise. We use their interaction with TQEM to investigate whether the effect

(http://www.bsdglobal.com/tools/ systems_tqem.asp).

of TQEM on pollution prevention is non-uniform, and if so, which types of activities (attributes) are associated with stronger TQEM effects. Firm fixed effects and a number of suitable controls to capture some effects discussed above are also included in the analysis. Our base estimates are complemented with a number of internal consistency checks that test the validity of our framework and some alternative explanations for the pattern of observed pollution prevention activities. Finally, we combine our estimates of the effect of TQEM on the pollution prevention activities of different types with the systematic differences in the prevalence of these activity types across industries to ascertain the degree to which TQEM impacts the rate of pollution prevention innovation differentially across industries.

Several studies have shown that organizational characteristics are important determinants of innovation by firms (see reviews by Hage, 1999; Damanpour, 1991; Sciulli, 1998). A survey of the vast literature on quality management and its key practices suggests that TQEM has many pro-innovation attributes, such as its emphasis on continuous improvement through the application of scientific information and a non-hierarchical organizational structure that enables the efficient creation and utilization of valuable specific knowledge at all levels of the organization (Sousa and Voss, 2002; Wruck and Jensen, 1998).[3] A few studies have focused specifically on the relationship between TQEM and innovation. Curkovic et al. (2000) use scaled responses on various aspects of total quality management systems and environmentally responsible manufacturing practices to construct measures of each and examine synergies between the two. They find that firms with advanced total quality management systems also have more advanced environmentally responsible manufacturing practices because the two concepts

[2] The resource based view of the firm suggests that heterogeneity in this expertise across firms lead to differences in the firm's ability to capture the profits associated with a new technology (see survey in Christmann, 2000).

share a similar focus, rely on similar tools and practices. Khanna et al. (2007) undertake a systematic empirical investigation of the linkage between an objectively measured aggregate count of pollution prevention techniques adopted and TQEM. They focus on explaining pollution prevention adoption rates as a function of the TQEM adoption decision, regulatory factors, and many other firm and industry characteristics that proxy for market pressures faced by firms and other relevant effects. Unlike that study, this paper analyzes the type (attributes) of pollution prevention activities adopted by firms and its variation across TQEM adopters and non-adopters using a more disaggregated and longer data series and employing fixed effects model to control for firm heterogeneity.[4]

Our findings demonstrate that the effect of TQEM on pollution prevention is non-uniform. TQEM supports the adoption of practices that involve procedural changes or that are customized or otherwise do not fall neatly into well established standard categories. We also find that the visibility to consumers or efficiency enhancement attribute of the practice does not incrementally contribute to the effect of TQEM on the adoption of pollution prevention practices. The stimulus provided by TQEM to the adoption of such practices is essentially determined by their functional attributes, either procedural or unclassified/customized. Moreover, the adoption of practices that involve material or equipment modifications is not statistically significantly responsive to TQEM adoption. Furthermore, we demonstrate that these effects are not driven by secular trends that favor one type of pollution prevention activity over another. Lastly, we also

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[3] TQM is "science-based" because individuals at all levels of the organization are trained to use scientific method in everyday decision making. It is non-hierarchical in that it provides a process for allocating decision rights in ways that do not correspond to the traditional corporate hierarchy.

[4] Technology characteristics have been shown to be significant drivers for the adoption and diffusion of specific technologies in other areas. Innovations that are costly and require a considerable investment were found to diffuse at a slower rate in manufacturing industries (Romeo 1975, 1977, Stoneman and Karshenas, 1993). Similarly, Karlson (1986) found that new innovations that are expected to yield higher cost savings and improve profitability tend to be adopted faster in the steel industry. In the agriculture sector, new innovations that were less risky, less complex and expected to increase yield and quality were adopted much faster than other (Batz et al 1999; Adesina

find that the adoption of pollution prevention practices is subject to diminishing returns and inertia.

We show the usefulness of our framework through simulations. In these simulations, we find that on the average, 16% of the count of pollution prevention activities adopted by firms can be attributed to the organizational structure inherent in TQEM. This effect is not uniform across firms but depends on their pollution prevention profile. In particular, firms in petroleum refining and chemical manufacturing industries are more strongly affected because their pollution prevention profile includes procedures and customized modifications.

The rest of the paper is organized as follows. Section 2 of the paper describes the conceptual framework while Section 3 describes our empirical implementation of this framework. Data is described in Sections 4, and we present and discuss our results in Section 5, followed by the conclusions in Section 6.

2. CONCEPTUAL FRAMEWORK

The TQEM philosophy has three strategic goals: (i) continuous improvement in quality, (ii) defect (waste) prevention while enhancing value added activities and (iii) meeting or exceeding customer requirements. To achieve these goals, quality management requires management commitment, long range planning, and close relationships with customers that allow anticipation of customer needs sometimes even before customers are aware of them. At the operational level, TQEM involves the adoption of certain management "tools" or processes. In TQEM firms, cross functional teams undertake research projects to develop or identify pollution prevention practices, managers do benchmarking visits to other organizations to learn about alternative ways of performing the work, and front-line employees are expected to search

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and Baidu-Forson 1995, Adesina and Zinnah 1993).

continuously for improved and simplified work practices (Hackman and Wageman, 1995). By allocating decision-making authority to problem-solving teams, enabling a high level of employee involvement in quality improvement, facilitating better communication and information sharing among all hierarchical levels in the organization and offering employee training and team-based rewards, Total Quality Management enables the efficient creation and utilization of valuable firm-specific knowledge at all levels of the organization. These system based changes are driven by identified consumer needs and aim to achieve quality improvements while lowering costs (Cole, 1998).

Growing concerns for environmental quality from consumers, the public, and regulators has led firms to expand their notion of product quality and apply TQEM to reduce the environmental impact of their production systems and products. This together with the belief that efficiency can be enhanced by minimizing pollution provides a rationale for firms to proactively integrate environmental considerations in product and process design.[5] The upstream prevention focus of TQM, together with the view that pollution is a defect and an indicator of waste in production, creates an explicit focus on source-reduction of pollution as opposed to end-of-pipe control (Curkovic et al. 2000). Case studies indicate that quality management tools such as affinity diagrams, Pareto analysis, cause-and-effect diagrams and cost of quality analysis help the teams responsible for environmental management to focus on the causes of their difficult environmental problems (PCEQ, 1993).[6] Moreover, TQM performance measures tend to be function- or task-specific, thus allowing isolation of the contribution of particular activities to

[5] Studies examining the relationship between TQM and innovative approaches to environmentally conscious manufacturing find that TQM goals and methods align well with those of environmental management and promote environmental excellence (Klassen and McLaughlin, 1993).

[6] Pareto analysis is used to identify the major factors that contribute to a problem and to distinguish the vital few from the trivial many causes. Cost of quality analysis is used to highlight the cost-savings that can be achieved by doing the work right the first time (Hackman and Wageman, 1995). See Ploch and Wlodarczyk (2000) and relevant references therein for an illustration of the successful application of these and related tools.

performance. This helps employees understand what actions they can take to improve overall performance (Wruck et al.).[7] This suggests that firms that adopt TQEM are more likely to be able to identify opportunities for waste reduction and select cost-effective pollution prevention practices. Indications of an inherent complementarity between the concepts of pollution prevention and TQEM can be found in case studies and surveys of firms which indicate that TQEM adopters are indeed more likely to adopt pollution prevention practices (Florida, 1996; Atlas, 1997; Klassen and McLaughlin, 1993; see survey in Curkovic et al., 2000).[8]

Pollution can be prevented using a variety of different practices that differ in their characteristics and in the degree to which their adoption is amenable to TQEM. The list of pollution prevention practices used in our analysis is included in Table 1. We distinguish three key characteristics of these practices. The first is functional or technical attributes, the second is whether they yield auxiliary efficiency-enhancing or cost saving benefits and the third is whether they are visible to consumers. The functional characteristic involves the partitioning of practices

[7] For example, employees under quality management are likely to readily understand how their actions affect cycle time or how they can reduce waste or scrap rates. The case Polaroid's application of TQEM through their Environmental Accounting and Reporting System (EARS) is a good example. The EARS allows the tracking of all 1400 materials at the chemical level at several stages (the input stage, end of process line before abatement, during abatement, and after abatement). It promotes accountability of all employees for each unit of chemical and encourages employees to devise new equipment or processes to use inputs more effective. For example, through the EARS, Polaroid employees have identified substitutes for toxic materials and adopted aqueous based coating systems in place of solvent-based coating systems which led to a 10% reduction of toxic emissions. Polaroid employees also had the incentive to develop a devise to scrape reactor vessels of every unit of chemical, which would have gone untraced and unused had the EARS system not been in place. Furthermore, the EARS also encouraged communication across various specialized units and encouraged multi-faceted types of innovations. The chemical-level reporting and accountability allowed the manufacturing division to put pressure on the R&D division to develop less toxic chemicals that the manufacturing divisions would be willing to use. As a result, these chemical substitutions further required changes in the manufacturing process and in the design of products as well. In 1990, two years after its introduction, the EARS allowed Polaroid to successfully achieve a 20% reduction of toxic chemicals from 1988 levels through input substitution, process changes and more environmentally-sound products (Nash et al., 1992).

[8] A survey of U.S. manufacturing firms in 1995 by Florida (1996) found that 60% of respondents considered P2 to be very important to corporate performance and two-thirds of these had also adopted TQM. Of the 40% of firms that considered P2 to be only moderately important, only 25% had adopted TQM. A survey of U.S. manufacturing plants in 1998 found that among the P2 adopters, the percentage of firms practicing TQM was twice that for other plants (Florida, 2001). A survey of Japanese manufacturing firms found that plants adopting a green design were more likely to be involved in TQM than other plants (Florida and Jenkins, 1996).

into four groups depending on whether they are likely to require physical modifications to equipment; changes in raw materials; changes in operating procedures for employees; or involve other hard to categorize/multiple changes. Practices requiring *Equipment* modifications include changes in container design, cleaning devices, rinse and spray equipment and overflow alarm systems. Practices requiring *Material* modifications involve substitutions of raw materials, new solvents, coating materials or process catalysts. Practices, such as improved maintenance scheduling, improved storage and stacking procedures, better labeling procedures, which involve changes in the way that operations are organized and managed, are classified as *Procedural* modifications. Practices that are hard to categorize because they do not belong in any of the EPA's well defined practice categories form the fourth group, henceforth denoted as *Unclassified/Customized* practices; this forms the omitted category in the econometric analysis.

Procedural changes require specific and detailed knowledge about work processes that is likely to reside with employees on the factory floor rather than with upper management (Hackman and Wageman, 1995; Wruck and Jensen, 2000). TQEM emphasizes cross-functional teamwork, allocation of decision-making authorities to employees and improved flow of information among employees; it is therefore more likely to promote "grass-roots" efforts at waste reduction using the full spectrum of information and expertise to bear on decisions about system wide problems. On the other hand, practices that involve technical changes in equipment and materials may be relatively easy to identify even by firms that are not practicing TQEM. Such modifications may be more process-specific rather than firm-specific and their benefits are more likely to be standard knowledge among firms. Their adoption may thus be less responsive to specific knowledge/training of a firm's employees or a firm's management system. We, therefore, test whether TQEM firms experience a larger increase in the adoption rate of pollution prevention practices that require procedural changes as compared to the adoption rate of practices that require physical or material modifications. In other words, we test whether practices with *Equipment* or *Material* modifications attribute get a smaller (if any) boost from TQEM systems while those with a *Procedural* modification attribute get a larger stimulus from TQEM.

The fourth *Unclassified/Customized* attribute is assigned to practices whose definitions in the dataset do not provide enough information to allow us to discern their attributes. This category includes some practices that do not belong to standard categories or approaches of preventing pollution and are individually tailored to a firm's production operations. For example, in the category Process Modifications, practices such as, 'instituting a re-circulation system' or 'modifying layout or piping' and 'changing the process catalyst', may be standard approaches to reduce pollution while practices included in 'other process modifications' may be those that are custom-designed and hence cannot be easily labeled. Such practices are likely to be based on in-depth understanding of the source of the problem to be fixed. We, therefore, expect that firms that adopt TQEM, and thus have a high level of cross-disciplinary employee involvement, a system for facilitating flow of information across departments and the tools needed to generate innovative ideas, are likely to adopt customized practices.

In addition to these technical considerations, the adoption of a practice may be influenced by attributes that affect the economic benefits from its adoption. One such attribute of a practice is its visibility to *Consumers*. A second such attribute is the ability of that practice to lead to improvements in production efficiency, reduction in costs and savings in time and resource use, enabling firms to gain a competitive advantage. We consider such practices to be production *Efficiency* enhancing.

Practices that involve changing the raw materials used or the specifications or composition of the product and affect its functionality, appearance or disposal after use could be considered visible to *Consumers*. Firms may include such information in product labels or advertisements to make consumers aware of the environmental friendliness of that product. Such practices can allow firms to appeal to environmentally conscious consumers and charge price premiums or increase market share. Firms that adopt TQEM are likely have closer relationships with customers and the tools (such as, life-cycle analysis to evaluate the environmental impacts of alternative product specifications) to identify the environmentally-friendly product modifications that customers' value. We, therefore, test whether TQEM adopters adopt more practices which are visible to *Consumers*. If this is the case, the results would reveal the extent to which TQEM is being implemented to increase the appeal of a firm's products to environmentally conscious consumers.

Pollution prevention practices that could enhance production-efficiency and provide cost-savings include improved recordkeeping, inventory control, installation of overflow alarms or automatic shut-off valves and better inspection, and monitoring and labeling procedures. Wruck et al. (1998) find that although TQEM is grounded in a concern for product quality, it reaches beyond these issues to emphasize efficiency throughout the organization on issues that may have little or no direct relation to product quality, such as equipment maintenance. We, therefore, test whether practices which are *Efficiency* enhancing, would get a significant boost in likelihood of adoption by TQEM firms. Empirical evidence of this would provide support for the contention that "lean and green," go hand in hand as firms seek to become more productive by pursuing strategies that enhance business and environmental performance (Florida, 1996). This would suggest that TQEM adopters consider pollution prevention as part of the broader corporate effort to improve quality and implement leaner management systems.

While the focus of this work is the identification of within-firm differential effects of TQEM on the adoption of pollution prevention practices, we also control for the effects of other factors on adoption rates. Ideally, we would adopt a purely treatment effects count data model which would include an exhaustive set of firm-cross-practice fixed-effects which would control for the baseline propensity of firms to adopt a particular pollution prevention practice. We depart from this ideal estimation strategy in that we use firm-fixed-effects and practice-fixed-effects. Including an exhaustive set of firm-cross-practice fixed effects is not feasible for our data as most firms have zero adoption rates for most practices. Instead, we use firm dummies to account for unobserved firm-specific characteristics such as technological knowledge and capacity or inherent propensity of the firm to undertake pollution prevention activities, and we use pollution-prevention dummies to control for the differential baseline adoption rates of these practices. Finally, we control for secular changes in adoption rates through year fixed effects, which in some specifications are interacted with the attributes to control for attribute specific trends, and also include some potentially important time varying firm specific factors that are relevant for the adoption of pollution prevention techniques.

3. ECONOMETRIC FRAMEWORK

3.1. Specification and Estimation

We consider a general framework that relates the count of adoption of pollution prevention practices with the presence of TQEM and the level of other time varying firm characteristics. The expected number of pollution prevention practices of type *j* adopted by firm *i* in year *t*, denoted as $P2_{ijt}$, is given by

$$E[P2_{ijt}] = \exp\{\alpha_j TQEM_{it} + \beta \log[TOTP2_{it-1}] + \gamma \log[CUMP2_{it-1}] + \delta \log[CHEM_{it}] + w_t + e_{ij}\} \quad (1)$$

where the variables and the parameters are defined as follows.[9] The indicator variable $TQEM_{it}$ takes the value of 1 if firm *i* applied TQM to the environmental aspects of its production in year *t*. The effect of $TQEM_{it}$ on the adoption rate of pollution prevention practices of type *j*, α_j, is the parameter vector of primary interest in our study.[10] The variable $TOTP2_{it-1}$ is the total number of pollution prevention activities of all types adopted by firm *i* in the preceding year (hereafter also referred to in the text as *Lagged Total P2*), and it proxies for slowly evolving (or transient) unobserved factors that affect the adoption of pollution prevention techniques. These would include effects of learning (which arise from experience with all types of pollution prevention practices but which are expected to decay over time), changes in managerial interest in pollution prevention (which is expected to revert to some steady state over time), transient changes in firm expertise through staff turnover, and other factors. We would expect the parameter β to be positive but smaller than 1, reflecting the non-permanence of the above factors. The variable $CUMP2_{it-1}$ is the cumulative number of pollution prevention techniques of any type adopted by firm *i* from 1991 until before the start of year *t* (henceforth referred to in the text as *Cumulative P2*), and it reflects the possible presence of diminishing returns to pollution prevention: the more techniques have been introduced by a firm, the fewer remaining pollution

[9] The description of the source data and the construction of the variables are deferred to the next section.

[10] We do not include attribute fixed effects because these would not be identified given our inclusion of practice fixed effects. Moreover, if we had included attribute fixed effects instead of practice fixed effects, the coefficients would not have been interpretable because they are not independent of artificial aggregation or subdivision of P2 categories. In contrast, the interactions of attributes times TQEM are identified because they reflect percentage changes from the baseline.

prevention opportunities may be left to exploit. It may also measure cumulative permanent learning in which in case it would tend to vary positively with *P2* adoption counts. For single facility firms, the variable $CHEM_{it}$ is the *Number of Chemicals* a firm uses in period *t*, while for multi-facility firms $CHEM_{it}$ aggregates this number over all facilities of that firm. The log specification for these variables allows the model parameters to be interpreted as elasticities. Finally, w_t and e_{ij} are year and firm cross practice fixed effects, respectively.

The primary parameters of interest, α_j, are assumed to relate to characteristics of pollution prevention practices *j* through the linear equation

$$\alpha_j = \alpha + \alpha_e EQUIP_j + \alpha_m MAT_j + \alpha_p PROC_j + \alpha_f EFF_j + \alpha_c CONS_j \tag{2}$$

where $EQUIP_j$, MAT_j, and $PROC_j$ are mutually exclusive dummy variables that indicate whether practice *j* has *Equipment*, *Material* or *Procedural* attributes, with the unclassified/customized attribute being the omitted category as described in the previous section. EFF_j is a dummy variable that indicates whether practice *j* is *Efficiency* enhancing, while $CONS_j$ indicates whether practice *j* is visible to the *Consumers* of the product. If *TQEM* affects the adoption rate of all types of practices equally, then the parameters α_e through α_c would all be zero and the effect of *TQEM* on pollution prevention would not be systematically related to the composition of pollution prevention practices employed by firms. However, if the effect of *TQEM* on pollution prevention practices is not uniform for reasons discussed in the conceptual framework, then the α_j's will be statistically significantly different from α and they will vary across practices. Since the functional attributes are mutually exclusive, the adoption of TQEM on the adoption of these practices would therefore depend on which of the four functional attributes characterize the particular practice and whether the practice is visible to consumers and/or is efficiency-enhancing.

We now turn to the estimation of equation (1). We make no assumptions on the distribution of $P2_{ijt}$ other than that each realization is conditionally independent of each other. Thus, we not only relax the Poisson assumption of equality of mean and variance, but we also relax the weaker assumption of proportionality of mean and variance. We also assume that all independent variables are exogenous, i.e., independent of the equation disturbance term. Our estimation and inference follow the Quasi-Maximum Likelihood (QML) estimation approach: while point estimates are obtained from Poisson regression which is the QML estimator (see Wooldridge 1997 and references therein), standard errors are obtained from the Huber-White robust covariance matrix constructed from the regression residuals.[11]

Estimation of the model specification given in equation (1) is complicated by a number of factors. First, though *Number of Chemicals* is always positive, *Cumulative P2* and *Lagged Total P2* are occasionally zero (albeit very rarely: *Cumulative P2* is zero in 2.63% of the sample, while *Lagged Total P2* is zero in only 8.5% of the sample). To prevent the loss of any observations, we add 1 to these two variables prior to taking the log, a rather small change in the transformation given the scale of the variables. For robustness, we have also re-estimated the model using these two variables in levels rather than in logs, though in this latter specification the model parameters can no longer be interpreted as elasticities. Second, estimation of the firm-cross-practice fixed effects e_{ij} is not possible using the above statistical framework as the typical firm has not adopted most of the practices over our 5 year period (and has only adopted some of the

[11] Implementation is through STATA 8 using the cluster option in the GLM Poisson command. The robust standard errors are similar to those obtained under the assumption that the variance of P2 is proportional to its mean, using

remaining practices only once). Therefore, we assume that e_{ij} has the additive structure $e_{ij} = u_i + v_j$, which prevents the loss of any observations (and the information they contain) and also eliminates any possible concerns about censoring, albeit by imposing a parametric assumption.

The parameter vector α_j is interpreted structurally. That is, we posit that if a firm were to adopt TQEM, the effect on the rate of adoption of pollution prevention activities would be given by the values of the parameters α_j. It is possible that the estimated values of α_j could differ from the true structural effect of TQEM due to endogeneity of $TQEM_{it}$, i.e. if $TQEM_{it}$ is correlated with the equation disturbance term. Given the presence of firm and year fixed effects, and the inclusion of *Lagged Total P2* as an independent variable, such correlation must be with the idiosyncratic disturbance terms for the period of TQEM adoption and the periods thereafter, but not the periods before TQEM adoption. In other words, such endogeneity cannot arise from some omitted permanent firm characteristic, but can arise from some characteristic that changes during our sample period and is correlated with the implementation of TQEM. For example, consider a “green” manager who arrives at the firm and ramps up both the pollution prevention innovation and adopts TQEM. If the manager stays for the remainder duration of our sample, then his arrival is a permanent shock that is (positively) correlated with the adoption of TQEM. Under this example, the estimates of α_j will be upwardly biased estimates of the true structural parameters. One approach to address the possibility of endogeneity due to time varying factors that are correlated with TQEM adoption and P2 adoption would be to have time varying instruments. In a cross-section setting one can use variables that explain the incidence of TQEM

the (normalized) Pearson residuals. However, Maximum Likelihood Poisson standard errors are smaller than either adoption across different types of firms (such as a predicted probability of TQEM adoption estimated using first stage models, as in Khanna et al. (2007)), but in a time-series analysis one needs instruments that are correlated with the systematic component of the timing of TQEM adoption decision. These instruments need to vary meaningfully and substantially over time and not simply due to random fluctuations. In the absence of such an instrument (since an instrument such as a predicted probability of TQEM adoption from a first stage regression would vary only slightly over time) we cannot directly eliminate the possibility of such endogeneity. However, we emphasize that its source cannot arise from the correlation of permanent firm characteristics with the application of TQEM (given the incorporation of firm fixed effects) or the correlation of economy wide shocks with the application of TQEM (given the incorporation of year fixed effects) or the presence of slow build-up of firm level factors that simultaneously lead to increases in pollution prevention innovation and to the application of TQEM (given the incorporation of *Lagged Total P2* in the regression). We thus posit that the likelihood that such endogeneity would lead to substantial bias is remote, an assumption made by the bulk of the panel data literature using short panels with fixed effects.

3.2. Counterfactual Simulation and Policy Analysis

In this section we describe our use of the model to quantify the impact of delaying the adoption TQEM for each firm who adopted TQEM for the first-time within our sample period. Let τ denote the year in which the firm has adopted TQEM for the first time i.e., the year that *TQEM* takes the value of 1 for that firm following a zero for that same firm. For these firms the simulated counterfactual number of pollution prevention practices of type j would be the actual

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of the above by a factor of 2, consistent with the presence of substantial over-dispersion in the P2 count.

value of $P2_{ij\tau}$ in year τ multiplied by the percent change due to TQEM de-adoption predicted by our model. Or simply:

$$P2^S_{ij\tau} = P2^A_{ij\tau}\left\{\exp\left(-\left(\alpha + \alpha_e EQUIP_j + \alpha_m MAT_j + \alpha_p PROC_j + \alpha_f EFF_j + \alpha_c CONS_j\right)\right) TQEM_{i\tau}\right\} \quad (3)$$

where $P2^S_{ij\tau}$ is the projected level and $P2^A_{ij\tau}$ is the actual baseline level for firm *i*'s type *j* pollution prevention activities at year τ. We aggregate the predicted *P2* count at the firm level to obtain $P2^S_{i\tau}$. The percent contribution of *TQEM* adoption on a firm's actual count of *P2* practices is measured by $(P2^A_{i\tau} - P2^S_{i\tau})/P2^A_{i\tau}$. Note that this simulation is looking only at the first year effects of *TQEM* adoption because in subsequent years the P2 count is also affected by dynamic factors such as *Cumulative P2* and *Lagged Total P2*. Given that firms have different "baseline" rates of employing each of these pollution prevention types, and given that *TQEM* turns out to have a differential impact on the adoption rate of different types of pollution prevention practices, the *TQEM* treatment effect varies by firm even when measured in percentage terms. We then aggregate $P2^S_{ij\tau}$ across all 8 categories of P2 activities (as defined by the EPA and described below) for each firm. We then group firms on the basis of SIC codes to investigate if the percentage effects of *TQEM* on pollution prevention counts varies systematically across industries.

4. Data Description and Variable Construction

The sample in this study consists of S&P 500 firms which responded to the Investor Research Responsibility Center (IRRC) survey on the adoption of corporate environmental management practices and whose facilities reported to the Toxics Release Inventory (TRI) over the period 1992-96. The IRRC surveys firms annually about their environmental management practices, one of which is the application of total quality management principles to environmental management. TRI was established under Section 313 of the Emergency Planning and Community Right to Know Act (EPCRA) in 1986. It requires all manufacturing facilities operating under SIC codes 20-39, with 10 or more employees, and which produce or use toxic chemicals above threshold levels to submit a report of their annual releases to the USEPA. Reporting of all pollution prevention activities adopted in a year to reduce the TRI chemicals became mandatory in 1991 following the National Pollution Prevention Act of 1990. Each facility of a firm is required to report their adoption of any of 43 different pollution prevention activities for each toxic chemical mandated in the TRI in a given year. These activities are classified by the EPA into eight broad categories: (1) changes in operating practices (2) materials and inventory control (3) spill and leak prevention (4) raw material modifications (5) process modifications (6) cleaning and degreasing (7) surface preparation and finishing practices and (8) product modifications. Table 1 contains the different types of pollution prevention activities under each broad category.

To match the facility level TRI data with the parent company level IRRC information on TQEM adoption, we constructed unique parent company identifiers for each facility in the TRI database.[12] Chemicals which have been added or deleted over the period 1991-1996 were dropped due to changes in the reporting requirements by the USEPA. This ensures that the change in pollution prevention activities in our sample over time is not due to differences in the chemicals that were required to be reported. Since all S&P 500 companies that reported to the TRI did not respond to the survey by the IRRC, observations with missing data were deleted.

[12] To match the facilities with their parent companies, the Dun and Bradstreet number is used, in addition, to facility name, location, and SIC code.

Our final sample consists of a five year unbalanced panel of 160 parent companies for a total of 34,400 observations. Of these 160 firms, 66 firms had adopted TQEM by the start of our sample period and 35 firms adopted it during our sample period. The remaining 59 firms had not adopted TQEM by the end of our sample period. Since the decision to adopt *TQEM* is not likely to be made year to year and even if a firm were to de-adopt *TQEM*, the culture and organizational practices are likely to persist, we assume that there is no de-adoption of *TQEM* during our sample period.[13] This allows us to "fill-in" missing values for TQEM for 15% of the sample and affects an additional 4% of the observations for which transient "de-adoption" of TQEM was reported.

Our dependent variable is the count of new pollution prevention techniques of each of these 43 specific activities adopted by a firm during a year. We call this variable *P2*. It is derived from information mandatorily reported by each facility to the USEPA on the source reduction activities newly implemented by it for each chemical in that reporting year.[14] We aggregated the

[13] This has two implications for our data. To avoid dropping the observations for which *TQEM* adoption data was not available for some years, we assume that if the firm did not report to the IRRC survey in a particular year, but reported to the IRRC and adopted *TQEM* in the immediately preceding and succeeding years, then that the firm also adopted in that year with missing data and filled in the blank year with "1". In addition, if the first time a firm responds to the IRRC survey it states that it has not adopted *TQEM* we assume that it has never adopted in the past and we fill in earlier years with missing data to be "0". For the (fewer) observations that have a zero preceded and followed by a 1 for *TQEM*, we convert the zero to a 1 for the reasons stated above.

[14] We verified if facilities do indeed report new P2 activities. We look at the USEPA Form R which is used to collect data for P2. Section 8.10 of Form R allows for 4 new source reduction activities, and 3 methods used to identify the activity (internal auditing, external auditing, government assistance, industry assistance). Section 8.10 specifically asks "Did your facility engage in any source reduction activities for this chemical during the reporting year?" The instructions/guide for filling out Form R specifies that Section 8.10 "must be completed only if a source reduction activity was newly implemented specifically (in whole or in part) for the reported EPCRA section 313 chemical during the reporting year." (EPA, 2004) We verified if firms do indeed report only new source reduction activities by examining the annually reported P2 counts by each facility belonging to S&P 500 firms and reporting to TRI, for each chemical for the period 1992-1996 and compared it with their reports for the previous period (1991-1995). We then derived the change in the reported *New P2* count for a total of 74,780 instances at the chemical-facility level. If firms were inadvertently reporting all P2 activities adopted instead of New P2 activities, we would expect that the annual count of P2 reported would be increasing or stay constant over time for all years. Our investigation focused at the facility level on the premise that any misinterpretation of the instructions in the TRI would be at the facility rather than chemical level. In particular, we have calculated the number of facilities for which the reported P2 counts were non-decreasing for all chemicals. We found that this was the case for only 236 facilities (5.68% of all facilities examined) and represents only 0.67% of the chemical-facility pairs (because these

number of P2 such practices adopted in a year across chemicals for each facility and then across all facilities belonging to a parent company to obtain *P2* at the firm-level for that year. We construct *Cumulative P2* as the cumulative number of pollution prevention techniques of all types that have been adopted between 1991 (when firms first began reporting this information to the TRI) and year *t-1*. We also constructed the total count of all types (from all eight categories) of pollution prevention activities undertaken in the previous year and labeled this as *Lagged Total P2*. We control for the number of pollution reduction opportunities a firms has by including the *Number of Chemicals* emitted. This variable is the count of chemicals reported by the firm which is obtained by summing up the chemicals reported by each facility over all facilites of that firm. This controls for the possibility that firms emitting a larger number of chemicals or having a larger number of facilities may adopt more pollution prevention practices simply because they have greater scope for the adoption of such practices.

To develop the attributes for the *P2s*, the authors started with brainstorming and developed a list of all possible attributes of these practices. In addition to the five attributes described above, the original expanded list included others such as visibility to stakeholders and regulators, practices requiring decision making at the upper vs. lower managerial levels, technological sophistication, and practices that will alter the production process. The characterization of the *P2s* according to different attributes was done by each of the authors separately. Characterizations of *P2s* by three other experts in the field of business and environmental strategy were also solicited. We then looked at the correlations among the attributes and found that some were very closely related to each other (for example, practices that were visible to consumers were also likely to be visible to other stakeholders) while for some

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facilities have a much lower than average number of chemicals). Therefore, even if there was any misinterpretation of the survey question, it impacted at most a small fraction of the data.

attributes our confidence in assigning them to practices based on information available in the TRI was not high. We therefore narrowed the list to the attributes described in Table 1 by dropping those for which agreement in assigning them to the pollution prevention practices was relatively low and merging together those with high correlations with each other.[15] This final classification was arrived at through discussion among the authors. Note that the *Unclassified*/*Customized* category is the omitted functional category (the category for which *Equipment*, *Procedural*, and *Materials* are all zero) (See Table 1).[16] Correlation between the characteristics is low. Positive correlation of 0.42 is observed between *Procedural* and *Efficiency* attributes and of 0.35 between *Consumers* and *Materials* attributes.

The summary statistics in Table 1 show that highest adoption rates for both TQEM and non-adopters of TQEM are for “maintenance scheduling and record-keeping procedures” (practice 13), “modification of equipment, lay-out or piping” (practice 52), “substitution of raw materials (practice 42), and practices that fall under miscellaneous or other categories (e.g., practice 19 and 58). Generally, the rate of adoption of P2 is higher among TQEM firms than

[15] Our initial set of attributes include (1) visibility to consumers, (2) visibility to shareholders, (3) visibility to regulator, (4) technological sophistication, (5) level of management decision involved, (6) frequency of activity, (7) time and cost savings, (8) production effects, and (9) final product functionality effects. Because the level of technological sophistication (4) is hard to determine, we instead used procedural changes as an attribute, i.e., whether it is involves changes in operations or procedures. These are distinguished from practices that involve physical changes in materials in equipment. We dropped visibility to shareholders and to regulators, as these are difficult to ascertain for each P2. We merged consumer visibility (1) and final product functionality effects (9) into one attribute. We also dropped the level of management decision-making involved in implementing each P2 (5) since this attributes is very difficult to determine. We also dropped production effects as these are not easily separable from the consumer visibility attribute

[16] We were able to provide a likely attribute to two of these practices based on the set of attributes that the rest of the pollution prevention activities in that same category possess. If all of pollution prevention activities in a category had a particular attribute, the “Other” pollution prevention activities were assigned the same attribute. For example, since all practices, 21, 22,23, 24 and 25, in the category Inventory Control, had the feature that they were efficiency enhancing, we expect that practice 29 (Other changes made in inventory control) would also have that attribute and assign it a 1 for *Efficiency*. Due to lack of definitive information on the functional attributes of practices included in categories 23,25,29,39,54,58,71,78 and 89 we assign a value of “0” for all their functional attributes and include them in the *Unclassified/Customized* category. These include practices that may involve combinations of changes in equipment, material or procedures as well as practices that cannot be labeled generically because they involve modifications designed specifically for a firm.

among firms that are non-adopters of TQEM.[17] These practices also differ considerably in their attributes. In Table 2, we summarize adoption rates of pollution prevention activities according to whether they possess a particular attribute. As shown there, the most widely undertaken pollution prevention activities for both adopters and non-adopters are those which are *Efficiency* enhancing or require *Procedural* changes.

5. RESULTS

5.1. Estimation of Count Models

We estimate a number of models that explain the count of each of the 43 different pollution prevention activities practices undertaken by firms, Our results, discussed in detail below, show that in all models, the firm-specific dummies and the practice-specific dummies are always jointly significant, indicating that there are indeed unobservable firm and practice-specific effects that need to be accounted for.

Table 3 presents our primary results, which consist of models I and II, and their variants. Model I examines the effects of only the functional attributes on the effects of *TQEM* on the adoption rates while Model II includes the full set of practice attributes. The base variant (Variant A) of these models includes no other controls except the *Number of Chemicals*, year fixed effects, firm fixed effects, and practice fixed effects, while Variant B includes *Lagged Total P2* and *Cumulative P2* as additional control variables in logs. We have also estimated variants of this and other specifications in which the latter two variables are in levels, with generally poorer fit. In these variants, variables of interest maintain their signs and significance

[17] With the exception of elimination of shelf-life requirements for stable materials (practice 23), improved procedures for loading and unloading and transfer operations (32), institution of recirculation within a process (51), change from small to big bulk containers (55), and to a lesser extent, modification of spray systems or equipment (72), substitution of coating materials (73), change from spray to other techniques (75) and modification of packaging (83).

and, therefore, we do not report or further discuss these results for brevity. All of the regressions show that TQEM adopters have higher adoption rates for pollution prevention practices that involve *Procedural* changes or are *Unclassified/Other*, but not for those that involve *Equipment* or *Material* modifications. This is supported by the positive statistically significant coefficients of *TQEM+TQEM*Procedural* (except Model II-B), the positive and statistically significant coefficient for *TQEM* (no interactions), and the statistically insignificant coefficients of *TQEM+TQEM*Equipment* and *TQEM+TQEM*Materials*.[18]

These results suggest that TQEM enables firms to identify specific areas that require changes in operational practices and procedures that might not be identified by non-adopters of TQEM, possibly because the latter do not benefit from the expertise and knowledge-sharing among various "grass-roots" employees. This explanation is particular apt for explaining the strong positive effect of TQEM on the adoption of practices in the *Unclassified/Other* category. These practices may comprise the less typical types of source reduction methods not classified by the regulator, and instead, may be composed of activities that firms develop themselves to address firm-specific operations and environmental goals. This further indicates that the bottom-up nature of TQEM stimulates the development of customized pollution prevention practices. However, *TQEM* may not have a similar positive effect on pollution prevention activities that require *Equipment* or *Material* modifications: the negative coefficients on *TQEM*Equipment* and *TQEM*Materials* offset the positive coefficient of *TQEM*, making the impact of *TQEM* on the adoption of practices with these attributes statistically insignificant. This suggests that identification and implementation of the equipment and material modifications needed to prevent pollution do not necessarily require an organizational structure such as TQEM.

[18] Note that our standard errors are not the maximum likelihood Poisson standard errors that tend to be biased downwards due to over-dispersion in the data. Rather our reference is based on GLM standard errors that allow for

Model II shows that the *Consumer* visibility and *Efficiency* enhancing characteristics of pollution prevention practices by themselves do not have a statistically significant incremental effect on the count of practices adopted by TQEM adopters as compared to TQEM non-adopters. The effect of *TQEM* on a practice with the *Consumer* or *Efficiency* attribute is determined by the functional characteristic of that practice. Given the discussion above, this effect will be positive and statistically significant for practices that have *Customized* or *Procedural* attributes. The effect is also positive for practices that have either Customized or Procedural attribute and Efficiency or Consumer attribute. The effect of TQEM is found to be insignificant for all other combinations of attributes (joint test statistics are not shown).

In addition to the attributes of pollution prevention practices, we find that experience with pollution prevention activities in the past has two distinct effects on *P2* adoption. In particular, we find that while *Lagged Total P2* is associated with higher levels of *P2*, the count of *Cumulative P2* adopted has a negative effect on incremental adoption rates. The first finding implies that adoption of more pollution prevention activities in the recent past (previous year) is associated with higher adoption counts in the current period, likely arising from the presence of slowly evolving unobserved factors (notice that we do not assign a causal interpretation to this variable). These could include complementary knowledge and expertise available to a firm, short-term learning, and management attitudes. The second finding suggests diminishing returns to the adoption of pollution prevention activities, possibly because of reduced opportunities to develop and undertake new pollution prevention practices when the number of environmental innovations already adopted in the past is high. In other words, a firm that has already reaped the "low hanging fruit" will find it more difficult to identify additional worthwhile pollution prevention practices.

arbitrary correlations between the disturbance terms for observations within a firm.

All models also consistently show that the *Number of Chemicals,* the number of opportunities to undertake pollution prevention activities increases the count of *P2s* adopted. We also find evidence of secular trends in technical change, as evidenced by the positive and significant signs of the year dummies in Models I-B and II-B after controlling for the past adoption levels of pollution prevention activities (*Lagged Total P2* and *Cumulative P2*). However, the negative significant signs of the time dummies in models I-A and II-A indicate that, in those models, diminishing returns are being captured by the time dummies because the dynamic effects from past pollution prevention activities, both *Lagged Total P2* and *Cumulative P2*, are not accounted for.

We investigate the robustness and internal consistency of our findings using a number of specification variants. We first consider the effect of combining the physical attribute categories *Equipment* modifications and *Material* modifications into a single *Physical* modifications category. The results, reported in Table 4 Models III-A and III-B, show that firms do not develop more physical modification *P2* techniques following their adoption of TQEM. However, *Procedural* changes and practices that have *Unclassified/Customized* attributes continue to be key attributes associated with higher adoption of pollution prevention practices by TQEM firms.

We conduct a second robustness of our classification strategy driven by the observation that most of the pollution prevention activities that are *Efficiency* enhancing also involve *Procedural* changes (see Table 1). In particular, we drop *Efficiency* from the regressions in order to see if our conclusions with regard to *Procedural* modifications remain valid (Models IV-A and IV-B). We find results that are similar to those described above: TQEM promotes the adoption of *Procedural* changes and *Unclassified*/*Customized* practices. We continue to find that practices that involve either *Equipment* or *Material* modifications do not respond significantly to TQEM adoption.

Our third robustness check is motivated by the possible concern that our findings are driven by a temporal correlation between TQEM adoption and secular trends in the popularity of pollution prevention practices with particular attributes. Suppose that procedure-based and customized modifications were becoming popular over time for reasons unrelated to TQEM adoption. Then, these trends would result in a spurious positive coefficient of the interaction terms between *TQEM* and these two practice attributes, given that the propensity to adopt TQEM also increases over time. To investigate if indeed there are time-specific factors that may favor the adoption of some pollution prevention activities over others we added interactions between each attribute with each year dummy for a total of 20 interaction terms as explanatory variables in Model II-B yielding Model V. We find that the joint test statistic for all *Year dummy*Attributes* interactions is not significant and the magnitude and significance of the coefficients of *TQEM* and its interactions with each the attribute are very similar to those in Model II-B.

A careful examination of fixed effects identification strategy reveals that the coefficient of *TQEM* is identified from the mean change in pollution prevention practices by the 35 firms whose TQEM status changed during our sample period. Firms for which the *TQEM* variable takes the same value for all five years in our sample, do not contribute to the identification of the baseline TQEM treatment effect, since we employ a fixed effects model. In contrast, the coefficients of interactions between *TQEM* and pollution prevention attributes are identified not only by the change in adoption patters by the 35 new TQEM adopters but also by comparison of the 66 existing TQEM adopters with the 59 TQEM non-adopters.

As an indication of the validity of applying the *TQEM* coefficient to all firms we would like to show that firms that changed TQEM status during our sample period ("recent adopters") do not differ significantly from firms that had adopted TQEM prior to the start of our sample ("early adopters") in the pattern of pollution prevention practices they employ (i.e., that the effect of TQEM on the *mix* of practices does not vary across the two types of firms). We, therefore, construct a *New TQEM* dummy variable to indicate a recent adopter as a firm that adopted TQEM for the first time within our sample, with *New TQEM* taking the value of 1 on the year a firm started adopting *TQEM* and thereafter, and 0 before it adopted TQEM. Those who never adopted or had adopted TQEM before the start of our sample (early adopters) are also given a value of 0.[19] Note that we include only the interaction of *New TQEM* with each of the attributes; inclusion of New TQEM itself would lead to co-linearity with the TQEM variable given that we have a fixed effects model.

As shown in Table 5, Model VI, we test for the difference in the pattern of pollution prevention practices adopted by early and recent adopters by examining the significance of the coefficients of each attribute interacted with *New TQEM*. We find that there is no systematic difference in the sign of these interaction terms between recent and early adopters. With the exception of the negative statistically significant coefficient of *New TQEM**Equipment*, all other coefficients of these interaction terms are not statistically significant.[20] Moreover, when we combine *Equipment* and *Material* modifications together as *Physical* modifications (results are not shown in the Table 5), we find that *New TQEM*Physical* is no longer statistically significant. Furthermore, we find that the signs and significance of all coefficients of *TQEM*, its interactions with each attribute, and of *Lagged Total P2*, *Cumulative P2*, and *Number of Chemicals* are

[19] We do not have data on how early they adopted *TQEM* prior to 1992. In any case, 1992, is the arbitrary cut-off year for early versus recent adopters.

similar to those in Model II-B. We also find that these results are robust to dropping *Efficiency* from these regression variants (results are not shown). We, therefore, conclude that identifying the *TQEM* coefficient from the recent adopters and projecting it to all adopters is a reasonable approach.

Nevertheless, to further investigate this issue, we check for the possibility that the smaller apparent response of *Equipment* to *New TQEM* may be driven by their lower initial propensity for adoption of equipment related pollution prevention practices. For these *New TQEM* adopters, we construct a variable *Pre-TQEM* which is equal to 1 for the years prior to their TQEM adoption, and 0 thereafter (This variable again takes the value of 0 if the firms are always adopting TQEM or never adopt TQEM within our sample). This is similar in spirit to a difference-in-difference type estimator at the firm-cross-practice-characteristic level for the new adopters (this type of estimation is not possible for all firms, since we do not observe the pre-adoption pattern for our early adopters). Again note that we include only the interaction of *Pre-TQEM* with each of the attributes since including the variable as a regressor would lead to co-linearity with *TQEM* given that we have a fixed-effects model. Results of estimating this model are reported in Model VII in Table 5. We find that the coefficient of *Pre-TQEM*Equipment* is also negative and statistically significant, suggesting that the recent adopters of TQEM were adopting fewer practices with the *Equipment* attribute even prior to the adoption of TQEM. The difference between the *Pre-TQEM*Equipment* coefficient and the *New TQEM* Equipment* coefficient is, however, not found to be statistically significant, as shown at the bottom of Table 5. Similarly, we find that the difference between *Pre-TQEM*Attribute* coefficient and the *New TQEM* Attribute* for all other attributes is also not statistically significant. Thus, once the differences in baseline rates of practices with the *Equipment* attribute between recent and non-

[20] The interactions of *New TQEM * Attribute* are also jointly significant.

adopters of TQEM is taken into consideration, the effect of *TQEM* on adoption count of equipment related practices is not statistically significantly different across recent and early adopters. The seemingly smaller impact of *TQEM* on the adoption of practices with the *Equipment* attribute among recent TQEM adopters is really driven by ex-ante differences among the recent and non-adopters of TQEM and not by TQEM *per se*. This finding provides additional support for the validity of the identification strategy.

5.2. Simulations

We now use the results of Model II-B to simulate the impact of TQEM adoption on the count of pollution prevention practices at the industry level for the firms that adopted TQEM during our sample period.[21] In order for our results to represent effects of TQEM on annual counts, we conduct this simulation by constructing the counterfactual count of practices that a firm would have adopted had it delayed the adoption of TQEM by one year. The method used to construct these counts is described in section 3.2 and results of this simulation are reported in Tables 6.[22]

The results in Table 6 can be used to investigate the implications of the adoption of TQEM for pollution prevention by different industries, despite the absence of SIC fixed effects in the analysis. This is because firms differ in the distribution of pollution prevention practices of different types they tend to adopt, i.e. in their baseline adoption rates. Thus, even though the same parameter estimates govern the responsiveness of every practice to the adoption of TQEM by every firm, the aggregate effect of pollution prevention activities at the firm level would differ

[21] Using Model II-A for the simulation yields similar results.
[22] There are a total of 35 firms who shifted their *TQEM* adoption decision from 0 to 1: 16 in 1993, 7 in 1994, 8 in 1995 and 4 in 1996. Table 6 is an average of P2 counts by one-digit category of all firms regardless of the year of the switch.

even in percentage terms. We expect that production processes of firms within an industry are likely to be similar in the extent to which they are amenable to the adoption of pollution prevention practices of particular types. As a measure of the effect of TQEM adoption at the industry level, in the last column of Table 6, we report the unweighted average of the percentage effects of TQEM adoption on pollution prevention counts of firms in each industry, treating each firm as an equally informative signal of the industry's propensity to adopt pollution prevention practices in response to TQEM. We find that Petroleum Refining and Related Industries (SIC 29) and Chemical and Allied Products (SIC 28) would have experienced the highest mean percent reduction in the number of activities had they delayed TQEM. In both these industries, practices with *Procedural* and *Unclassified/Customized* attributes are very heavily represented in the pre-*TQEM* baseline of pollution prevention practices adopted. Industries that gained less from TQEM adoption include SICs 34 and 35 that tend to be sectors involved in the manufacturing of metals, machinery and computer equipment, likely because of the equipment and materials oriented nature of the pollution prevention practices employed in these industries.

6. FURTHER DISCUSSION AND CONCLUDING REMARKS

Organizational structure plays a large role in dictating the number and type of innovative activities that firms undertake. The impact of a management structure such as TQEM, on different pollution prevention activities is not uniform because some practices are more complementary to the philosophy of quality management than others or more easily identified and designed given the tools embodied in TQEM. Our analysis shows that TQEM is conducive to the greater adoption of pollution prevention practices that involve procedural and unclassified/customized modifications. We also find that the adoption of practices that enhance efficiency or are visible to consumers is not being driven by TQEM more than practices without these characteristics. Moreover, we find that TQEM does not appear to promote the adoption of practices that involve physical changes in equipment and materials.

The variations in the adoption rates of various practices based on their attributes in response to TQEM is useful for better understanding how TQEM works in practice, and possibly for inferring the strategic motivations that underlie TQEM adoption and the type of outcomes that TQEM is designed as an instrument to achieve. We find that TQEM systems seem to be more amenable to using specifically generated knowledge to search for, identify and implement improvements in recurrent operations that are tailored to a firm's processes and/or involve non-standard modifications. Finally, the fact that TQEM adoption does not yield disproportionately high increase in pollution prevention activities that have efficiency enhancing or consumer visibility attributes, suggests that TQEM adoption is not driven primarily by the economic or strategic outcomes that might be achieved.

Our findings provide insight on the extent to which policymakers can rely upon corporate environmental management for inducing voluntary pollution prevention and the types of practices that are likely to be adopted by firms. To the extent that other types of practices, such as those requiring changes in equipment or materials are considered necessary to improve environmental quality, policy makers may need to rely on mandatory regulations rather than on promoting the adoption of TQEM by firms. Moreover, our results show that the benefits in the form of technological innovation from promoting TQEM differ across industries, suggesting the usefulness of targeting policy efforts to promote TQEM adoption to firms in particular industries. In particular, we find that firms in the petroleum refining and chemical products industries would gain the most in their count of pollution prevention practices from the adoption of TQEM while firms in the manufacturing of metals, machinery and computer equipment industries gain less from TQEM adoption. Finally, our analysis shows that firms do experience diminishing returns to pollution prevention. While there exists some “low hanging fruit,” further adoption of pollution prevention practices of any type is likely to be increasingly costly, and thus diminish over time in the absence of any regulatory stimulus.

Table 1. Types of P2, their Attributes and Mean and Standard Deviations of P2 Adoption Rates.

P2 Activities and Codes		Consumers	Efficiency	Equipment	Material	Procedural	Customized Functional Attributes	Remarks	*TQEM* Adopters	Non-*TQEM* Adopters	Total Sample
1 Good Operating Practices	13 Improved maintenance scheduling, record keeping, or procedures		X			X		This activity involves changes in procedures for basic upkeep and for documentation of activities which provides firms with time savings.	2.990 (6.202)	2.165 (4.293)	2.685 (5.584)
	14 Changed production schedule to minimize equipment and feedstock changeovers		X			X		Similar to Category 13, for procedural changes associated with planning of operating activities.	0.970 (3.186)	0.716 (2.493)	0.876 (2.949)
	19 Other changes made in operating practices		X			X		Similar to Category 13 and Category 14.	3.519 (17.244)	2.426 (4.381)	3.115 (6.356)
2 Inventory Control	21 Instituted procedures to ensure that materials do not stay in inventory beyond shelf-life		X			X		It is a procedural change as it involves modifications in the cataloging of and accounting of stocks and materials. As such, it saves inventory costs and reduces disposal of expired materials.	0.633 (2.163)	0.436 (1.222)	0.560 (1.872)
	22 Began to test outdated material — continue to use if still effective		X			X		Similar to Category 21.	0.175 (1.246)	0.155 (0.656)	0.168 (1.066)
	23 Eliminated shelf-life requirements for stable materials		X				X	This activity saves inventory costs by improving management of inputs and materials. It may or may not be a procedural change.	0.006 (0.077)	0.024 (0.152)	0.012 (0.111)
	24 Instituted better labeling procedures		X			X		This improves procedures for the classification of supplies and in effect provides time savings.	0.127 (0.834)	0.139 (0.574)	0.131 (0.748)
	25 Instituted clearinghouse to exchange materials that would otherwise be discarded [b/]		X				X	Similar to Category 23.	0.181 (0.791)	0.047 (0.242)	0.131 (0.648)
	29 Other changes made in inventory control		X				X	Characterization of these activities depends on Categories 23 and 25.	0.700 (2.486)	0.341 (1.364)	0.568 (2.146)

Table 1. *(continued)*

P2 Activities and Codes		Consumers	Efficiency	Equipment	Material	Procedural	Customized Functional Attributes	Remarks	*TQEM* Adopters	Non-*TQEM* Adopters	Total Sample
3 Spill and Leak Prevention	31 Improved storage or stacking procedures		X			X		This activity involves changing the system for organization of materials and equipment and can save time and space.	0.359 (1.400)	0.236 (0.916)	0.314 (1.244)
	32 Improved procedures for loading, unloading, and transfer operations		X			X		Similar to Category 31, except it is a procedural change for transporting materials and equipment.	0.552 (1.746)	0.669 (1.715)	0.595 (1.734)
	33 Installed overflow alarms or automatic shut-off valves		X	X				Installation of such fixtures can save costs of cleanup as it can prevent leaks and spills.	0.194 (0.904)	0.128 (0.591)	0.170 (0.803)
	35 Installed vapor recovery systems		X	X				This equipment change can serve to save of clean up costs associated with residue from vapors and can also conserve material.	0.401 (1.339)	0.091 (0.438)	0.286 (1.106)
	36 Implemented inspection or monitoring program of potential spill or leak sources		X			X		This is a procedural change which can save firms cost of clean-up.	1.998 (6.562)	0.733 (2.171)	1.530 (5.406)
	39 Other changes made in spill and leak prevention		X				X	Other Category 3 *P2s* are presumed to provide savings like all other Category 3 *P2s*. However, we cannot characterize them according to other attributes,	1.450 (4.078)	0.540 (1.600)	1.114 (3.407)
4 Raw Material Modifications	41 Increased purity of raw materials				X			This activity involves a physical change in materials and inputs Raw material modifications may or may not bring about savings.	0.169 (0.695)	0.115 (0.451)	0.149 (0.616)
	42 Substituted raw materials	X			X			Similar to Category 41.	2.268 (4.160)	1.622 (3.525)	2.029 (3.947)
	49 Other raw material modifications made				X			Similar to Category 41 and Category 42.	0.891 (3.439)	0.324 (0.857)	0.681 (2.791)
5 Process Modifications	51 Instituted re-circulation within a process		X	X				This activity involves installation of new equipment It may provide savings.	0.609 (1.446)	0.794 (2.663)	0.677 (1.986)
	52 Modified equipment, layout, or piping			X				It involves physical equipment changes. It may or may not bring about savings.	2.313 (5.183)	2.051 (3.960)	2.216 (4.766)
	53 Used a different process catalyst				X			The use of a new catalyst is a change in materials used. It may or may not bring about savings.	0.077 (0.399)	0.101 (0.416)	0.086 (0.405)

Table 1. *(continued)*

	P2 Activities and Codes	Consumers	Efficiency	Equipment	Material	Procedural	Customized Functional Attributes	Remarks	*TQEM* Adopters	Non-*TQEM* Adopters	Total Sample
5 Process Modifications	54 Instituted better controls on operating bulk containers to minimize discarding of empty containers		X			X		This is a procedural activity that needs to be done regularly as part of periodic checks in operations. This can also provide firms savings in clean up costs from possible spills that may result from operation of bulk containers.	0.357 (1.414)	0.166 (0.752)	0.286 (1.215)
	55 Changed from small volume containers to bulk containers to minimize discarding of empty containers		X	X				These involve physical changes and can provide savings in packaging and waste disposal.	0.212 (0.946)	0.348 (1.537)	0.262 (1.200)
	58 Other process modifications made						X	It is difficult to characterize "other" Category 5 *P2s* due to differences among *P2s* in this Category.	3.304 (7.168)	1.753 (3.606)	2.730 (6.141)
	59 Modified stripping/cleaning equipment			X				Similar to Category 52.	0.226 (0.931)	0.115 (0.553)	0.185 (0.813)
6 Cleaning and Degreasing	60 Changed to mechanical stripping/cleaning devices (from solvents or other materials)			X				Because this activity involved a shift from material inputs to a physical equipment it is characterized by both equipment and material modifications.	0.058 (0.382)	0.071 (0.366)	0.062 (0.376)
	61 Changed to aqueous cleaners (from solvents or other materials)				X			This is a change in materials.	0.811 (2.343)	0.682 (1.952)	0.764 (2.206)
	63 Modified containment procedures for cleaning units					X		This is a procedural change.	0.067 (0.372)	0.034 (0.215)	0.055 (0.323)
	64 Improved draining procedures					X		Similar to Category 63.	0.097 (0.437)	0.010 (0.100)	0.065 (0.355)
	65 Redesigned parts racks to reduce drag out			X				This is a physical equipment change.	0.026 (0.193)	0.020 (0.163)	0.024 (0.182)
	66 Modified or installed rinse systems			X				Similar to Category 65 except that it does not involve material modification	0.029 (0.192)	0.020 (0.183)	0.026 (0.189)
	67 Improved rinse equipment design			X				Similar to Category 65 and Category 66.	0.083 (0.543)	0.024 (0.192)	0.061 (0.447)
	68 Improved rinse equipment operation					X		Similar to Category 63 and Category 64.	0.153 (1.010)	0.024 (0.152)	0.105 (0.809)

Table 1. *(continued)*

	P2 Activities and Codes	Consumers	Efficiency	Equipment	Material	Procedural	Customized/ Functional Attributes	Remarks	*TQEM* Adopters	Non-*TQEM* Adopters	Total Sample
7 Surface Preparation and Finishing	71 Other cleaning and degreasing modifications made						X	It is difficult to characterize "other" Category 7 *P2s* due to differences among *P2s* in this Category.	0.514 (1.303)	0.358 (1.144)	0.456 (1.248)
	72 Modified spray systems or equipment			X				Similar to Category 65, Category 66 and Category 67.	0.308 (1.429)	0.324 (1.488)	0.314 (1.450)
	73 Substituted coating materials used				X			This involves a physical change in materials.	0.621 (1.810)	0.834 (2.354)	0.700 (2.029)
	74 Improved application techniques					X		This may only be a procedural change since the physical changes are covered by Category 72 and Category 73.	0.549 (3.291)	0.294 (1.469)	0.455 (2.762)
	75 Changed from spray to other system			X				Similar to Category 72.	0.046 (0.413)	0.064 (0.507)	0.052 (0.449)
	78 Other surface preparation and finishing modifications made						X	It is difficult to characterize "other" Category 7 *P2s* due to differences among *P2s* in this Category.	0.117 (0.535)	0.071 (0.337)	0.100 (0.472)
8 Product Modifications	81 Changed product specifications	X					X	This activity is visible to consumers but may not require changes in physical equipment or materials.	0.401 (1.392)	0.311 (1.311)	0.367 (1.363)
	82 Modified design or composition of product	X			X			This is also visible to consumers but may or may not involve equipment modification. However, change in composition implies changes in materials.	0.556 (1.836)	0.297 (0.867)	0.460 (1.554)
	83 Modified packaging	X			X			Packaging is definitely visible to consumers and usually involves physical change in material.	0.014 (0.117)	0.027 (0.259)	0.019 (0.183)
	89 Other product modifications made	X					X	Other product modifications would definitely visible to consumers. However, other attributes may or may not be present.	0.442 (1.912)	0.206 (0.756)	0.355 (1.5389)
Total P2									29.58 (46.38)	19.91 (28.67)	26.00 (41.00)

The standard deviation of counts is given in parentheses below the mean count. See text for sources and details on the construction of this table.

Table 2. Descriptive Statistics.

Explanatory Variables	All Firms	TQEM Non-Adopters	TQEM Adopters		
			All TQEM Adopters	New TQEM Adopters	Existing TQEM Adopters
Different Types of P2 According to Attributes					
Consumers	0.073 (0.261)	0.071 (0.26)	0.075 (0.26)	0.069 (0.25)	0.074 (0.26)
Efficiency	0.32 (0.47)	0.29 (0.45)	0.34 (0.47)	0.32 (0.47)	0.32 (0.47)
Material	0.14 (0.34)	0.13 (0.34)	0.14 (0.34)	0.13 (0.33)	0.14 (0.34)
Equipment	0.20 (0.40)	0.20 (0.40)	0.20 (0.40)	0.18 (0.38)	0.20 (0.40)
Procedural	0.24 (0.43)	0.22 (0.42)	0.25 (0.44)	0.25 (0.43)	0.24 (0.43)
Other Functional Attributes	0.065 (0.25)	0.04 (0.20)	0.079 (0.27)	0.075 (0.26)	0.063 (0.24)
All Types of P2	0.60 (2.57)	0.46 (1.85)	0.69 (2.91)	0.79 (3.32)	0.58 (2.44)
Other Explanatory Variables					
Total Cumulative P2	94.73 (160.34)	57.74 (75.56)	116.46 (190.19)	93.50 (147.28)	87.17 (135.93)
Total Lagged P2	29.20 (45.94)	21.98 (34.37)	33.44 (51.06)	36.81 (65.43)	28.05 (42.10)
Number of Chemicals	75.69 (107.55)	55.71 (71.79)	87.42 (122.32)	93.50 (147.28)	73.00 (99.92)
Number of Firms	160	59	101	35	66

See text for sources. New TQEM adopters are the firms that have adopted TQEM within our sample period; the reported values correspond to their activity level following adoption (pre-adoption observations are included in the non-adopters column). Existing TQEM adopters are firms that have adopted TQEM prior to our sample period. The values for all TQEM adopters reflect the observations of the existing TQEM adopters and the post-adoption observations of the new TQEM adopters.

Table 3. The Role of Practice Characteristics on the Effects on TQEM on Pollution Prevention.

Variables	Model I-A	Model I-B	Model II-A	Model II-B [a/]
TQEM	0.488*** (0.105)	0.444*** (0.102)	0.484*** (0.115)	0.440*** (0.112)
TQEM * Equipment	-0.560*** (0.109)	-0.560*** (0.109)	-0.554*** (0.110)	-0.554*** (0.110)
TQEM * Material	-0.366*** (0.102)	-0.366*** (0.101)	-0.390*** (0.123)	-0.390*** (0.122)
TQEM * Procedural	-0.242*** (0.092)	-0.242*** (0.091)	-0.231** (0.114)	-0.231** (0.114)
TQEM * Consumers			0.05 (0.123)	0.05 (0.122)
TQEM * Efficiency			-0.007 (0.108)	-0.007 (0.108)
ln(Lagged Total P2)		0.645*** (0.102)		0.645*** (0.102)
ln(Cumulative Total P2)		-0.704*** (0.248)		-0.704*** (0.248)
Number of Chemicals	0.870*** (0.159)	0.696*** (0.158)	0.870*** (0.159)	0.696*** (0.158)
Year 2	-0.116** (0.053)	0.403** (0.175)	-0.116** (0.053)	0.403** (0.175)
Year 3	-0.227*** (0.056)	0.588** (0.267)	-0.227*** (0.056)	0.588** (0.267)
Year 4	-0.406*** (0.059)	0.668** (0.336)	-0.406*** (0.059)	0.668** (0.336)
Year 5	-0.539*** (0.060)	0.743* (0.386)	-0.539*** (0.060)	0.743* (0.386)
Constant	-4.548*** (1.037)	-4.572*** (1.037)	-4.547*** (1.037)	-4.572*** (1.037)
Joint Tests of Significance				
TQEM+TQEM*Equipment	-0.073 (0.108)	-0.117 (0.106)	-0.071 (0.115)	-0.114 (0.113)
TQEM+TQEM*Material	0.121 (0.105)	0.077 (0.102)	0.094 (0.132)	0.050 (0.128)
TQEM+TQEM*Procedural	0.246 *** (0.094)	0.202 ** (0.091)	0.252 * (0.145)	0.208 (0.142)
Firm dummies (χ^2)	1872.95***	5246.96***	1843.44***	275.24***
P2 dummies (χ^2)	5218.30***	275.24***	5219.76***	52248.82***
Residual squared	98.0	77.76	98.04	77.76
Number of Observations	34400	34400	34400	34400

[a/] Total *P2* and Cumulative *P2* are in logs. Standard errors are in parentheses: *** Significant at 1%, ** significant at 5%, * significant at 10%.

Table 4. Robustness Checks

Variables	Model III-A	Model III-B	Model IV-A	Model IV-B
TQEM	0.483*** (0.115)	0.439*** (0.112)	0.481*** (0.106)	0.438*** (0.103)
TQEM * Equipment			-0.554*** (0.110)	-0.554*** (0.110)
TQEM * Material			-0.388*** (0.119)	-0.388*** (0.118)
TQEM * Physical	-0.486*** (0.095)	-0.486*** (0.095)		
TQEM * Procedural	-0.205* (0.112)	-0.205* (0.112)	-0.236** (0.093)	-0.236** (0.093)
TQEM * Efficiency	-0.034 (0.107)	-0.034 (0.107)		
TQEM * Consumers	0.130 (0.103)	0.130 (0.103)	0.051 (0.122)	0.051 (0.121)
ln(Lagged Total P2)		0.645*** (0.102)		0.645*** (0.102)
ln(Cumulative Total P2)		-0.704*** (0.248)		-0.704*** (0.248)
Number of Chemicals	0.870*** (0.159)	0.696*** (0.158)	0.870*** (0.159)	0.696*** (0.158)
Year 2	-0.116** (0.053)	0.403** (0.175)	-0.116** (0.053)	0.403** (0.175)
Year 3	-0.227*** (0.056)	0.588** (0.267)	-0.227*** (0.056)	0.588** (0.267)
Year 4	-0.406*** (0.059)	0.668** (0.336)	-0.406*** (0.059)	0.668** (0.336)
Year 5	-0.539*** (0.060)	0.743* (0.386)	-0.539*** (0.060)	0.743* (0.386)
Constant	-4.546*** (1.037)	-4.571*** (1.037)	-4.548*** (1.037)	-4.572*** (1.037)
Joint Tests of Significance				
TQEM +TQEM * Equipment			-0.073 (0.108)	-0.117 (0.106)
TQEM +TQEM * Material			0.094 (0.131)	0.049 (0.128)
TQEM +TQEM * Physical	-0.003 (0.102)	0.047 (0.099)		
TQEM +TQEM * Procedural	0.278 * (0.144)	0.234 * (0.141)	0.246 *** (0.094)	0.202 ** (0.091)
Firm dummies (χ^2)	1874.35***	275.31***	1873.41***	275.23***
P2 dummies (χ^2)	5238.45***	5267.74***	5215.95***	5244.79***
Residual squared	98.04	77.76	98.04	77.76

Standard errors are in parentheses: *** Significant at 1%, ** significant at 5%, * significant at 10%.. Number of observations is 34400.

Table 5. Timing of TQEM Adoption and the Pattern of Pollution Prevention Activities.

Variables	Model V	Model VI	Model VII
TQEM	0.449*** (0.113)	0.526*** (0.131)	0.313** (0.139)
TQEM * Equipment	-0.540*** (0.114)	-0.478*** (0.114)	-0.624*** (0.125)
TQEM * Material	-0.411*** (0.125)	-0.454*** (0.124)	-0.488*** (0.142)
TQEM * Procedural	-0.264** (0.117)	-0.255** (0.115)	-0.304** (0.121)
TQEM * Efficiency	0.005 (0.110)	0.062 (0.107)	0.021 (0.116)
TQEM * Consumers	0.051 (0.126)	0.044 (0.127)	0.114 (0.145)
New TQEM * Equipment		-0.357** (0.145)	-0.358** (0.145)
New TQEM * Material		0.22 (0.180)	0.219 (0.180)
New TQEM * Procedural		0.123 (0.214)	0.122 (0.214)
New TQEM * Efficiency		-0.319 (0.211)	-0.320 (0.210)
New TQEM * Consumers		0.018 (0.171)	0.018 (0.172)
Pre-TQEM * Equipment			-0.667*** (0.209)
Pre-TQEM * Material			-0.136 (0.191)
Pre-TQEM * Procedural			-0.224 (0.243)
Pre-TQEM * Efficiency			-0.14 (0.218)
Pre-TQEM * Consumers			0.224 (0.189)
Joint Tests of Significance			
Year dummy * Attribute jointly zero χ^2 stat (p-value)	12.560 (0.8956)		
(New TQEM * Equipment) – (Pre TQEM * Equipment)			0.309 (0.252)
(New TQEM * Material) – (Pre TQEM * Material)			0.356 (0.261)
(New TQEM * Procedure) – (Pre TQEM * Procedure)			0.347 (0.321)
(New TQEM * Efficiency) – (Pre TQEM * Efficiency)			-0.179 (0.303)
(New TQEM * Consumers) – (Pre TQEM * Consumers)			-0.206 (0.254)

Standard errors are in parentheses, except for the χ-square test statistics for which p-value are reported: [/]*** Significant at 1%, ** significant at 5%, * significant at 10%.. For brevity, the coefficient for each *Attribute*Year dummy*$_i$ for all *i=1993, 1994, 1995 and 1996*, and all coefficients and standard errors of the other variables are suppressed. Lagged *P2* and Cumulative *P2* are in logs for all models in this table. Lagged P2 is positive significant and Cumulative p2 is negative significant. *Year dummies*, *Number of chemicals*, and *Constant* are similar to previous models. The chi-square statistic for the joint test of significance of all New TQEM*Attribute for Model VI is 28.9 which is statistically significant,

Table 6. Contribution of TQEM on Total Pollution Prevention Counts of New TQEM Adopters, by 2-Digit SIC Code

SIC Code and Industry Name		Number of New TQEM Adopters	Total Actual P2 by New TQEM Adopters (with TQEM)		Total Projected P2 by New TQEM Adopters (without TQEM)		% of Pollution Prevention Counts due to TQEM
			Mean	(Min, Max)	Mean	(Min, Max)	Mean
13	Oil & Gas Extraction	3	9.0	(2,17)	7.35	(1.93,13.68)	14.17
20	Food & Kindred Products	4	33.0	(0.0,106)	28.00	(0.0,90.18)	13.58
21	Tobacco Products	1	8.0	(8, 8)	6.88	(6.88, 6.88)	14.00
26	Paper & Allied Products	4	9.25	(1,17)	7.85	(0.95, 14.41)	12.01
28	Chemicals & Allied Products	5	11.8	(3,18)	9.68	(2.09, 15.75)	20.08
29	Petroleum Refining & Related Industries	1	2.0	(2, 2)	1.45	(1.45, 1.45)	27.71
32	Stone, Clay, Glass, & Concrete Products	1	42	(42, 42)	34.45	(34.45,34.45)	17.98
33	Primary Metal Industries	4	27.75	(1, 90)	23.70	(0.64,77.44)	19.23
34	Fabricated Metal Products	1	19	(19.19)	16.94	(16.94, 16.94)	10.85
35	Industrial & Commercial Machinery & Computer Equipment	4	5.5	(0,16)	5.00	(0.0,14.72)	10.03
36	Electronic & Other Electrical Equipment	3	96.33	(0, 269)	78.52	(0.0, 219.48)	18.97
37	Transport Equipment	2	190	(149, 231)	161.33	(122.84,199.82)	15.53
38	Measuring, Analyzing, Controlling Instruments	1	0	(0, 0)	0	(0, 0)	---
48	Communication	1	2	(2, 2)	1.61	(1.61,1.61)	19.39
All Industries		35	32.29	(0, 269)	27.09	(0.0, 219.48)	16.05

The columns under Total Actual P2 report the mean (and min and max) of the count of all P2 practices adopted by new adopters of TQEM, by industry, in the first year of TQEM adoption. The columns under Total Projected P2 report the mean (and min and max) of the simulated counterfactual count of all P2 practices by the same firms in the same year, assuming they had not adopted TQEM. The last column represents the average of the percentage P2 count due to the TQEM adoption, by industry (each firm's percentage change is weighted equal in computing the average). See notes of Table 6 and text for details on the construction of this table.

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ORDER WITHOUT LAW? THE ROLE OF CERTIFIED MANAGEMENT STANDARDS IN SHAPING SOCIALLY DESIRED FIRM BEHAVIORS

ANN TERLAAK
University of Wisconsin–Madison

Certified management standards (CMS), like norms, rely on decentralized enforcement processes to guide firm behaviors. I analyze how two elements of CMS—codification and certification—enable this institution to shape firm behaviors in settings where norms are ineffective. I further theorize that these same two elements limit the effectiveness of CMS by weakening enforcement processes. I contribute to institutional theory by identifying possibilities and limitations for normlike institutions to function beyond established boundary conditions.

Norms, informal rules, and codes of behavior can create order without law by relying on a decentralized enforcement process where noncompliance is penalized with social and economic sanctions (Ellickson, 1991; Greif, 1993; North, 1990). Scholars suggest that these normlike institutions are particularly effective if firms share a consensus about expected behaviors, if behaviors are observable, and if decentralized enforcement processes are consistent (Bendor & Swistak, 2001; Ostrom, 2000; Weiss, 2000). Yet, absent such conditions, these institutions exert only a weak force on firm behaviors. Given the potentially powerful effect of normlike institutions on firm behaviors, possibilities to extend their functioning beyond established boundary conditions carry important implications for institutional theory and management practice. In this article I analyze the ability of one such normlike institution to extend its functioning beyond these conditions through the codification and certification of desired behaviors. I theorize that codification and certification enable this institution to shape firm activities when consensus about expected behaviors is incomplete and when behaviors are difficult to observe. I further theorize, however, that these same two elements limit the scope of normlike institutions by encouraging patterns of compliance that introduce inconsistencies into decentralized enforcement processes.

I focus on certified management standards (CMS) to build my arguments. By doing so, my analysis addresses a gap in existing institutional theory for predicting factors that influence organizations in settings where firms lack both consensus about expected behaviors and information about compliance. CMS codify practices that are socially desirable (and potentially profitable) in areas as diverse as environmental management, labor management, and ecommerce security, and they grant certification to firms that adhere to these practices (Organization for Economic Cooperation and Development [OECD], 2001). Examples of CMS include the ISO 14001 environmental management standard and the SA 8000 labor management standard.

CMS constitute a normlike institution in that they are, like norms, classified as a private-decentralized institution (Ingram & Clay, 2000; King, Lenox, & Terlaak, 2005). They are private because they are created by nonstate actors, and they are decentralized because they rely on diffuse social and economic interaction for enforcing compliance (Ingram & Clay, 2000). For policy makers, understanding the functioning of private-decentralized institutions has become particularly important as they attempt to ensure social welfare by supplementing state-made laws and regulations with nonmandatory initiatives, such as CMS, codes of conduct, and reporting frameworks (Delmas & Terlaak, 2001;

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Gunningham, Grabosky, & Sinclair, 1998; Khanna, 2001; Post, 2000). The use of nonmandatory social initiatives is also an important phenomenon for management practice. Some managers report that adoption of such initiatives has been essential for their firms' organizational and financial health (Grow, Hamm, & Lee, 2005).

Previous research on CMS has built on their similarities to norms and, consequently, has likened the functioning of CMS to the functioning of norms (Delmas, 2003; Guler, Guillen, & Macpherson, 2002; Mendel, 2002). While such a conceptualization seems intuitive and has generated important insights, I contribute to institutional theory by focusing on CMS's unique attributes: codification and certification. Highlighting this difference between CMS and norms enables me to shed light on the potential of private-decentralized institutions to create order without law in settings with incomplete consensus and information—settings where normlike institutions are expected to be ineffective (Greif, 1993; Ostrom, 2000; Weiss, 2000).

My study furthermore contributes to theory by considering how strategic firm responses affect the ability of private-decentralized institutions to guide firm behaviors. Modeling firm responses to such institutions as strategic is relatively common in New Institutional Economics (e.g., Ostrom, 2000) but much less so in the management literature (Ingram & Silverman, 2002; Scott, 2001). Yet conceptualizing firm responses as passively driven by isomorphic pressures unnecessarily restricts our understanding of the mechanisms through which private-decentralized institutions guide firms. This has prompted scholars to call for integrating strategic behavior into the analysis of private-decentralized institutions (Dacin, Goodstein, & Scott, 2002; Ingram & Silverman, 2002; Oliver, 1991). Taking this strategic perspective, I theorize how codification and certification may limit the effectiveness of private-decentralized institutions by soliciting patterns of firm compliance that undermine decentralized enforcement processes.

My analysis also contributes to the growing literature on corporate social responsibility (e.g., Frederick, 1994; McWilliams & Siegel, 2001). An important debate in this literature centers on the role of nonmandatory social initiatives in guiding desired firm behaviors (Jiang & Bansal, 2003; Khanna, 2001; King & Lenox; 2000; Post, 2000). My analysis contributes to this debate by offering insights into the functioning of one strong example of a nonmandatory social initiative. It furthermore contributes by providing potential contingent effects that can support the transition from corporate social responsiveness (i.e., socially responsible behaviors caused by external forces) to corporate social responsibility (i.e., socially responsible behaviors caused by intrinsic conviction; Frederick, 1994).

I follow the behavioral assumptions of the boundedly rational choice perspective, and I assume that firms are self-interested and seek to maximize profits (Ingram & Clay, 2000; Simon, 1957). These assumptions associate my analysis with a direction in the literature on corporate social behavior that focuses on institutional reforms *given* organizational values, rather than on the development of theories that provide the moral underpinnings for better firm behavior (Frederick, 1994). Examples of studies on corporate social behavior that have relied on these assumptions include Russo and Fouts' (1997), King and Lenox's (2001), and McWilliams and Siegel's (2001). However, my assumptions do not take into account that intrinsic and self-enlightened considerations may drive firm responses to institutions (Scott, 2001) and that some firms may pursue social initiatives even if they imply economic losses (Windsor, 2001). I return to this issue in the discussion of my analysis.

The article has four parts. First, I use Ingram and Clay's (2000) categorization of institutions to juxtapose CMS against other institutions that may shape socially desired firm behaviors. Doing so allows me to circumscribe my research context, and it clarifies differences between private-decentralized institutions such as CMS and public-centralized institutions such as laws. Second, I use a macro perspective to theorize about the enabling effects of codification and certification. Specifically, I hold constant firm attributes and analyze how codification and certification may enable CMS to command firm compliance in various settings where norms would normally fail. Third, I take a micro perspective and allow for firm differences in order to investigate how codification and certification may solicit a pattern of compliance that undermines the decentralized enforcement process and, thus, limits CMS's effectiveness to guide firm behaviors. Fourth, I discuss my analysis and outline implications for future research.

EMPIRICAL CONTEXT

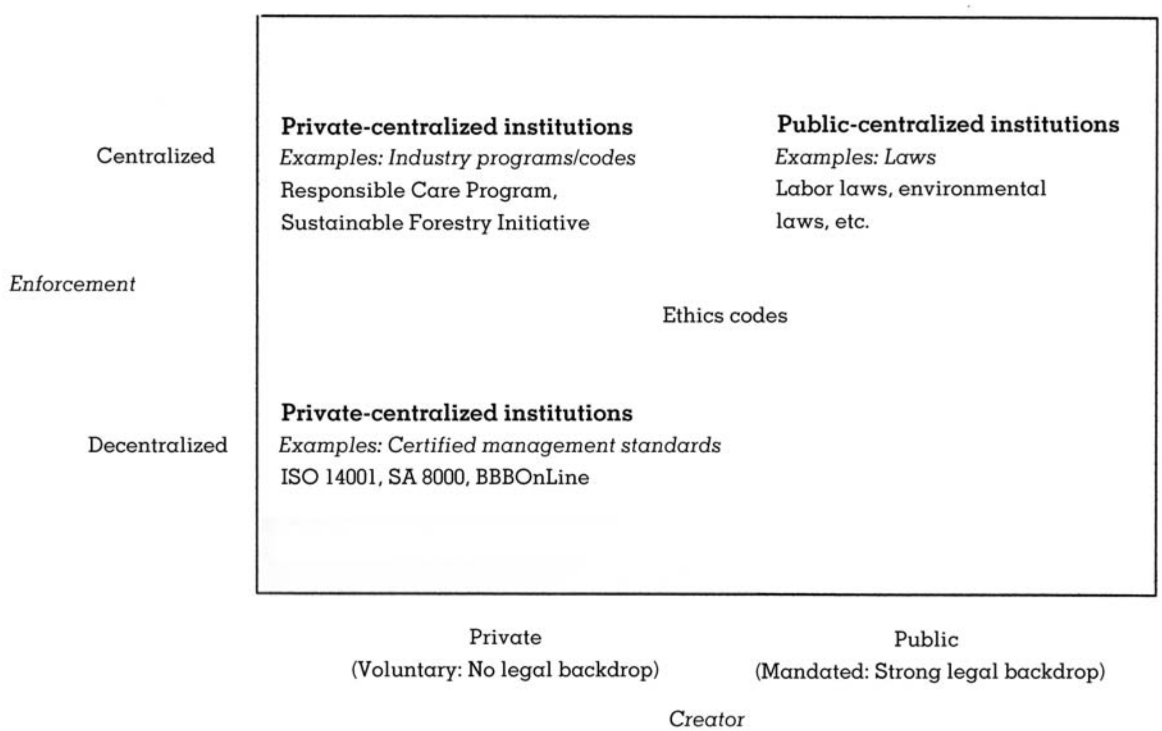
Ingram and Clay (2000) classify institutions based on two dimensions: (1) public or private and (2) centralized or decentralized. Public or private refers to who makes the institution. States produce public institutions, whereas organizations and individuals create private institutions. The second dimension, centralized versus decentralized, refers to how the institution is enforced. Centralized institutions are enforced through designated central functionaries, whereas decentralized institutions rely on diffuse individuals to punish institutional violations (Ingram & Silverman, 2002).

Laws are a classic example of a public-centralized institution (Ingram & Clay, 2000). They are public because they are created by the state, and they are centralized because they are enforced by a court system—that is, a designated functionary. Note that this classification considers both private law and public law as public-centralized institutions. Although private law gives standing to private and decentralized actors to bring a cause of action, it is a central designated functionary (the courts) that adjudicates violations and imposes penalties. Hierarchies and industry codes (e.g., the codes that govern members of the diamond and cotton industries) are examples of private-centralized institutions (Bernstein, 1992, 2001; Ingram & Silverman, 2002). They are private because they are created by organizations other than states, and they are centralized because they designate an authority that enforces compliance. Finally, norms are the archetype of a private-decentralized institution (Ingram & Silverman, 2002). They emerge from unorganized social interaction, and they are enforced through uncoordinated and decentralized interactions of individual actors.

Voluntary social initiatives may take the form of private-decentralized institutions or private-centralized ones. Figure 1 illustrates the various positions.

Voluntary social initiatives resemble a private-centralized institution if they are centrally enforced. The chemical industry's Responsible Care Program and forestry's Sustainable Forestry Program, for example, are created and enforced through the respective industry associ-

FIGURE 1
Institutional Classification of Social Initiatives



ations. These associations have central enforcement power because they arbitrate violations and can exclude noncompliant firms from the associations (King & Lenox, 2000).

As a private-decentralized institution, CMS lack a designated enforcement functionary. Instead, CMS derive their power from the uncoordinated social and economic interaction among firms and other transacting parties, such as industrial buyers, end consumers, and communities (Loya & Boli, 1999). Examples of CMS include the ISO 14001 environmental management standard, the SA 8000 labor management standard, and the BBBOnLine information management standard. Note that these standards are housed in specific (centralized) institutions: ISO 14001 is housed in the International Organization for Standardization, a private nongovernmental organization; SA 8000 is housed in Social Accountability International, a nonprofit organization; and BBBOnLine is housed in the Council of Better Business Bureaus, another private nonprofit organization. However, these institutions merely maintain the standards and are not responsible for their enforcement. By the end of 2003, approximately 66,000 firms were ISO 14001 certified (International Organization for Standardization, 2003), 18,000 firms had received BBBOnLine certification (Better Business Bureau, 2004), and 429 firms were certified with SA 8000 (Social Accountability International, 2004a).[1] Besides sharing the defining features of a private-decentralized institution, these standards also have in common that their creation involved representatives from various stakeholder groups (e.g., NGOs, industry, and consumers; European Commission, 2003; OECD, 2001). They furthermore resemble one another in that they all provide codified management practices and third-party certifications for compliant firms.

A distinction that coincides with the differentiation of public and private institutions is whether or not litigation can be used to enforce compliance. Because of the authority vested in states, noncompliance with public (i.e., state-created) institutions can have legal consequences. For Figure 1, considering this additional distinction allows a more differentiated treatment of ethics codes. I position ethics codes as a hybrid between a private-decentralized institution and a public-centralized one. I use these codes to highlight the possibility that private institutions that are theoretically voluntary (i.e., not legally required) may not be voluntary in practice and that they consequently resemble a public-centralized institution that is enforced through a designated functionary. In the case of ethics codes, adoption has become practically mandatory and centrally enforced, because the Federal Sentencing Guidelines reduce sentences for firms that have compliance and ethic codes.[2]

Thus, as far as the absence of an ethics code can be interpreted to give private actors the right of action for breach of directors' fiduciary duty, ethics codes begin resembling a public-centralized institution that is enforced through a designated functionary. The Sarbanes-Oxley Act further strengthens the legal backdrop of ethics codes by requiring firms to disclose their code or else explain why they do not have one. For my analysis, distinguishing between initiatives that are only theoretically voluntary versus those that are also practically voluntary is important. My analysis examines how a private-decentralized institution may create order *without* law. Thus, my reasoning refers to the functioning of initiatives that operate against weak legal backgrounds, maintain that noncompliance is legal, and leave firms with a real choice to comply or not.

THEORY DEVELOPMENT

Institutional similarities between CMS and norms make it tempting to liken the functioning of CMS to that of norms. Yet, rather than uncovering parallels between these two institutions, I

[1] Differences in uptake partially reflect the standards' varying ages. The ISO 9000 quality management standard is another private-decentralized institution that fits this list of examples. Some scholars argue that ISO 9000, although focused on quality management, has a strong social component and, thus, serves to enhance social welfare (Raiborn & Payne, 1996). However, while the logic of my analysis does not preclude this standard, I do not include it so as to avoid a distracting discussion about its social relevance.

[2] Courts find that the absence of such codes can be a cause of action for managerial breach of fiduciary conduct. In the *Caremark* case, for instance, the Delaware court dismissed allegations of criminal violations on the grounds that the company's directors had performed their duties as evidenced by the existence of a compliance and ethics program (Transparency International, 2004).

use the literature on norms to theorize how codification and certification enable CMS to shape firm behaviors in settings where norms are expected to fail. For this analysis I initially employ a macro perspective that does not consider firm differences and implies that hypotheses are governed by ceteris paribus assumptions with regard to firm attributes. Subsequently, I adopt a micro perspective and allow for firm differences in order to analyze how codification and certification may result in compliance patterns that inhibit CMS's effectiveness in guiding firm behaviors.

CMS and Norms

How do CMS shape firm behaviors under conditions of incomplete consensus and information—settings that violate the boundary conditions for norms to function? I first review how norms shape firm behaviors before analyzing the enabling and impeding effects that codification and certification have on private-decentralized institutions.

Despite the lack of legal sanctions, norms can be a powerful influence on firm behaviors (Ellickson, 1991; North, 1990; Ostrom, 2000; Uzzi, 1996): "norms specify how things should be done; they define legitimate means to pursue valued ends" (Scott, 2001: 55). Intrinsic incentives are an important driver of firm compliance when norms are internalized (Scott, 2001). Concepts from New Institutional Economics emphasize how external incentives can cause interest-seeking firms to adhere to norms, even if the norms are not internalized (Greif, 1993; Ingram & Clay, 2000; Ostrom, 2000). One such incentive is the threat of penalizing noncompliance with economic and social sanctions. Rejection of a norm may be punished through cessation of social relationships, ostracism from the group, and refusal of future economic exchange (Ellickson, 1991; Ingram & Silverman, 2002). Thus, while these social and economic penalties cannot be sought through litigation (as would be the case for noncompliance with laws), norms may be able to create order without law by using decentralized social and economic interaction to tie the potential for future gains to current compliance (Axelrod, 1986; Greif, 1993).

Research on norms suggests that a number of boundary conditions must exist for norms to command compliance (Axelrod, 1986; Greif, 1993; Ostrom, 2000). One condition is a consensus about the means and ends implied by the norm (Salbu, 1994; Weiss, 2000). Another condition is the risk of tarnishing one's reputation when rejecting the norm. This risk is perceived if there is agreement about the worth of compliance and if noncompliance can be detected (Bendor & Swistak, 2001; Greif, 1993; Weiss, 2000).[3]

Interestingly, while CMS share the defining institutional features of norms, they appear to guide firm behaviors in settings that do not meet the conditions for norms to function. Internet security management standards, for example, operate in a field that is young and still lacks consensus on best practices (Hunker, 2002). Other standards guide firm behaviors in settings that lack consensus about best practices because of firms' heterogeneous cultural backgrounds. Labor management standards, for example, coordinate the interaction of firms from various countries and continents. Furthermore, some CMS operate in settings where noncompliance with practices is difficult to detect. End consumers in the United States, for instance, cannot observe whether a garment manufacturer indeed complies with best labor management practices in remotely located textile mills. The question, then, is how CMS may guide firm behaviors when consensus about best practices is incomplete and when transacting parties have difficulties observing relevant firm practices.

Enabling Effects of Codification and Certification

CMS and norms share their defining institutional features, but CMS differ from norms in that they capture in a written and codified form how things should be done. Furthermore, unlike norms, CMS entail a certification element that makes visible whether a firm indeed does things in the way they should be done. I theorize that these two features allow CMS to engage firms in settings where norms would fail to do so.

Codification of practices. Norms are typically unwritten and, as a result, agents must share a

[3] Other factors that shape a norm's effectiveness in guiding firms include participation rules, relationship duration, access to a mechanism to resolve disputes, and a shared desire to maximize welfare (Ostrom, 2000; Weiss, 2000).

common understanding of the legitimate means to pursue valued ends regarding them (Bendor & Swistak, 2001; Bilder, 2000; Scott, 2001). If agents lack consensus on the interpretation of means and ends, sanctioning will become unsystematic because different behaviors constitute compliance or defection, and the norm will consequently lose its effectiveness in guiding firm behaviors (Weiss, 2000). For example, with respect to the informal laws that coordinated the activities of the Maghribi traders, Greif argued that "for punishment to be effective there must be a consensus about which actions constitute 'cheating'" (1993: 531). Building on insights from the literature on collaboration and knowledge codification, I argue that codification of how things should be done may enable CMS to shape the behavior of firms even in settings where consensus on how things should be done is incomplete.

Collaborating firms need to agree on ways to interact and manage the transfer of knowledge, products, and services. Codification of organizational rules and knowledge can facilitate such consensus in two ways. First, codification can increase consensus by requiring agents (organizations) to make their rules explicit (Benezech, Lambert, Lanoux, Lerch, & Loos-Barain, 2001). Research on the Delphi method suggests that by forcing agents to spell out their own rules, codification can enable iterative rounds of benchmarking that foster consensus on various issues (Munier & Ronde, 2001). Second, codification may reduce the problems of incomplete consensus by creating reference points that limit room for divergent interpretations (Avadikyan, Llerena, Matt, Rozan, & Wolff, 2001). Codified contents may become an authority to which agents can turn when uncertain about appropriate behaviors (Cowan, David, & Foray, 2000). Thus, codification allows the reconstitution of knowledge and rules for different periods, geographical locations, and agents (Cohendet & Meyer-Krahmer, 2001; Cowan et al., 2000).

For CMS, these findings suggest that, through codifying best practices, CMS may both foster consensus and reduce the problems of incomplete consensus. They foster consensus by encouraging conversations about how things should be done (Salbu, 1994), and they ameliorate the negative consequences of incomplete consensus by creating explicit reference points firms can refer to in order to assess behavior. However, this is not to suggest that codification can overcome deep divisions in organizational interpretations of values and ideas (Salbu, 1994). Just as firms need to agree on basic aspects in firm collaborations, they also need to agree on, for example, the desirability of worker safety. Once a basic agreement is in place, codification may help reconcile different notions of managing worker safety.

As far as codification fosters consensus or counteracts the negative consequences of incomplete consensus, it should facilitate the decentralized process that enforces compliance with private-decentralized institutions. Consequently, I expect that CMS are more effective than (unwritten) norms in guiding firm behaviors in settings where there is incomplete consensus on how things should be done. I posit the following.

> *Proposition 1: CMS will be more effective than norms in guiding firm practices in settings where consensus about these practices is incomplete.*

Proposition 1 assumes that it is possible to codify relevant practices. Yet in some contexts codification may not be possible because of the contexts' complexity and variability. For example, practices may be particularly difficult to codify if they need to capture tacit knowledge possessed by individuals (Fernie, Green, Weller, & Newcombe, 2003; Subramaniam & Venkatraman, 2001). This conclusion restricts the superiority of CMS as suggested by Proposition 1 to contexts in which codification of practices is feasible.

Proposition 1 can be made more applicable by specifying contexts in which consensus about best practices is likely to be incomplete. One such situation is an emerging management field. Just as emerging industries lack consensus on dominant business models (Aldrich & Fiol, 1994; Sanders & Boivie, 2004), recently emerged management fields frequently lack consensus on how to do things. For instance, Eisenhardt and Martin (2000) cite examples of internet firms' adoption of simple rules to guide strategic decisions as a response to a lack of dominant solutions in rapidly evolving industry conditions. It takes time for firms to form a consensus in such emerging fields because learning is slow, situations are complex, information is sparse and contradictory, and mind frames are resistant to change (Cole, 1998). As a result, different notions still exist, for example, for how best to manage the security and reliability of the internet and other distributed information technology systems (Hunker, 2002). Yet despite incomplete consensus, CMS that address internet and information security (such as BBBOnLine) have started guiding firm behaviors in this area. To the extent that codification of practices helps reconcile and reduce the effects of incomplete consensus about best practices, I expect the following.

> *Hypothesis 1a: CMS will be more effective than norms in guiding firm practices in recently emerged management areas.*

Consensus may also be incomplete when transactions involve parties with heterogeneous cultural backgrounds (Adler, 1986; Graham, Mintu, & Rodgers, 1994; Hofstede, 1980). Stephens and Greer (1995) note that cross-national firm alliances are frequently doomed to fail because of heterogeneous cultural assumptions that initiate or compound differences in organizational processes, technology, and practices. For instance, U.S. employees typically consider participatory management as part of best labor management practices, whereas Mexican employees feel more uncomfortable providing decision-making input or assuming decision-making responsibilities (Stephens & Greer, 1995).

Salbu (1994) notes that cultural differences are particularly stark in the context of international business ethics because culturally derived norms (rather than, for example, technology) define limits of acceptable behaviors. Yet despite distinct cultural differences and associated incomplete consensus, CMS now guide labor management practices in cross-border firm transactions (OECD, 2001). Cultural firm differences also exist, albeit to a lesser degree, in cross-industry transactions. In fact, cross-industry differences in cultures and beliefs may be sufficiently stark to hamper collaborative efforts (Albino, Garavelli, & Schiuma, 1999; Simonin, 1999). Yet various CMS—for example, environmental management standards—guide firm practices in cross-industry interactions. Thus, if differences in cultural backgrounds are associated with incomplete consensus on how things should be done, and if codification reduces such incomplete consensus, I anticipate the following.

> *Hypothesis 1b: CMS will be more effective than norms in guiding firm practices in cross-cultural transactions.*

Certification of practices. The threat of sanctioning noncompliance by tarnishing the defector's reputation is an important driver of firm compliance to norms (Bendor & Swistak, 2001; Ingram & Clay, 2000). For this threat to be effective, however, relevant firm activities need to be visible to transacting partners so that defection can be detected and publicized (Greif, 1993; Weiss, 2000). For instance, letter exchanges between Maghribi traders who relied on a system of private-decentralized institutions to regulate the behavior of agents underline the degree to which information about behaviors is a critical element for the functioning of so-called lawless systems. In the case of the Maghribi traders, merchants had established a letter exchange system to verify trade-related information and to inform one another about past behaviors of agents (Greif, 1993).

Many firm activities are inherently difficult to observe for transacting partners. Environmental or labor management practices, for example, primarily relate to internal firm processes, which makes them difficult for external exchange partners to observe. I argue that certification may partially overcome this problem and allow CMS to guide firm behaviors in settings where incomplete information would, ceteris paribus, reduce the effectiveness of norms to shape firm behaviors. Consequently, CMS play an important role in guiding firm activities when norms are ineffective or absent. CMS offer third-party certification to firms that comply with the practices outlined in the standard. Firms need to recertify at regular time intervals (typically, every three years), as well as submit to annual surveillance audits in order to maintain certification (SAI, 2004b). Certified companies have permission to publicly display their certification. This certification makes transparent a firm's behavior in conditions where such behavior could not otherwise be inferred.

At a minimum, certification indicates to transacting parties that the firm has implemented the practices outlined in the CMS. As far as these practices result in superior performance, certification may also be a proxy indicator for firm performance in the area targeted by the standard (e.g., superior environmental protection or information security; European Commission, 2003). Furthermore, if best practices are linked to general firm competencies (Wenmoth & Dobbin, 1994), certification can also be an indicator of underlying firm capabilities. However, certification cannot indicate what a firm does poorly or does not do at all. This is because certification is voluntary, and a lack of certification, hence, does not allow inference about the practices and attributes of noncertified firms.[4] As a result, certification can merely identify firms that do good, but it cannot necessarily identify those that do bad.

Despite revealing only compliance (and not defection), certification may nonetheless be able to shape firm behaviors by enabling transacting parties to reward compliance (rather than sanction defection). Of course, transacting parties will reward certification only if they attach a worth to firm compliance with the practices outlined in the CMS. In the context of environmental management standards, for example, transacting partners may reward certification because they believe that best environmental practices are evidence of superior operational performance that translates into higher-quality products (Russo & Fouts, 1997). Industrial buyers may furthermore attach a worth to supplier compliance because best environmental practices may reduce the risk of accidents that cause shortages of important input materials and damage the reputation of supply chain partners (Reinhardt, 1999; Slawsky, 2004). End consumers may be willing to reward certification because supporting environmentally conscious firms may confer prestige within a community, induce others to purchase from these firms, or simply fulfill an enlightened self-interest (Reinhardt, 1998).

A similar logic may influence the willingness of transacting parties to reward compliance with best labor management practices. Therefore, as far as certification of compliance with CMS practices is associated with a reward, certification may be a substitute for the incentive effect that results from sanctioning noncompliance in settings with full information. As a result, CMS may be more effective than norms in guiding firm behaviors in settings where relevant firm activities are difficult to observe.

> *Proposition 2: CMS will be more effective than norms in guiding firm practices in settings where these practices are difficult to observe.*

Next, two hypotheses increase the applicability of Proposition 2 by stipulating conditions that make it difficult for transacting partners to observe firm activities. First, physical distance may prohibit interested parties from observing firm practices (Katz & Tushman, 1979). This is because physical distance makes it more difficult for parties to visit relevant firm sites and to collect information. Furthermore, any information that does spill out from the firm is likely to be localized and slow to travel, the more so the greater the distance (Adams, 2002). As a result, certification may enable CMS to be more effective than norms in guiding firm practices when geographical distance inhibits transacting parties from fully observing relevant practices. Cases in point are CMS that guide labor management practices in overseas garment manufacturing plants. Therefore, I expect the following.

> *Hypothesis 2a: CMS will be more effective than norms in guiding firm practices that are physically removed from transacting parties.*

Some products and services allow transacting parties to draw inferences about specific firm activities. For example, poor customer service allows customers some inference about the firm's employee training programs (Guy, 1997; Reidenbach & Minton, 1991). Similarly, poor quality control practices may manifest in defective products. To the extent that firm behaviors translate into output attributes and to the extent that these attributes are observable, the need to make firm behavior observable through certification decreases. Yet product (or service) quality may not always be assessable, and, furthermore, not all firm practices translate into noticeable product attributes.

The quality of goods and services may not be assessable at all—even after consumption—in

[4] For example, survey results suggest that firms sometimes comply with best practice yet forgo certification to avoid certification costs, further adjustments to systems, or inspection by outside agents (Naveh, Marcus, Allen, & Koo Moon, 1999).

the case of credence goods (Nelson, 1974). For example, assessing the services of medical doctors is problematic. Even after receiving treatment, patients often cannot assess whether the specific treatment was required and whether their subsequent well-being (or discomfort) is linked to the treatment (Emons, 1997). Whereas credence qualities make it particularly difficult to assess product attributes and, thus, prohibit inference about *any* underlying firm practices, other goods may reveal their quality prior to or after consumption and yet still may not allow inference about particular firm activities. For example, although a defective garment may allow inference about the manufacturer's quality control practices, it does not allow inference about the firm's environmental management practices, nor does it inform the buyer about whether the firm treats its workers fairly. This is because environmental management practices and most labor management practices primarily manifest at the firm's site—for example, through decreased emissions or greater worker health—rather than in end products. For cases in which product and service attributes do not allow transacting parties to draw inferences about a firm's practices of interest (such as environmental practices or information security practices), I expect that certification of these practices enables CMS to be more effective than norms in guiding firm behavior in the respective management areas.

> *Hypothesis 2b: CMS will be more effective than norms in guiding firm practices that are not manifested in product and service attributes.*

Thus far, I have held firm attributes constant and have theorized how codification and certification of practices may enable CMS to be more effective than norms in establishing order without law. Next, I hold environmental conditions constant while allowing for firm differences in order to theorize how codification and certification may reduce the effectiveness of CMS.

Impeding Effects of Codification and Certification

Following the assumptions of a boundedly rational approach to firm behavior, firm responses to CMS are driven by explicit, firm-individual, cost-benefit considerations, and a firm will comply only if it deemes it profitable to do so. Because firms diverge in resources and performance, compliance costs and benefits will differ across firms, and firm responses to CMS therefore will vary. I explain these differential firm responses and theorize how resulting patterns of compliance may result in inconsistent enforcement processes that reduce the effectiveness of CMS to guide firm behaviors.

Codification of practices. Research in corporate social responsibility suggests that firm inefficiencies can create room for win-win situations—that is, situations in which an improvement in firm practices increases firm efficiencies as well as social welfare (Graedel & Allenby, 1995; Porter & van der Linde, 1995; Reinhardt, 1999). Boyd, Tolley, and Pang (2002), for example, found that technical improvements allowed producers of glass containers to reduce nitrogen oxide emissions while improving their productivity. The magnitude of such win-win situations is debated (Palmer, Oates, & Portney, 1995), but agreement exists that firm inefficiencies are quite common and difficult to ameliorate (Frantz, 1988; Leibenstein, 1966). One reason for the persistence of substandard practices is the cost of identifying better ones (Arrow, 1974). Through compilation and codification of available best practices in their respective management areas, CMS may reduce this cost. Research suggests that compilation and codification are increasingly important since operational choices have become more numerous and complex (O'Dell & Grayson, 1998; Ruggles, 1998). Thus, assuming a potential for win-win situations, codification of best practices may enable CMS to improve social welfare as well as firm efficiency in the standards' respective management areas.

Levels of firm inefficiencies vary across firms (Frantz, 1988). These levels and the ability of codified practices to reduce inefficiencies may be related in two ways. From the perspective of theories of absorptive capacity (Cohen & Levinthal, 1990), high-performing, efficient firms may be better able to exploit codified practices. This is because firms require absorptive capacity to utilize external knowledge, and firms with larger absorptive capacity presumably have smaller inefficiencies because of their greater ability to update and adapt their resource bases (Cohen & Levinthal, 1990; Zahra & George, 2002).

Conversely, firms with higher inefficiencies—that is, poor performers in the respective management areas—may benefit more from codified practices because their marginal costs for improving efficiency are smaller. Presumably, firms with substandard practices have more opportunities to exploit low-hanging fruit (Reinhardt, 1999). Furthermore, arguments of absorptive capacity have proven particularly relevant in the context of transferring and exploiting complex and tacit knowledge in alliances and technology ventures (Lane & Lubatkin, 1998; Mowery, Oxley, & Silverman, 1996). CMS, however, tend to offer a relatively simple set of codified good practices (Hemenway & Hale, 1996). As a result, the level of absorptive capacity required for exploiting these practices may be comparably small. Thus, I expect that codification of practices translates into comparably greater efficiency gains for firms with lower performance in the management area targeted by the CMS and that these firms thus comply with the CMS.

> *Proposition 3a: CMS engage firms that have below-average performance in the respective management areas targeted by the standards.*

Certification of practices. Incomplete information about a firm's performance may reduce social welfare by inhibiting transacting parties from identifying and encouraging better-performing firms (Akerlof, 1970). For example, transacting parties may be willing to reward firms that protect their private information. However, incomplete information about relevant firm performance inhibits transacting parties from differentiating between truthful claims of superior consumer privacy and false ones. As a result, they are unwilling to reward firms that claim to protect consumer privacy, and firms thus have little incentive to ensure the safety of private information. This may result in an underprovision of socially desired goods, such as consumer privacy in ecommerce, environmental protection, or protection of labor (Reinhardt, 1998). Certification of best practices may be one way to address this problem of asymmetric information (Akerlof, 1970).

Following the structure of a signaling game (and temporarily leaving aside the effect of codification) suggests that the net benefit of certification is larger for firms with superior performance in the management area targeted by a management standard (Spence, 1973). This is because the willingness of transacting parties to reward certification should be similar across certified firms (at least within an industry), but poor performers incur greater certification costs. As far as poor performance is symptomatic of a lack of underlying firm capabilities, poor performers will incur greater costs, because each unit of adjustment that is required for bringing practices up to par for certification requires greater effort. Firms with higher performance, in contrast, incur lower certification costs, because practices are already up to par and because better firm capabilities reduce the cost of any needed adjustments. Scholars find that, in the context of environmental management standards, compliance costs are indeed greater for firms with lower environmental performance (Darnall & Edwards, 2004; Ferrer, Gavronski, & de Laureano, 2003). Practitioners confirm a compliance cost function that slopes downward with firm performance in the context of quality management standards (Marquardt, 1992).

If the reward for certification is constant and if certification costs increase with a decrease in firm performance, then the net benefit of certification is larger for firms with better performance in the standards' respective management areas. Thus, I expect that certification of practices translates into comparably greater benefits for firms with higher performance and that such high performers will engage in CMS.

> *Proposition 3b: CMS engage firms that have above-average performance in the respective management areas targeted by the standards.*

Combining the effects of codification and certification. Private-decentralized institutions derive their power from uncoordinated social and economic interaction (Ingram & Clay, 2000). I argue that codification can reduce the effectiveness of this decentralized interaction by causing failure in the sorting effect of certification. This failure results in compliance by both high and low performers and introduces inconsistencies into the enforcement process.

Certification of practices allows transacting parties to differentiate high performers from low performers if gaining certification is too costly or is impossible for the latter group (Spence, 1973). Recall that, in the context of CMS, certification does not attest to specific performance levels or outcomes; instead, it attests to the existence of (or compliance with) certain practices (European Commission, 2003). However, attesting to practices rather than outcomes does not automatically preclude certification from differentiating among performance levels. Differentiation is still possible if compliance to best practices either is indicative of superior levels of performance or induces superior performance. I argue that codification reduces the likelihood either scenario will occur.

Certification of CMS practices may be indicative of high firm performance if identification and implementation of these practices require capabilities that are more frequently possessed by firms that perform well in the management area targeted by the CMS. In fact, research suggests that, in general, better-performing firms tend to have a greater capability to execute thorough searches and identify best practices (George, 2005). However, CMS codify best practices and make them widely available, thereby reducing search and implementation costs and enabling poor performers to receive certification. A practitioner explains that in the case of ISO 14001, for example, the standard "outlines system elements, with advice on how to initiate, implement, improve, and sustain the system" (Jayathirtha, 2001: 248).

A simplified analogy describes this situation: one can think of certification of practices as an exam that tests *how* students solve problems (i.e., the process of problem solving).[5] Presumably, only intelligent students are able to identify best processes. However, the provision of codified practices translates into the provision of a course reader that outlines best approaches to problem solving. Given this course reader, merely testing whether students can recite approaches to problem solving would no longer differentiate intelligence levels.

Certification of practices and simultaneous codification would not necessarily reduce the sorting effect of certification if compliance with codified practices resulted in comparably superior performance levels. Returning to the analogy, passing the exam could still be indicative of higher intelligence levels if studying the course reader allowed poorer-performing students to improve their intelligence. Yet the effect of complying with codified practices on firm performance is likely to vary according to firm capabilities and initial firm performance (Cohen & Levinthal, 1990). It is possible that codified practices remove the worst inefficiencies, but they may not turn laggards into leaders. Absent other firm capabilities that enable a firm to modify codified practices in order to meet individual needs, and absent capabilities that allow an ongoing learning process, improvements may be limited, and resulting performance levels may vary and continue to lag behind (Zahra & George, 2002). Research suggests that, in some cases, implementation of codified practices may even decrease performance (Westphal, Gulati, & Shortell, 1997).

If compliance with best practices does not allow one to draw inferences about superior firm performance and if compliance does not necessarily induce superior performance, certification can no longer differentiate high performers from poor performers. This situation threatens the decentralized enforcement process: as ongoing interaction between firms and transacting parties provides some information about the performance level of compliant (certified) firms, parties may cease rewarding certification as they realize that both high and low performers are certified. This is a major issue for the ISO 9000 quality management standard, which served as the role model for its younger ISO 14001 sibling. For ISO 9000, a practitioner remarked that "our worst supplier was ISO registered and our best is not" (Naveh et al., 1999: 278). Another practitioner remarked that "ISO continues to be perceived as no sign of quality" (Naveh et al., 1999: 273). As transacting parties cease rewarding compliance, however, firms will lack the incentive to comply with practices at socially desired levels.[6]

Problems also arise if some parties use evidence of compliant high performers to interpret CMS certification as a signal of superior performance while others infer from compliant low

[5] For this analogy to correspond, the exam needs to test whether students can perform certain processes (practices), rather than whether they arrive at a specific answer to a given problem (outcome).

[6] Note that as far as compliance allows firms to remove inefficiencies, we should continue to observe some compliance. However, underprovision will result as soon as socially desired levels of compliance are above levels required for firms' internal improvements.

performers that CMS serve as an improvement tool for laggards. For example, in the context of the ISO 14001 environmental management standard, some practitioners expect the CMS to "distinguish companies that are doing the bare minimum from those that are committed to environmental excellence" (Morella, 1996), whereas others expect the CMS to provide "a toolbox of good ideas" that removes inefficiencies in poorly performing firms (Collins, 1996; Fielding, 1998; Klaver & Jonker, 2000). Such different interpretations are problematic because they result in inconsistent patterns of enforcement. Specifically, parties that view CMS as improvement tools may sanction noncompliant firms that they believe to be poor performers or, conversely, reward compliant firms that they believe to be poor performers. Such a pattern of enforcement is inconsistent with that pursued by those who interpret CMS as signals of superior performance. As a result, firms are confronted with inconsistent and spotty enforcement patterns that ultimately reduce the effectiveness of CMS to guide firm behaviors.

Codification (and certification) may thus be a double-edged sword. On the one hand, I suggested earlier that codification may create consensus on how things should be done—for example, codification may spell out the reporting procedures that help protect consumer information. On the other hand, codification, in combination with certification, may create a pattern of compliant firms that causes confusion about the more general meaning of the CMS—for example, are these reporting procedures part of superior consumer protection systems on which leading firms rely, or are they basic tools that allow firms that lack comprehensive systems to minimally respond to consumer concerns? As far as this confusion results in inconsistent enforcement patterns, decentralized enforcement processes are impeded, and the effectiveness of CMS to guide firm behaviors will be reduced.

> *Proposition 4: Engaging above- and below-average performers weakens decentralized enforcement processes and thereby reduces the effectiveness of CMS to guide firm practices.*

DISCUSSION

I analyzed one example of a private-decentralized institution—CMS—to develop an understanding of the role that nonmandatory social initiatives may play in shaping socially desired firm behaviors. A macrolevel analysis in which I did not consider firm differences suggests that codification and certification may allow CMS to guide firm behaviors in settings where private-decentralized institutions are thought to fail. However, an analysis that considers firm differences suggests that codification and certification may reduce CMS's effectiveness by encouraging patterns of compliance that introduce inconsistencies into decentralized enforcement processes. My findings have implications for institutional theory and the literature on corporate social behavior. They also have some important implications for practitioners.

Implications for Institutional Theory

As a private-decentralized institution, CMS differ from laws (the archetype of a public-centralized institution) in that they are nonstate-created institutions where compliance is voluntary (i.e., not legally required) and they are enforced through decentralized social and economic interaction (Ingram & Silverman, 2002). Yet CMS resemble laws in that they codify behaviors (Salbu, 1994). My analysis of the role of codification suggests that codification may enable CMS to guide firm practices in settings where private-decentralized institutions are thought to be ineffective. For institutional theory, this argument implies that current conceptualizations of the scope of private-decentralized institutions may be too narrow.

More important, however, my theoretical reasoning suggests that the mechanisms through which various institutional forms shape firm behaviors may be more complex than previously assumed. It may be possible that private-decentralized institutions can substitute for public-centralized institutions *not* through emulating some of the latter's defining institutional features—legally mandatory compliance and centralized enforcement—but, instead, through emulating seemingly less important features—in this case, codification. Thus, future research may enhance our understanding of institutions by examining how various institutional features (e.g., codification and certification) may enable one institutional form to cross into the realm of another form without relying on the latter's mechanisms for shaping firm behaviors.

Scholars have repeatedly called for greater consideration of firm strategic behavior in the analysis of private-decentralized institutions (Dacin et al., 2002; Ingram & Silverman, 2002; Oliver, 1991). Modeling firm responses to CMS as strategic, rather than assuming that responses are myopic and isomorphic, I have argued that codification and certification can trigger compliance patterns that ultimately undermine the effectiveness of CMS. For institutional theory, this reasoning suggests that our understanding of the effect of private-decentralized institutions on firm behaviors can be aided by exploring the incentive structures through which they engage interest-seeking firms. Thus, rather than focusing on how differential institutional pressures affect the behaviors of strategizing firms (Kostova & Roth, 2002; Oliver, 1991), I suggest considering how an institution's inherent incentive structure solicits or suppresses responses of strategizing firms. Analysis of incentive structures and accompanying strategic responses has generated considerable insights into understanding the effectiveness of private-centralized institutions (like hierarchies). Comparable insights may be gained in the context of private-decentralized institutions.

Implications for Research on Corporate Social Behavior

Following previous research on CMS, I have conceptualized CMS as a private-decentralized institution. Yet, unlike previous researchers, I have not focused on broader environmental conditions, such as regulatory environments and isomorphic pressures, to explain firm responses to CMS (Delmas, 2003; Guler et al., 2002; Mendel, 2002). Instead, I have examined how some of CMS's unique features (i.e., codification and certification) may affect this institution's ability to guide socially desired firm behaviors. I found that codification and certification have both enabling and impeding effects. Thus, my analysis implies that success and failure of CMS may be only partially explained through analysis of broader institutional conditions. Future research on CMS may benefit from further investigating this institution's inherent features. For example, some CMS (like BBBOnLine) require that firms submit to a clearinghouse system that keeps track of complaints against each firm. Such a system may enable CMS to command firm compliance in short-term transactions—a situation in which compliance to private-decentralized is thought to be low because it lacks the incentive effect of the shadow of the future (Axelrod, 1984).

Conceptualizing CMS as a private-decentralized institution implies that compliance to CMS is voluntary rather than legally mandated. Empirically, such a conceptualization seems appropriate, since most CMS indeed currently operate against comparably weak legal backdrops (Brunsson & Jacobsson, 2000). Generally, legal backdrops are weaker in the context of institutions that span national borders and legislative terrains (Brunsson & Jacobsson, 2000). Yet institutional conditions may change such that some CMS begin operating against stronger legal backgrounds. For example, as firms seek to comply with the information security theme in the Sarbanes-Oxley Act (Messmer, 2003), compliance to information management standards such as ISO 1799 and BBBOnLine may eventually become practically (though not technically) legally required. Thus, future research may consider conceptualizing CMS as a hybrid that incorporates features of both a private-decentralized institution and a public-centralized institution.

For practitioners, this paper has a very clear message: the design of CMS matters. For policy makers, design elements like codification and certification matter in that they critically influence whether and how CMS guide desired firm behaviors. This, in turn, has implications for the degree to which CMS may complement or replace public-centralized institutions in the pursuit of social welfare. For managers, design matters because it affects enforcement patterns and facilitates (or impedes) coordination with transacting partners. This paper suggests that although codification and certification may broaden the applicability of CMS, they risk getting CMS stuck in the middle. Providing a tool for improvement and acting as a signal for superior performance may be exclusive endeavors that can be made compatible only under some very specific conditions.

This article also speaks to recent efforts to connect the literature on corporate social responsibility (CSR1) with that on corporate social responsiveness (CSR2; Frederick, 1994). "CSR2 shuns philosophy in favor of a managerial approach" and replaces "the abstract and often highly elusive principle of CSR1" with a "focus on the practical aspects of making organizations more socially responsible to tangible forces in the surrounding environment" (Frederick, 1994: 155). CSR2 explicitly acknowledges that corporate social responsiveness may face constraints imposed by capital markets, and it calls for exploration of institutional reforms that make social responsiveness a practical reality (Frederick, 1994).

My analysis moves in the realm of CSR2, and I model firm responses to CMS as driven by external sanctions and the quest for internal benefits. This conceptualization echoes recent survey results that suggest that firms continue to be designed as profit-making mechanisms with "no interest in the good of society" (Bartlett & Preston, 2000: 199), but it limits my analysis in that it does not address corporate social behavior that is driven by higher considerations (Windsor, 2001). Yet my analysis does not categorically exclude some of the more philosophical issues tied to corporate social responsibility. In fact, it is possible that CMS represent the middle stage that bridges corporate social behavior driven by laws and corporate social behavior driven by firms' intrinsic considerations of right and wrong. As management practices evolve, CMS may present a temporary state that is akin to "a provisional statement of the present status of the moral conversation" (Salbu, 1994: 359). As CMS practices become an integral part of transacting, firms may internalize them such that compliance is ultimately driven by firms' internal notions of how to do socially responsible business rather than by external sanctions and the potential for internal benefits. Future research should explore the role of CMS in providing a stepping-stone in this process.

Finally, note that the framework I developed in this study is not restricted to CMS; in fact, it applies to any social initiative that operates against weak legal backgrounds (and, thus, tends to be created by nonstate agents), that lacks a centralized enforcement authority, and that includes codification and certification. Therefore, it also informs us about the functioning of a variety of codes of behavior that meet these criteria. Narrowing my empirical focus for the purpose of this study facilitated the development of a tight theoretical framework, but this focus should not distract from this study's applicability to other social voluntary initiatives.

Limitations

The framework has some limitations that need consideration as the ideas presented get refined and tested in future research. Rather than assuming that firm responses to CMS are driven by isomorphic pressures, I have conceptualized firm responses as strategic, in the sense that firms actively respond to CMS and comply only if benefits outweigh costs. I have, however, not considered the possibility that firms, in an effort to look good without doing good, may act strategically in the sense that they decouple stated practices from actual behaviors. Research on the adoption of ethics codes suggests that such decoupling is especially likely when external pressures for social performance are high (Kimerling, 2001; Weaver, Treviño, & Cochran, 1999). Decoupling processes also have been documented in the context of quality management (Kostova & Roth, 2002) and the adoption of stock repurchase programs (Westphal & Zajac, 2001). In the context of CMS, decoupling may be less of a concern, because third-party certification limits the extent of such behaviors. However, while making decoupling less likely, recent accounting scandals suggest that certification systems can be faulty and may fail to prevent decoupling. Certification systems may break down as certifiers are caught in conflicts of interest due to consulting activities and fee collection (Naveh et al., 1999; OECD, 2001; O'Rourke, 2002). Thus, decoupling may remain a risk, and there is a need for future research to identify conditions when such risks become salient.

My analysis partially hinges on the willingness of transacting parties to assign a worth to firm compliance to best practices. For my analysis, I assumed that this willingness is given. Yet actual willingness to reward compliance will depend on the degree to which transacting parties can internalize the benefits that arise from firm compliance to best practices. I have argued that even in the case of a public good (such as environmental protection), willingness to reward compliance exists to the extent to which the public good can be bundled with private benefits. Yet as long as benefits remain that cannot be internalized, resulting levels of compliance will be below socially desired levels. Thus, the ability of CMS to entice firms into the production of public goods is limited.

When discussing CMS as a means to guide socially desired firm behaviors, it is important to acknowledge the difficulty of defining effectiveness. I have explored the ability of CMS to trigger immediate effects on firm behavior. However, besides assessing CMS with respect to their intended effect on firm behavior, one might assess CMS (and other voluntary social initiatives) with respect to their capacity to initiate a dialogue, increase awareness, and change mind frames (Massie, 2000; Salbu, 1994). The Sullivan Principles (a voluntary initiative on labor practices in South Africa), for example, may not have been particularly effective in changing employment practices, but they have successfully changed corporate investors' perceptions about apartheid (Massie, 2000). Last, it also is important to acknowledge a potentially much darker side of CMS. Through fostering compliance to codified practices, CMS may run the risk of reducing social welfare by erecting trade barriers that limit competition from firms that, for various reasons, may not be able to meet certification requirements.

CONCLUSION

Over the last decade, practitioners have increasingly relied on voluntary social initiatives as a means of closing the gap between enforceable mandatory laws and the social goals derived from universal principles and values (European Commission, 2003; Gunningham et al., 1998; Massie, 2000). Although nonmandatory institutions such as norms and informal rules can be a powerful driver of firm behavior, they risk failing when consensus about expected behaviors is incomplete (e.g., in cross-cultural settings and in emerging management fields) and when firm practices are difficult to observe.

In this article I have analyzed one example of a voluntary social initiative, CMS, to theorize how codification and certification may both broaden and restrict the scope of normlike institutions. I have reasoned that codification and certification enable these institutions to function in settings where nonmandatory initiatives are thought to fail but that they limit their scope by encouraging patterns of compliance that introduce inconsistencies into decentralized enforcement processes. My analysis contributes to institutional theory and the norms literature by theorizing about the ability and limitations of private-decentralized institutions to create order without law in settings that violate the boundary conditions for norms to function. This analysis contributes to the literature on corporate social behavior by shedding light on the functioning of voluntary social initiatives. For practitioners, my study provides guidance for the design of these initiatives. It suggests that inclusion of both codification and certification may broaden an initiative's scope but can risk triggering counteracting effects that reduce the initiative's effectiveness.

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Ann Terlaak (aterlaak@bus.wisc.edu) is an assistant professor of strategy at the University of Wisconsin–Madison. She received her Ph.D. from the Bren School of Environmental Science and Management at the University of California, Santa Barbara. Her current research explores how nongovernmental institutions shape firm behaviors and provide opportunities for vicarious learning.

SATISFICING SIGNALING: CORPORATE SOCIAL STRATEGY AND CERTIFIED MANAGEMENT STANDARDS

ANN TERLAAK
School of Business
University of Wisconsin Madison
Madison, WI 53706

ABSTRACT

I explore corporate use of environmental certified management standards (CMS). I propose that multi-plant firms with poor environmental performance seemingly respond to stakeholder pressures by adopting a CMS. However, this may merely be a "satisficing signal" because these firms will choose their better, not poorer, performing plants for adoption.

INTRODUCTION

Certified management standards have become omnipresent. An example of a standard that has enjoyed widespread diffusion is ISO 14001, which is a management standard that certifies a firm's environmental management practices. Signaling theory from economics offers a compelling explanation for the popularity of these certification schemes. When information asymmetries make it difficult for one party to assess the practices of another party, the informed party may use certification to communicate about the superiority of its practices (Spence, 1973).

Research on environmental certified management standards (CMS) indeed suggests that firms are more likely to certify their practices when information asymmetries with their stakeholders are high (Jiang & Bansal, 2003). Yet empirical irregularities indicate that there are limits to applying signaling theory to the analysis of environmental CMS. In particular, certified organizations often do not have better environmental performance (Andrews, Darnall, Gallagher, et al., 2001) and poor performers, rather than superior ones, tend to select into certification (King, Lenox, & Terlaak, 2005).

In this paper, I address this incomplete fit between signaling theory and the actual usage of environmental CMS by developing a framework of "satisficing signaling". I use the example of an environmental CMS to develop this framework. However, the framework is applicable to any CMS that aims at influencing and communicating about firm practices that are at least partially associated with positive external effects for society ("social" CMS).

HYPOTHESES DEVELOPMENT

I identify three aspects of social CMS that differentiate these standards from certification schemes typically analyzed by signaling theory, and argue how these aspects warrant the development of a modified signaling framework.

Changes in Underlying Attributes

Classic signaling theory assumes that the attribute about which the informed party signals is stable. In Spence's job market signaling model (Spence, 1973), education does not significantly alter the productive capabilities of a student. This notion conflicts with the core idea of human capital theory that education augments natural abilities (Becker, 1965). Thus, while both theories agree that schooling earns a premium, human capital theory attributes this premium to the students' learned skills whereas signaling theory argues that the premium is a reflection of the diploma's signal about the students' innate skills. Empirical studies suggest that the premium paid to college graduates ultimately is a combination of the effect of human capital accumulation and of being recognized as having inherently higher productivity (e.g., Bedard, 2001).

Just as education both influences and is indicative of a student's capabilities, an environmental CMS may both influence and indicate about a firm's environmental performance. Environmental CMS outline best environmental practices that companies need to implement in order to receive certification. These practices are expected (Darnall & Edwards, 2006) and found (King et al., 2005) to reduce a firm's impact on the natural environment.

If certification with a CMS not only communicates about firm performance but also improves this performance, stakeholders -- who are "motivated by a desire to bring about changes in a targeted firm's behavior along some dimension of concern to the group" (Eesley & Lenox, 2006: 6) -- should be particularly likely to pressure firms with poor environmental performance into adopting a CMS. Of course, for stakeholders to focus their efforts on these firms they need to be able to identify such low performers. While information asymmetries may inhibit stakeholders to undertake fine-grained differentiations, data available from news reports, non-profit groups, governments likely provide sufficient information for stakeholders to differentiate between firms that have very good and very poor environmental performance. Thus, stakeholders should be able to identify and apply adoption pressures to heavy polluters such that I expect:

Hypothesis 1: Organizations with poor environmental performance are more likely to adopt an environmental CMS than organizations with good environmental performance.

Internalizing the Benefits of Adopting a Social CMS

Signaling theory assumes that uninformed parties are willing to pay a premium to parties that reveal their attributes through signaling. In the case of an environmental CMS, however, a firm may be uncertain whether it will receive such premium in return for certifying with a CMS. This is because market participants may have a limited willingness to pay (WTP) for the provision of a public good such as environmental protection. (Note that certified firms may provide environmental protection either through <u>having</u> superior environmental performance or through <u>improving</u> their environmental performance). This is not to say that WTP always is zero – under certain conditions, both end consumers and industrial buyers may reward environmentally conscious firms (Reinhardt, 1998). However, the extent of this WTP often is unknown and furthermore likely remains below the costs of producing environmental protection.

The uncertainty of a market premium could be secondary if firms are able to receive an operational benefit, rather than a market benefit, for adopting an environmental CMS. This would be the case if best environmental practices improved firm operations. Research suggests that such effect is possible, but that it is conditional upon a myriad of factors including whether the firm pursues waste prevention versus waste treatment (King & Lenox, 2002), the degree to which environmental efforts are supported by upper management (Maharaj & Ramnath, 2005), and the ownership structure of the company (Russo & Fouts, 1997).

Thus, both the market benefits and operational benefits of adopting an environmental CMS are uncertain. Adoption costs, in contrast, are more concrete -- a firm is required to rearrange its practices or adopt new ones in order to comply with the CMS, and it needs to pay certification fees. This creates an interesting situation when considered in combination with the decision making structures in multi-plant firms.

Signaling in Multi-Tiered Decision Structures

Research suggests that the majority of companies adopt an environmental CMS because their parent company either required or encouraged them to do so (Darnall, 2003). Translated into the context of Spence's job-market signaling model, it may be the family head, rather than the student, who decides which of the family's children should attend college. If a multi-plant firm decides which of its plants to certify with an environmental CMS, which ones will it chose?

I argue that multi-plant firms will select a plant that has better environmental performance than other firm plants because minimizing adoption costs is important given the problems of internalizing the potential benefits of a social CMS. Choosing a better performing plant minimizes adoption costs because the plant may already have in place the practices required by the standard, thereby reducing the costs of otherwise needed rearrangements. Better performing plants may also have greater absorptive capacity which facilitates the implementation of new practices where needed.

A firm may furthermore minimize adoption costs by choosing a plant that operates in an industry with inherently smaller environmental impacts and where adherence to best environmental practices is less costly. Finally, a multi-plant firm may reduce adoption costs by choosing a plant with prior experience with CMS.

Note that the choice of a multi-plant firm likely looks different if it was certain that it could internalize the benefits of adopting an environmental CMS. If it expected CMS practices to improve its internal operations, it would have good business reasons to mandate adoption by its poorest performing plant because this plant could realize the greatest improvements at lowest costs. Similarly, a firm would choose a poor performing plant if it were certain that market participants were willing to pay a premium that fully and proportionally rewarded each unit of improvement. Yet, given the uncertainty about the operational benefits and market benefits of adopting an environmental CMS, multi-plant will seek to minimize adoption costs and I expect:

Hypothesis 2: Within multi-plant firms, organizations with good environmental performance are more likely to adopt an environmental CMS than organizations with poor environmental performance.

Hypothesis 3: Within multi-plant firms, organizations operating in cleaner industries are more likely to adopt an environmental CMS than organizations operating in dirtier industries.

Hypothesis 4: Within multi-plant firms, organizations with prior experience with CMS are more likely to adopt an environmental CMS than organizations without such prior experience.

Simultaneous consideration of Hypotheses 1 through 4 suggests that while stakeholder pressures may cause lower performing organizations to adopt an environmental CMS (H1), the uncertainty associated with the payoffs of adoption in combination with the decision making structure of multi-plant firms result in a situation in which certified organizations are better within-firm performers (H2), operate in cleaner industries (H3), and have prior experience with management standards (H4). I label this adoption pattern 'satisficing signaling': While poor performing organizations seemingly respond to stakeholder pressures by adopting and certifying best practices, these organizations are ultimately better within-firm performers. Yet certification by better performers conflicts with the interests of stakeholders who would rather see that the poorest performers adopted best environmental practices.

EMPIRICAL ANALYSIS

Sample

The sample consists of 5,215 facilities drawn from the population of U.S. manufacturing facilities from the years 1995 to 2002. The sample was constructed using data from U.S. EPA's Toxic Release Inventory (TRI), Dun & Bradstreet's directory of facilities, COMPUSTAT, the Bureau of Economic Analysis, the Census Bureau of Foreign Trade, and the QSU database of ISO 14001 and ISO 9000 certified facilities. The sample includes all facilities that report to the TRI and for which there was complete information for all relevant variables. My theory stipulates that firms can choose which of their plants to certify and the sample is therefore restricted to multi-plant firms that own three or more facilities.

Variables

Dependent variable. The dependent variable is the binary variable *Certification.* It takes on unity in the year that a facility certifies with the ISO 14001 environmental management standard.

Independent variables. *Facility Environmental Performance* tests H1. For each facility and year, I use TRI data to capture a facility's toxicity-weighted emissions. I normalize these emissions by industry and year so as to measure a facility's emissions relative to the emissions of other industry plants and I inverse the sign. C*leaner Firm Performer* tests H2. This binary variable takes on unity if a facility's (normalized) environmental performance is better than the average of the (normalized) environmental performances of all firm plants in that year. *In Cleaner Industry* tests H3. This binary variable takes on unity if a facility operates in an industry that is cleaner than the average industries of the other firm facilities. *ISO 9000 Certification* tests H4. It indicates for each facility and year whether the facility is certified with ISO 9000.

Control variables. *R&D Intensity* and *Export* capture the degree to which information asymmetries affect a plant's propensity to adopt ISO 14001. The former variable indicates a facility's industry's annual R&D intensity, whereas the latter indicates a facility's industry's percentage of exports of shipments. *Auto Supplier* and *Regulatory Stringency* control for the effect of coercive pressures. The former variable indicates whether a facility sells its products to an automobile manufacturer. The latter is the inverse of the logged aggregate emissions per state over the sum of the Gross State Product in four main polluting sectors. *Industry Certification* measures the influence of mimetic adoption pressures. It is the annual percentage of ISO 14001 certified facilities in each industry. *Relative Facility Size* is the logged and normalized (by industry and year) count of employees. *Firm Size* is the logged sum of the employees of all facilities belonging to a firm. I also include the binary variable *Publicly Held* and control for year fixed effects.

Analysis & Results

I analyze certification with ISO 14001 using a discrete time random effect logistic model. Table 1 reports results. Focusing on the fully specified Model 2 in Table 1, I find support for the hypothesis that plants with poorer environmental performance (relative to other industry plants) are more likely to certify with ISO 14001 (H1).

Table 1 about here

Results also indicate that plants with better environmental performance than other firm-plants are more likely certify with ISO 14001 (H2). Furthermore, the propensity for certification is greater for plants that operate in industries that are cleaner than the industries of other firm facilities (H3) and that have prior experience with a certified management standard (H4).

Model 3 includes industry fixed effects to test whether results are confounded by underlying industry-specific tendencies to certify. Model 4 is specified as a non-parametric partial-likelihood Cox-regression (with observations clustered on the facility level) to test whether results are robust to the log odds specification in previous models. Models 3 and 4 confirm the results for the independent variables in sign and significance. (Note that the coefficients in Model 4 represent hazard rates. Coefficients greater than unity indicate that the variable has a positive effect on adoption propensities).

CONCLUSIONS

I develop a framework of satisficing signaling to explain corporate use of social CMS. This framework considers (i) that implementation of CMS practices may change underlying firm attributes, (ii) that payoffs of adopting a social CMS are uncertain, and (iii) that multi-plant firms may behave strategically when they choose which of their plants to certify. I use the context of an environmental CMS to argue that the combination of these factors causes firms with poor performing plants to seemingly respond to stakeholder pressures by adopting an environmental CMS – however, this signal of responsible environmental behavior may merely be a satisficing one because these firms will choose their better performing plants, rather than their worst performers, for adopting and certifying best environmental practices. This conflicts with the interests of stakeholders who would rather see that plants with the lowest environmental performance adopted best environmental practices.

While signaling theory provides some important insights into the use of CMS, this paper suggests that only a few elements of the original signaling model may apply to the use of social CMS. As proposed by signaling theory, adoption and certification with a social CMS may help firms overcome information asymmetries with stakeholders. Yet contrary to signaling theory, the signaling action may actually change underlying firm attributes as CMS practices likely influence a firm's practices and performance in the area targeted by the standard. Furthermore, the premium associated with changing these underlying attributes is uncertain. This can result in a situation where a social CMS is neither a signal of (fixed) superior social performance nor a signal of efforts to improve firm social performance. Instead, a social CMS might run the risk of simply being a satisficing signal that firms employ to assuage stakeholder pressures without attempting to improve substantially their social performance.

REFERENCES AVAILABLE FROM THE AUTHOR

TABLE 1: Model Results

Variables	Model 1	Model 2	Model 3	Model 4
Facility Environmental Perf.		-0.160** (0.058)	-0.168** (0.059)	0.852** (0.046)
Cleaner Firm Performer		0.255* (0.113)	0.292* (0.115)	1.265* (0.133)
In Cleaner Industry		0.375*** (0.101)	0.267* (0.118)	1.402*** (0.134)
ISO 9000 Certification		0.557*** (0.100)	0.464** (0.104)	1.733*** (0.164)
R&D Intensity	9.273** (2.704)	8.815** (2.880)	10.215* (4.194)	3.941** (11.048)
Export	0.836 (0.842)	0.553 (0.866)	-0.208 (1.239)	1.964 (1.638)
Auto Supplier	1.404*** (0.130)	1.524*** (0.134)	24.772** (1.126)	4.309*** (0.508)
Regulatory Stringency	3.598 (2.909)	2.887 (2.933)	3.456 (3.191)	1.542 (4.003)
Industry Certification	0.071** (0.026)	0.064* (0.026)	-0.034 (0.034)	1.052* (0.022)
Relative Facility Size	0.377*** (0.056)	0.324*** (0.058)	0.381** (0.061)	1.359*** (0.071)
Firm Size	0.001** (0.000)	0.001** (0.000)	0.001* (0.001)	1.001*** (0.000)
Publicly Held	-0.254* (0.117)	-0.335** (0.118)	-0.312* (0.122)	0.720** (0.079)
Year Fixed Effects Industry Fixed Effects	Incl. -	Incl. -	Incl. Incl.	Incl. -
Chi-Square (df) Log Likelihood	641 (15)*** -1976.89	680 (19)*** -1949.89	1281 (91)*** -1853.49	753 (20)*** 1499.47

N = 36093
* = p<0.05; ** = p<0.01; *** = p<0.001. All tests are two tailed.

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FOLLOW THE SMALL? INFORMATION-REVEALING ADOPTION BANDWAGONS WHEN OBSERVERS EXPECT LARGER FIRMS TO BENEFIT MORE FROM ADOPTION

ANN TERLAAK[1]* and ANDREW A. KING[2]
[1] *School of Business, University of Wisconsin–Madison, Madison, Wisconsin, U.S.A.*
[2] *Tuck School of Business, Dartmouth College, Hanover, New Hampshire, U.S.A.*

We extend understanding of information-revealing bandwagons by considering a common condition under which adoption of a practice by small organizations, rather than large ones, has a disproportionate influence on future adoption propensities. We hypothesize that when the value of adoption increases with organizational size, smaller adopters have such disproportionate influence because they allow observers better to infer that adoption will be profitable for their own organization. We elaborate the theory by predicting that alternative information sources moderate the influence of smaller adopters. Empirically, we test our theory with longitudinal data on the adoption of the ISO 9000 quality management standard. Copyright © 2007 John Wiley & Sons, Ltd.

INTRODUCTION

Scholars have argued that adoption bandwagons are more likely to develop if organizations with certain attributes are already on board (Rosenkopf and Abrahamson, 1999). One explanation for this phenomenon is that adoption by certain organizations spurs future adoption because these organizations increase the social or economic value of adoption (DiMaggio and Powell, 1983; Scott, 2001; Tolbert and Zucker, 1983). Another theory is that adoption by certain organizations sets off bandwagons because these adopters better reveal information about the value of adoption (Bikhchandani, Hirshleifer, and Welch, 1992; Greve, 1996; Rao, Greve, and Davis, 2001). Although these two perspectives are not exclusive, we separate them in our discussion and label the former 'value-enhancing' and the latter 'information-revealing' theories of adoption bandwagons.[1]

Proponents of both adoption theories have stressed the role of large organizations in promoting bandwagons. Within theories of value-enhancing adoption, large organizations have a disproportionate effect on bandwagons because their actions increase the value of adoption (Haunschild and Miner, 1997; Haveman, 1993). Within theories of information-revealing adoption, large organizations have a disproportionate effect because they are more visible and thus more likely to be emulated (Baum, Li, and Usher, 2000). Large size also often brings with it greater resources, thereby giving an organization's actions an aura of good judgment (Rogers, 1995).

Keywords: bandwagons; mimetic adoption; institutional theory; inference; information cascades, vicarious learning

* Correspondence to: Ann Terlaak, School of Business, University of Wisconsin–Madison, 4261 Grainger Hall, 975 University Avenue, Madison, WI 53706, U.S.A.
E-mail: aterlaak@bus.wisc.edu

[1] To simplify our exposition, we drop the repeated use of 'bandwagon.'

The common agreement of the two theories on the importance of large organizations has made it difficult to untangle their effects on adoption bandwagons. In this paper, we contribute to efforts to differentiate the two perspectives by identifying a case in which an information-revealing theory of adoption makes the unusual prediction that adoption of a practice by smaller organizations, not larger ones, will more strongly influence future adoption propensities. Specifically, we argue that when observers expect the value of using a practice to increase with organizational size, adoption by smaller organizations will have a disproportionate influence because it reveals more information to observers about the size threshold at which adoption becomes valuable. This, in turn, can help observers determine whether adopting the practice would provide value for their own organization.

Our argument can be extended to attributes other than an organization's size. A more general statement of our argument would be that when observers expect the value of a practice to vary systematically with any attribute, these actors will be more strongly influenced by observing adoption at an entity that has less of this attribute (and consequently is expected to benefit less). For example, if the degree of automation in an organization increases the value of using just-in-time inventory (JIT) techniques, then the adoption of JIT techniques by a less automated organization should have a greater influence on the future adoption of JIT.

Despite the generalizability of our analysis to other organizational attributes, three rationales cause us to emphasize the effect of organizational size. First, as discussed earlier, previous research has theorized that the size of adopters plays an important role in shaping adoption processes (e.g., Baum *et al*., 2000; Haunschild and Miner, 1997; Haveman, 1993). Secondly, previous studies have demonstrated that the value of adopting practices and technologies often varies with organizational size (Cohen and Klepper, 1996; Dunne, 1994; Rogers, 1995). For example, adoption of manufacturing techniques, like computer-aided design or numerically controlled machine tools, generally provides a greater net benefit to larger organizations (Astebro, 2002). Finally, the size of an organization is a relatively observable and comparable attribute, and thus is more likely to be used in the adoption calculus of managers.

Previous research provides some precedence for theorizing that large size is not always the predominant determinant of influence. Some scholars have investigated the effect of similarly sized adopters and argued that these adopters may influence adoption propensities because they provide high-fidelity information to observers (Baum *et al*., 2000; Greve, 1998; Kraatz, 1998). The potential effect of smaller adopters, however, has largely been neglected. There has been some research on how cumulative adoption by fringe players shapes future adoption, but fringe players are not always associated with a specific size (Burt, 1980; Krackhardt, 1997; Rosenkopf and Abrahamson, 1999).

Our research contributes to the literature on adoption bandwagons in multiple ways. Firstly, we analyze an important case where theories of value-enhancing and information-revealing adoption make differing predictions about adoption patterns. Secondly, we develop a method for empirically exploring the relative influence of the two theories, and we find evidence that both play some role in adoption. Thirdly, we analyze how alternative information sources combine to determine adoption propensities. Specifically, we integrate theories of knowledge flows with those of adoption by exploring how localized adoption experience and corporate resources moderate the information effect of previous adopters. Finally, our study contributes to recent research efforts to explore the contingencies of adoption patterns and outcomes (Greve and Taylor, 2000; Kim and Miner, 2000; Miner *et al*., 1999).

THEORY AND HYPOTHESES

Theories of information-revealing adoption bandwagons

Scholars have identified several mechanisms by which adopters provide observers with information (Bikhchandani *et al*., 1992; Rao *et al*., 2001; Rosenkopf and Abrahamson, 1999). At the most basic level, adopters can make observers aware of the mere existence of alternatives. More central to the theme of this paper, however, adopters can also provide observers with information about the potential value of adoption. When actors and observers have rich communication links, observers may be able to gather information from previous adopters about the realized costs and benefits of using a particular practice or technology.

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More commonly, however, observers must gather information by witnessing only the fact that others have adopted a practice (Greve, 1998; Mansfield, 1961).

Witnessing adoption can inform observers about the value of the diffusing practice by allowing them to infer the calculus that led to the adoption decision. Specifically, if observers assume that managers in other organizations are making decisions based on benefits and costs, they can infer that adopters thought that the practice would provide a positive return. In making this inference, observers can update their own beliefs about the value of adopting the practice themselves (Bikhchandani *et al*., 1992). After each subsequent observed adoption, this updating process is repeated, and a bandwagon can result. Such information-revealing adoption has been documented in the contexts of trading behavior in stock markets (Choe, Kho, and Stulz, 1999; Wermers, 1999), coverage behavior of securities analysts (Rao *et al*., 2001), and radio stations' adoption of market positions (Greve, 1998).

Though information-revealing adoption bandwagons are thought to result from each actor's attempt to infer beneficial actions, these bandwagons do not always result in efficient outcomes or *ex post* rational behavior. Indeed, an extensive literature has considered how 'information cascades' can cause undesirable outcomes (Bikhchandani, Hirshleifer, and Welch, 1998; Rosenkopf and Abrahamson, 1999). For example, if only a few organizations have private signals (i.e., information) about a practice's value, observers may be unduly influenced by the action of a few early adopters. Believing that previous adopters are acting on better information, observers (both informed and uninformed) may choose to follow the example of these early actors. This process can lead to bandwagon adoption of a useless or even harmful practice (Bikhchandani *et al*., 1998).

Note that theories of information-revealing adoption are agnostic about whether the value of adoption results from a practice's technical or symbolic benefits. These theories posit only that adoption is driven by growing awareness or clearer expectation of this potential value. As a result, this perspective is compatible with research suggesting that symbolic value can be a critical element of adoption decisions (Westphal and Zajac, 2001).

Smaller adopters in information-revealing adoption bandwagons

Theories of information-revealing adoption suggest that observation of certain adopters allows stronger inference about the potential value of adoption (Bikhchandani *et al*., 1998; Rosenkopf and Abrahamson, 1999). Assuming adoption can be observed at all, stronger inference can be made when (1) observers expect that adopters are likely to have made profitable adoption decisions, and (2) adopters provide relevant information to observers. This logic often causes scholars to theorize that larger and more similar organizations have a greater influence on future adoption propensities. Larger organizations are thought to have more impact because observers expect them to have greater resources for identifying valuable practices and thus to make more profitable adoption decisions (Bikhchandani *et al*., 1998; Rogers, 1995). Similar organizations are expected to have more impact because observers expect them to provide more relevant information, particularly when the profitability of adoption varies with organizational characteristics (Baum *et al*., 2000; Greve, 1998).

We extend this line of reasoning by considering how expectations of variable profitability could influence the relative impact of observed adoption by smaller organizations. We theorize that if observers expect larger organizations to benefit more from using a practice (but are uncertain whether their own organization would benefit as well), adoption by a smaller organization will exert a greater stimulus on future adoption. Since observers expect smaller adopters to benefit less, observed adoption by a larger organization need not indicate that a smaller organization can profit as well. In contrast, adoption by a smaller organization provides (*ceteris paribus*) more convincing evidence. Thus, when observers expect larger adopters to benefit more, a smaller organization's decision to adopt can allow particularly useful insight on the value of adoption.

In essence, we propose that observers reason: 'If the managers in *that* (smaller) organization think that they can profit from adoption, I can assume that my organization will profit as well.' To refine our intuition, we used Bayesian analysis to develop a formal model of how adopters of different sizes might influence future adoption propensities (see Appendix). This model assumes that adoption is visible to other organizations, that managers in all organizations expect the value of adoption to increase with size, and that some organizations have private information about the value of adoption. The model confirms our intuition that under these conditions smaller organizations will have a greater effect on future adoption propensities.

Hypothesis 1: When the value of adoption increases with organizational size, a focal organization's adoption propensity will increase more following adoption by a smaller organization than it will following adoption by a larger organization.

It is important to stress that the direction of Hypothesis 1 is contingent on expectations of a positive relationship between the profitability of adoption and organizational size.[2] Such a positive relationship is not universal, but it has been frequently hypothesized and demonstrated empirically (Astebro, 2002; Cohen and Klepper, 1996; Sinclair, Klepper, and Cohen, 2000). Larger organizations are expected to profit more from adoption because they can (1) amortize fixed adoption costs or (2) achieve production efficiencies or market premiums over a larger number of units. Empirical studies confirm that smaller organizations frequently have difficulty profitably adopting practices in health insurance, human resource management, automation, and quality management (McGregor and Gomes, 1999; Scott *et al*., 1996). Using the survey *Manufacturing Technology 1988* from the U.S. Department of Commerce, Bureau of the Census, Current Industrial Reports, Dunne (1994) finds that the value of various technologies (ranging from flexible manufacturing systems to automatic storage and sensors) increases with organizational size. The common occurrence of a positive relationship between adoption value and size indicates the importance of research that explicitly considers how expectations of this relationship influence adoption processes.

The moderating effect of alternative sources of information

In the previous section, we extend theories of information-revealing adoption by suggesting that when the value of adopting a practice increases with organizational size, observation of smaller adopters can provide more information about the value of adopting. In an effort to further corroborate our argument, we next explore whether alternative sources of information moderate the influence of smaller adopters. If the influence of smaller adopters is indeed due to an information effect, it follows that alternative sources of information should reduce the influence of smaller adopters.

The preponderance of evidence suggests that information, as with most factors, exhibits diminishing returns, and that information from different sources usually act as partial substitutes (Arrow, 1974). Haunschild and Beckman (1998) argue that information from different sources tends to act as substitutes because the sources provide redundant information or cause information overload. In the context of foreign direct investment, Shaver, Mitchell, and Yeung (1997) also find that information sources act as substitutes so that organizations with prior investment experience gain relatively less from the information spillover created by other foreign entrants. Empirical studies in manufacturing and product development also have shown diminishing returns to information from different sources (Allen, 1995; Chase and Aquilano, 1992). Thus, in forming our hypotheses, we assume that information from different sources act predominantly as substitutes. Drawing on previous research, we identify two important alternative sources of information: local adopters and corporate information-gathering resources.

Research has demonstrated that information transfers more readily within the locale of an organization (Jaffe, Trajtenberg, and Henderson, 1993; Zucker, Darby, and Brewer, 1998). For example, Jaffe *et al*. (1993) used patent citations to demonstrate that innovators are likely to cite patents from geographically local sources. In the context of adoption processes, the notion of localized information spillovers implies that information about a practice should more easily disperse among organizations that are located in spatial proximity (Abrahamson and Rosenkopf, 1993; Knoke, 1982). Local adopters can provide detailed information about the circumstance and the rationale of adoption, thereby enabling observers to assess the value of adoption for their own organization. Through informal conversations among managers of local organizations, exchange of employees, or local networks of organizational relationships,

[2] Note, however, that the information effect from smaller adopters should be independent of whether or not every smaller adopter indeed made a profitable adoption choice. What matters is that observers believe that these adopters are not systematically mistaken.

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managers may also be able to gather information about *realized* costs and benefits among adopters (Darr, Argote, and Epple, 1995). Information about realized experiences may provide a powerful substitute to information inferred from observation of the mere fact of adoption.

Given the effectiveness of information diffusion within locales, we expect local adopters to diminish the influence of the information gained from observing smaller adopters, and we hypothesize:

> *Hypothesis 2: When the value of adoption increases with organizational size, adoption in the focal organization's locale reduces the effect of smaller adopters on the adoption propensity of the focal organization.*

Organizations vary in their ability to acquire information in order to identify and assess new opportunities. Some of these abilities reside within corporate development centers. One of the key roles of such centers is the identification and dissemination of information about valuable new practices (Lenox and King, 2004). Corporations also vary in their ability to engage outsiders or use information networks in finding and assessing new practices and technologies (Haunschild and Beckman, 1998). Cohen and Levinthal (1990) argue that this 'absorptive capacity' determines how well an organization can identify, assess, and acquire potentially valuable new practices.

Research suggests that organizational size provides a suitable proxy for information-gathering ability and activity. This is because size is closely related to investments in specialized knowledge activities. Haunschild and Beckman (1998) argue that corporate size is a suitable proxy for an organization's access to information because larger corporations tend to have greater slack (George, 2005) that can be used to employ boundary spanners and information acquisition personnel. In a similar vein, Dewar and Dutton (1986) find that larger organizations have more technical personnel who are better able to assess the suitability of new practices and technologies. The above discussion suggests that organizations that belong to larger corporations will have greater access to alternative information and thus be less influenced by the observation of smaller adopters. We expect:

> *Hypothesis 3: When the value of adoption increases with organizational size, the size of the corporation to which the focal organization belongs reduces the effect of smaller adopters on the adoption propensity of the focal organization.*

EMPIRICAL ANALYSIS

Research setting

Our study requires a setting in which adoption is observable and the value of adoption is positively related to organizational size. These constraints caused us to choose to explore certified adoption of the ISO 9000 quality management standard.[3] Certification with ISO 9000 allows organizations credibly to communicate to their customers attributes of their quality management system (Anderson, Daly, and Johnson, 1999). It allows us a way to ascertain that organizations have adopted a set of standardized practices for quality management. Since its creation in 1988, more than 500,000 organizations across the world have adopted ISO 9000 (ISO, 2003).

Empirical studies suggest that the cost of adopting ISO 9000 is relatively fixed and thus proportionally lower for larger organizations (e.g., Burg, 1997; SBRT, 1994). Research conducted by a team from several universities found that the average cost of certification for organizations in petrochemicals, for example, is about \$9 per thousand dollars of sales for organizations with sales volumes smaller than \$25 million, and \$1 per thousand dollars of sales for companies with sales volumes of \$25–100 million (Naveh *et al*., 1999). Similar patterns hold for organizations in six other industries investigated.

Research also suggests that per unit benefits from certification are either independent of or positively related to organizational size. The dominant finding is that larger organizations benefit more because certification provides a price premium (or sales winning benefit) across a larger number of products (Zuckerman, 1997). Studies suggest that this premium is an important motivation for and benefit from certification (Anderson *et al.*, 1999; Cole, 1998). Because per unit costs of ISO 9000 are smaller for large organizations, and per unit

[3] In this paper, we use interchangeably the terms 'adoption of' and 'certification with' ISO 9000.

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benefits are equal or larger, the expected net benefit from adopting ISO 9000 should be positively related to organizational size.

Empirical evidence reveals that managers in relevant industries share the expectation that the net benefit of adoption increases with an organization's size. In a survey on ISO 9000, managers reported that 'it is difficult for small companies to pay the costs associated with obtaining and maintaining registration'; ISO may be 'a good system but too involved for small companies'; 'maintaining a quality system compliant to ISO 9000 is still hard for a small company'; and finally, 'the cost to get ISO certified was very high considering we are a small company' (Naveh *et al*., 1999: 291–293). Other surveys revealed that managers felt that 'the benefit of the accreditation process is more easily seen in larger businesses', and that 'marketing and competitive advantages ... are outweighed for most small firms by the cost and administrative burden' (Sims, 1994: 14). Finally, a survey that directly measured expected benefits from ISO 9000 revealed that managers of large organizations expected greater financial gains from adoption than managers of medium- and small-sized companies (Sun and Cheng, 2002).

Sample

ISO 9000 is principally adopted by manufacturing facilities. Thus, our unit of analysis is adoption at U.S. facilities in industries with SIC codes between 2000 and 4000. We use several data sources to construct our sample, including the McGraw-Hill Directory of ISO 9000 certificates, the Dun and Bradstreet (D&B) database of all U.S. manufacturing facilities, the Toxic Release Inventory (TRI), data from the Bureau of Economic Analysis (BEA), and data from the U.S. Census Bureau. The sample is somewhat constrained by the characteristics of the TRI database. Facilities must report to the TRI if their manufacturing processes generate scrap above certain levels and if they have more than nine employees.

Our sample comprises 13,710 U.S. manufacturing facilities. Because we need information on previous adopters to perform our analysis, a facility enters our sample after the first adoption by any facility in that industry. Some facilities enter the sample in 1988, but 1993 is the average entry year. For all industries, our panel ends in 1999 (2000 for the dependent variable). Facilities exit the sample once they have adopted ISO 9000, or at the end of the panel. Because we wish to explore how observation of other adopters influences the focal facility's adoption decision, we need to have a certain number of facilities in each industry for such an observation process to be plausible. We therefore only consider industries that contain more than 20 facilities. We distinguish 178 industries on the four-digit SIC code level.

Measures

Dependent variable

We measure adoption with ISO 9000 as a binary variable that takes on a value of '1' if the organization certifies with ISO 9000 anytime between 1988 and 2000. Certification occurs at the facility level. In our sample, 3,112 facilities (23%) gain certification.

Independent variables

To test Hypothesis 1 and ensure the robustness of our findings, we employ three different operationalizations of our main construct. The need for multiple operationalizations is driven in part by the dynamic properties of our theory. We conjecture that adoption by smaller organizations provides information to managers in larger organizations about whether or not their organization should also adopt. Analyzing this effect over two periods is straightforward: we can simply analyze how the pattern of adopters in the first period influences adoption in the subsequent period. Analyzing adoption for more than two periods, however, requires us to make assumptions about how observers might be differentially influenced by adopters in the first period (who presumably adopted because of their private information) and adopters in the following periods (who might themselves have been influenced by earlier adopters). Our three approaches use different assumptions of this process and allow us to test the robustness of our analysis.

Our first approach assumes that managers are predominantly influenced by the initial adopters. We create a measure (*Smaller Adopter*) that captures the pattern of adoption in the first year of adoption in each industry. The measure is a binary variable that captures for each facility whether a smaller facility in the industry (four-digit SIC code) adopted ISO 9000 in the first year of adoption (see below for our measure of facility size). To compare the influence of smaller and larger initial adopters, we follow the equivalent procedure to create *Larger Adopter*. Operationalizing *Smaller Adopter* and *Larger Adopter* in this way has the advantage that the variables only capture adopters whose adoption decisions were driven by private information and decision making (as opposed to some imitation or updating rule). From the perspective of theories of information-revealing adoption, it should be these initial adopters from whom observers can best infer information about the profitability of adoption.

Our second approach uses a common heuristic for how organizations may be influenced by the information provided by previous adopters. The variable used in this approach, *Number Smaller Adopters*, captures for each facility and year the logged number of adopters in the facility's industry (four-digit SIC code) that are smaller than the focal facility. We employ a logged count of adopters because previous research has shown that inference processes often follow a log form[4] (Argote, Beckman, and Epple, 1990; Rao *et al*., 2001). The variable *Number Larger Adopters* captures for each facility and year the logged number of adopters in the facility's industry that are larger. Using the count of previous adopters has the advantage that it represents a common method for capturing the influence of previous adopters (Haunschild and Miner, 1997; Haveman, 1993; Kraatz, 1998; Rao *et al*., 2001), thereby making our analysis more comparable to existing research. This specification has, however, the disadvantage that it does not differentiate between the influences of previous adopters who acted based upon private information and those who were themselves influenced by observed adoption.

The third operationalization of our main independent variable (*Bayesian Inference*) uses Bayesian inference analysis to estimate precisely what inferences an uninformed but rational manager could make by observing previous adopters. Our Bayesian model assumes that all managers expect the value of adoption to increase with size, but only some managers have private information about the size necessary to make adoption profitable. Other managers have no information (diffuse priors) about this threshold value. Uninformed managers attempt to infer the threshold value by observing previous adopters and using Bayes' rule. This final operationalization of our main independent variable has the advantage of allowing a formal derivation of our construct (see Appendix) but it sacrifices intuitive clarity.[5]

We use two approaches to test whether adoption in an organization's locale moderates the effect of adoption by smaller organizations (Hypothesis 2). Both approaches assume that internal information about realized costs and benefits of adoption disperse to geographically local organizations and that this internal information is valuable to all observers, not just those of a particular size. The two approaches differ in the assumptions they make about the parametric form of the moderating effect of local adoption. *Adopter in MSA* is a binary variable that captures whether there is any adopter in the industry (four-digit SIC code) and local area (measured by Metropolitan Statistical Area or MSA). *Number Adopters in MSA* captures the logged number of adopters that are located in the focal facility's industry and MSA. Both variables are updated for each year.

MSAs are defined by the U.S. Census and represent large population nucleus (and adjacent communities) that have a high degree of economic and social integration (FIPS, 1995). Approximately 20 percent of U.S. counties are captured in MSAs. Because most facilities in our sample are located in metropolitan areas, we are able to identify a Census-defined MSA for 75 percent of our facilities. For facilities whose zip code cannot be linked to an identifiable MSA, we assume that they are located in areas not captured as an MSA. For each of these facilities, we create a unique MSA, reflecting that these facilities do not belong to a local collective that has economic and social ties. For our measures, we only capture those facilities in the MSA that are also in the focal facility's industry because the exact relationship between size and value of adoption may be industry specific. A meat-processing plant with more than 20 employees, for example, may find adoption of ISO 9000 profitable, while the size threshold may be much

[4] As discussed later in the paper, we conducted robustness tests using other parameter specifications.

[5] Because the Bayesian inference process implicitly considers the potential influence of larger adopters, testing Hypothesis 1 using *Bayesian Inference* does not require including a separate measure of larger adopters.

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higher for a chemical manufacturer. As a result, even within an MSA, observers should find industry internal adoption to be the most informative. We capture previous local adopters irrespective of their size because we argue that spatial proximity enhances information flow such that observers learn not only about the fact of adoption but also about realized costs and benefits. Such internal information should provide sufficient details for observers to find the information useful irrespective of the size of the information sender.[6] To test the robustness of our spatial specification, we used an alternative measure of local area as the 50-mile area surrounding each facility. We obtained results that confirmed the interpretation of those reported.

We use *Corporate Size* to test Hypothesis 3. We capture corporate size as the number of facilities belonging to a corporation in each year. To test the robustness of this variable, we also measured corporate size as the logged sum of total employees of all facilities belonging to a corporation in each year. These two variables are correlated at 84 percent and generate results that are substantially the same. We chose to use the number of facilities in our reported results because the variability of labor intensity across our different industries may confound use of total corporate employees as an accurate measure of relative corporate size. Furthermore, in the context of our study, the number of facilities might be the more appropriate measure of corporate size because we examine adoption of ISO 9000 at the facility level.

Control variables

Alternative mimetic and normative processes, coercive pressures, and desires for operational improvement could shape ISO 9000 adoption decisions (Cole, 1998; Guler, Guillen, and MacPherson, 2002; Uzumeri, 1997). We use control variables to capture the influence of these factors.

Two variables control for the influence of alternative mimetic processes: peer pressure and the degree of certification within each industry. We capture peer pressure by controlling for the potential influence of similarly sized adopters on mimetic adoption. Specifically, we construct *Peer Pressure* to estimate the extent to which adoption of ISO 9000 is more common among facilities of similar size to the focal facility. Using the total number of adopters in industry j and year t, we calculate a constant density function ($\phi(z_{jt}) = \alpha$) for adoption. We then estimate a function of observed density ($o(z_{jt})$) as a function of facility size in that industry and year (z_{jt}). When $o(z_{jt}) > \alpha$, it means that in industry j in year t facilities of approximately size z appear to have a greater than average tendency to adopt. We create a normalized measure of this tendency ($\gamma(z_{jt})$) by subtracting and dividing by the average adoption propensity α:

$$\gamma(z_{jt}) = \frac{o(z_{jt}) - \alpha}{\alpha} \tag{1}$$

Theories of peer influence speculate that facilities are more likely to be influenced by more similar others, but the functional form of this similarity has not been fully specified. For our analysis, we give it an inverse proportional form. Thus, for a facility i of size x in year t, the formula for peer group pressure can be written:

$$\text{Peer Group Pressure}_{it} = \int_0^{\infty} \frac{\gamma(z_{jt})}{(1 + |z_{jt} - x_{it}|)} \tag{2}$$

As desired, the behavior of more similar organizations will have a disproportionate effect on this measure. As z approaches x, the denominator approaches 1 and the effect of peers approaches $\gamma(z_{jt})$. As z moves away from x, the effect of other organizations on the focal organization decreases as an inverse function of the difference in their size.

Our second control variable for mimetic adoption captures the possibility that the sheer number of previous adopters shapes adoption propensities (Haunschild and Miner, 1997; Rosenkopf and Abrahamson, 1999). We measure *Industry Certification* as the annual percentage of certified facilities in each four-digit SIC code.

Industry associations may exert normative pressures for adoption. For example, the Aerospace Industries Association influenced the diffusion of ISO 9000 among U.S. airframe and jet engine companies (Velocci, 1999) and the Chemical Industries

[6] To test the robustness of this argument, we also tested the effects of (i) a smaller adopter and (ii) the number of smaller adopters in the focal facility's MSA and industry. Consistent with our hypotheses, we found that both a smaller adopter and a greater number of smaller adopters in the same MSA and industry significantly reduced the information effect of a smaller adopter(s) on the focal organization's adoption propensity. Detailed results of this analysis are available from the authors upon request.

Associations in the U.K., Germany, and France were instrumental in the diffusion of ISO 9000 in the European chemical sectors (Chynoweth and Roberts, 1992). Yet not every industry association is equally active—in fact, budgets, staff, and committee activities vary greatly across associations (Barnett, 2006; Barnett, Mischke, and Ocasio, 2000). To capture the potential influence of industry association activity, we create *Association Pressure*. This variable measures the logged ratio of an industry association's expenses per association member.[7] Data for industry association expenses were taken from the Urban Institute, which makes available data collected on Form 990 by the Internal Revenue Service. Data for industry association membership were taken from the 2002 Encyclopedia of Associations Database provided by Thomson Gale, Gale Research Co., Detroit, Michigan, U.S.A.[8] Each industry association indicates a primary SIC code, and we use this SIC code to match facility and association data. Because association data are available for only 90 manufacturing SIC codes at the four-digit level, we fill in missing values by calculating the median value of *Association Pressure* at the three-digit SIC code level.

To account for the effect of coercive pressures, we calculate two supply chain variables. First, *Supply Chain Pressure* captures pressure to adopt from downstream supply chain partners in the United States. These pressures are particularly strong when supply chain partners are themselves certified (Uzumeri, 1997). *Supply Chain Pressure* thus measures for each year and SIC code the probability that a facility from that SIC code sells its outputs to an ISO certified buyer. To trace supplier relationships among industries, we transform the Input–Output codes from the BEA into four-digit SIC codes and convert the Input–Output tables into 'Sell-to and Buy-from' tables.

Coercive pressures for adoption may also originate from foreign buyers. Buyers that are located outside of the United States have greater difficulty accessing information about U.S. suppliers and thus find it harder to assess their quality (Caves, 1996). To overcome this problem of asymmetric information, foreign buyers may request suppliers to be ISO 9000 certified. In fact, many companies in the United States perceive ISO 9000 certification to be a prerequisite for exporting into Europe (Mendel, 2002; Uzumeri, 1997). To capture this coercive effect, we use export data from the Census Bureau of Foreign Trade and create *Supply to Foreign*. This variable measures the percentage of shipments that is exported for each four-digit SIC code and year. We tested for the effect of varying export destinations (e.g., Europe vs. Asia) but did not find differential effects for different export destinations.

We also control for the effect of facility-level variables. Controlling for a facility's size and operational performance is important since the value of adoption is expected to vary with organizational size and because some facilities may adopt ISO 9000 to improve their operations (Cole, 1998). We measure *Relative Facility Size* as the log of the number of employees employed in each facility in each year. Owing to the industry-level differences in labor intensity mentioned above, we normalize this variable by industry and year. We measure operational performance by using government-mandated data to estimate scrap rates for public and private facilities. To create *Operational Performance*, we calculate the difference between the observed level of scrap generated by the facility and the expected level for a facility of that size in that industry in that year (King and Lenox, 2000). Specifically, separately for each year and industry, we regress the log of scrap generation on *Facility Size* and the squared term of *Facility Size*. The residual of this regression (normalized by its standard error) provides an assessment of the facility's performance relative to its industry in that year. Facilities with positive residuals generated more scrap than expected given their size. We reverse the sign of this measure because relatively more scrap is evidence of lower operational performance.

Finally, we include industry and year dummies in our analysis. It is possible that larger diffusion patterns affect how adoption hazards change with time. To address the temporal elements of this concern in a nonparametric way, we include *Year Fixed Effects*. It is also possible that unobserved industry differences could confound our results. To account for this, we include *Industry Fixed Effects* (at the three-digit SIC code level). We present the descriptive statistics of our variables and a correlation table in Tables 1 and 2.

[7] An alternative specification with expenses per industry member yields confirmatory results.

[8] We would like to thank Michael Barnett from the University of South Florida for collecting and manipulating all association-related data, and for generously sharing these data with us.

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Table 1. Descriptive statistics

Variable	Mean	S.D.	Min.	Max.
1 Smaller Adopter	0.47	0.50	0.00	1.00
2 Number Smaller Adopters	1.32	1.21	0.00	5.26
3 Bayesian Inference	0.84	0.30	0.01	1.00
4 Larger Adopter	0.87	0.34	0.00	1.00
5 Number Larger Adopters	1.99	1.29	0.00	5.26
6 Number Adopters in MSA	0.30	0.63	0.00	5.01
7 Adopter in MSA	0.16	0.36	0.00	1.00
8 Corporate Size	1.71	1.56	0.00	5.76
9 Peer Pressure	−0.08	0.55	−2.51	2.84
10 Industry Certification	0.06	0.08	0.00	0.73
11 Association Pressure	9.75	1.40	7.31	13.45
12 Supply Chain Pressure	0.04	0.04	0.00	0.23
13 Supply to Foreign	0.04	0.04	0.00	0.55
14 Relative Facility Size[a]	−0.06	0.99	−5.51	5.37
15 Operational Performance[a]	0.02	1.01	−4.35	6.43

$N = 66,520$.
Year variables omitted from table.
[a] Variable values are normalized. Note that the means of these normalized variables do not perfectly equal zero. This is because we calculated the summary statistics considering only facilities until they adopt (once a facility adopts, it no longer is part of the risk set). For the normalization process, however, we used the entire sample.

Analysis

We use a logistic regression to perform the statistical tests of our theory. The model is specified as:

$$P_{it+1} = F(Z) = F(\mathbf{b}\mathbf{X}_{it}) = e_{it}^{(Z)}/(1 + e_{it}^{(Z)})$$

where P is the probability that facility i will adopt ISO 9000 in the next period ($t + 1$). The vector $\mathbf{X}_{it}$ represents the characteristics of the ith facility in period t. Once a facility adopts, it is no longer at risk for adoption and is removed from the sample. We also add a random-effect term to the analysis to partially correct for unobserved facility differences. We use a random- rather than a fixed-effect specification because the fixed-effect model would disregard all observations that do not adopt ISO 9000 within our panel. Furthermore, a fixed-effect specification would prohibit the interpretation of any variables with values that do not vary across groups. The drawback of the random-effect specification is that it assumes facility heterogeneity that is randomly distributed across facilities. To investigate the robustness of our estimations to violations of this assumption, we specified a reduced model that included facility fixed effects. For our main effect, we found confirming evidence for our findings.

Results

Table 3 reports the results of our statistical analysis. Considering first the effect of our control variables, we find that adoption propensities increase with corporate size. With respect to normative and coercive pressures for adoption, we find that peer pressure, association pressure, supply chain pressure, and supplying to foreign buyers all increase adoption propensities. The degree of industry certification does not significantly affect adoption propensities in most models. However, this variable becomes strongly significant if we exclude the industry fixed effects, indicating that adoption trends may be industry specific. With respect to the influence of facility attributes, we find that greater relative facility size increases adoption propensities. This finding may represent confirmation that the net benefit of adoption increases with size. Below-average operational performance also increases adoption propensities, possibly indicating that facilities with inferior performance seek ISO 9000 in order to improve their performance.

Turning to the hypothesized impact of smaller adopters (Hypothesis 1), we find evidence that facilities have an increased tendency to adopt ISO 9000 if they are larger than an adopter in the initial year of adoption (Models 1 and 2), if there is a greater number of smaller facilities that have adopted (Models 3 and 4), and if Bayesian inference would predict that they are large enough to adopt profitably (Models 5 and 6). Using Model 1 to assess the economic impact of our independent variable, we find that initial adoption by smaller organizations increases the adoption propensity of an average facility from a 0.23 percent chance of adoption per year to a 0.45 percent chance. For the entire 10-year panel period, this implies that smaller initial adopters almost double future adoption propensities from 2.3 percent to 4.5 percent.

To fully test Hypothesis 1, we need to compare the effect of smaller adopters with that of larger adopters. Models 1–4 indicate that larger adopters exert a statistically significant influence, but one that is comparably weaker than that exerted by smaller adopters. For Models 1 and 2, a t-test reveals that the effect of smaller initial adopters is significantly stronger than that of larger initial adopters ($p < 0.05$). Similarly, for Models 3

Table 2. Correlation table

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Smaller Adopter	1.00														
2 Number Smaller Adopters	0.34	1.00													
3 Bayesian Inference	0.40	0.58	1.00												
4 Larger Adopter	−0.41	−0.12	−0.21	1.00											
5 Number Larger Adopters	−0.24	0.45	0.21	0.41	1.00										
6 Number Adopters in MSA	−0.01	0.39	0.17	0.06	0.39	1.00									
7 Adopter in MSA	−0.01	0.31	0.15	0.05	0.32	0.74	1.00								
8 Corporate Size	0.16	0.12	0.10	−0.14	−0.14	−0.01	0.00	1.00							
9 Peer Pressure	0.30	0.30	0.06	−0.11	−0.33	−0.04	−0.03	0.15	1.00						
10 Industry Certification	0.04	0.57	0.25	0.10	0.59	0.36	0.25	0.04	−0.13	1.00					
11 Association Pressure	−0.05	0.07	0.02	0.10	0.12	0.03	0.06	0.08	−0.04	0.11	1.00				
12 Supply Chain Pressure	0.02	0.58	0.30	0.06	0.60	0.37	0.28	−0.06	−0.11	0.73	0.12	1.00			
13 Supply to Foreign	0.05	0.11	0.07	−0.11	0.08	0.08	0.06	0.12	−0.05	0.20	0.19	0.06	1.00		
14 Relative Facility Size	0.53	0.47	0.53	−0.44	−0.37	0.00	0.00	0.25	0.49	−0.04	−0.01	−0.04	−0.01	1.00	
15 Operational Performance	0.00	0.01	0.02	0.00	0.01	0.00	0.00	−0.06	−0.01	0.01	0.00	0.01	0.00	0.01	1.00

N = 66,520.
Year variables omitted from table.

Table 3. Model results

	Model 1[a]	Model 2[a]	Model 3[b]	Model 4[b]	Model 5[c]	Model 6[c]
Independent Variable (IV)	0.477***	0.458***	0.563***	0.542***	1.204***	1.233***
	(0.087)	(0.086)	(0.055)	(0.054)	(0.184)	(0.185)
Larger Adopter/Number Larger Adopters	0.194*	0.191*	0.171***	0.174***		
	(0.082)	(0.083)	(0.041)	(0.041)		
IV × Number Adopters in MSA	−0.145*		−0.119***		−0.353	
	(0.063)		(0.028)		(0.206)	
IV × Adopter in MSA		−0.164		−0.157**		−0.804**
		(0.110)		(0.047)		(0.294)
IV × Corporate Size	−0.120***	−0.120***	−0.086***	−0.087***	−0.170*	−0.173*
	(0.030)	(0.030)	(0.012)	(0.012)	(0.069)	(0.069)
Number Adopters in MSA	0.171**		0.319***		0.413*	
	(0.051)		(0.083)		(0.203)	
Adopter in MSA		0.358***		0.510***		1.010***
		(0.085)		(0.124)		(0.287)
Corporate Size	0.177***	0.177***	0.281***	0.283***	0.261***	0.264***
	(0.025)	(0.025)	(0.030)	(0.029)	(0.065)	(0.065)
Peer Pressure	0.205***	0.201***	0.160**	0.154**	0.288***	0.286***
	(0.045)	(0.045)	(0.049)	(0.048)	(0.045)	(0.045)
Industry Certification	−0.181	−0.189	−1.299*	−1.427**	0.021	0.037
	(0.475)	(0.473)	(0.530)	(0.531)	(0.465)	(0.462)
Association Pressure	0.243***	0.234***	0.122	0.126	0.218**	0.209**
	(0.066)	(0.066)	(0.070)	(0.069)	(0.065)	(0.065)
Supply Chain Pressure	7.714***	7.526***	6.079***	5.993***	7.029***	6.880***
	(1.550)	(1.552)	(1.629)	(1.630)	(1.533)	(1.533)
Supply to Foreign	2.439***	2.386**	1.881**	1.849*	1.861**	1.771**
	(0.685)	(0.688)	(0.728)	(0.728)	(0.661)	(0.661)
Relative Facility Size	0.306***	0.307***	0.226***	0.233***	0.199***	0.200***
	(0.037)	(0.037)	(0.049)	(0.049)	(0.035)	(0.035)
Operational Performance	−0.118***	−0.118***	−0.126***	−0.126***	−0.118***	−0.118***
	(0.024)	(0.024)	(0.025)	(0.025)	(0.024)	(0.024)
Year and Ind. Fixed Effects	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Log Likelihood	−11322.36	−11316.71	−11219.08	−11220.3	−11314.71	−11306.27
Chi-square (d.f.)	1847.9 (75)	1859.2 (75)	2054.4 (75)	2051.9 (75)	1863.1 (74)	1880.1 (74)

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$. All tests are two-tailed.
Number of observations = 66,520. Number of facilities = 13,710.
Constant omitted from table due to inclusion of industry and year dummies.
[a] The independent variable in Models 1 and 2 is the binary variable ‘Smaller Adopter.’ Models 1 and 2 use the binary variable ‘Larger Adopter.’
[b] The independent variable in Models 3 and 4 is the count variable ‘Number Smaller Adopters.’ Models 3 and 4 use the count variable ‘Number Larger Adopters.’
[c] The independent variable in Models 5 and 6 is the inference variable ‘Bayesian Inference.’

and 4, we find that a greater number of smaller adopters has a significantly stronger effect than a greater number of larger adopters ($p < 0.001$). For Models 5 and 6, such a comparative analysis is unnecessary because our specification of *Bayesian Inference* represents a test of a predicted functional form for the relative effect of smaller and larger adopters. Thus, across all models, we find consistent support for the hypothesis that smaller adopters exert a comparably stronger influence on future adoption than larger adopters.

Given that our theory suggests that smaller adopters provide more useful information, what might drive the significant effect of larger adopters? It is possible that our measures of larger adopters capture some industry-level adoption propensities. The tendency of *Industry Certification* to gain significance as we remove *Larger Adopters* supports this explanation. It also is possible that a larger adopter spuriously picks up the information effect that was initiated by a smaller adopter. For example, consider a case in which a small adopter triggers adoption by a large facility in $t+1$ and adoption by a medium-sized facility in $t+2$. Here, the medium-sized facility seems influenced by both the small and the large adopter, but the measured effect of the large adopter would be a spurious result. That said, the influence of larger adopters may well also represent evidence of a value-enhancing bandwagon that, albeit with a comparably weaker effect, may work in tandem with the information-revealing bandwagon as larger adopters influence the perceived legitimacy of the practice.

Turning to Hypothesis 2, we find some evidence that adoption within the organization's locale moderates the information effect of smaller adopters. Across two of the three specifications, we find significant evidence that adoption by a nearby organization in the same industry reduces the importance of smaller adopters on future adoption propensities (Models 4 and 6). Likewise, more adopters in the facility's MSA reduce the information effect of a smaller initial adopter (Model 1) as well as that of more numerous smaller adopters (Model 3). A single local adopter does not, however, significantly reduce the information effect from a smaller initial adopter (Model 2), and more local adopters do not reduce the information effect from the Bayesian inference process (Model 5). We surmise that this weakness in our findings may be partially caused by the tendency of industries to cluster. The resulting correlation among industry and location variables may have expanded our standard error estimates.

We find consistent support for Hypothesis 3. Across all of our specifications, we find that facilities that are part of larger corporations are less influenced by smaller adopters. This result is consistent with the notion that larger organizations have better access to information about new practices such that facilities belonging to large organizations are less dependent on information inferred from observed adoption.

The chi-squares for all models indicate good model fits. Note, though, that the models are not nested and that a cross-model comparison of this fit criterion therefore would be misleading.

Robustness and specification analysis

To test the robustness of our analysis and to further explore its meaning, we investigated numerous alternative specifications. First, we relaxed the log odds specification of our logistic analysis and instead used a nonparametric partial-likelihood Cox regression. We obtained results for the hypothesized relationships that were consistent in sign and significance to those shown.

Second, we investigated whether or not our measure of the effect of smaller adopters might be confounded with the effect of general adoption. The concern is that as we observe more adopters, the probability of observing smaller adopters could increase even if adoption occurred randomly. This is because the more adopters we randomly 'draw' in one industry, the greater the variance in their size, and thus the greater the probability of drawing a small adopter in this industry. Thus, with more adopters, we should expect the smallest adopter to be relatively smaller, causing our independent variables to increase in value. To address this concern, we calculated the expected smallest adopter given the observed number of adopters in each industry and year (i.e., the first-order statistic), and created a dummy variable that takes a value of '1' if the size of the focal organization is above the size of the expected smallest adopter. The effect of this variable is insignificant when included in our analysis, and does not change the sign or significance of the reported results.

Third, we used Monte Carlo simulation to test whether or not failure on the part of managers to observe all adopters might influence our analysis. We performed this test for our *Baysian Inference* variable and describe it in more detail in the Appendix. We find that our results are robust as long as observers do not overlook more than 50 percent of the actual adopters.

Fourth, we explored the sensitivity of our analyses in Models 3 and 4 to the log specification of the impact of previous smaller adopters. We substituted two variables, the number of smaller adopters and the squared number of smaller adopters, and obtained similar results.[9]

We conducted a final robustness test to ensure that our analysis is capturing the effect of smaller adopters on observers in other facilities and not their effect on our estimation. Put differently, we wanted to rule out the possibility that a pre-existing size threshold existed and that we (the authors of this article) were simply learning about this

[9] For both Model 3 and Model 4, the coefficient of the main effect equals 0.034 ($p < 0.001$) and the coefficient for the square term equals -0.0003 ($p < 0.001$).

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threshold by observing successive adoption. To test this, we created for each industry the final Bayesian estimate of the size threshold based on all adoption in that industry up to the final period. We then included this estimate as a constant variable for all years. Including this variable in Models 5 and 6 did not change the sign or significance of the coefficient for our main independent variable, but it did reduce the significance of our interaction terms. This loss of significance may be caused by the expansion of the standard errors caused by the multicollinearity between our independent variable and the measure of the final size threshold used in the robustness test.

DISCUSSION

We extend theories of information-revealing adoption to analyze a case in which smaller adopters have an unusual and disproportionate influence on future adoption propensities. We empirically explore the adoption of ISO 9000—a setting that meets our case conditions—and find evidence that smaller adopters have a greater effect on future adoption propensities than larger ones. Moreover, we further validate our theory that observation of smaller adopters allows insight into the value of adoption by showing that access to other information sources reduces the effect of smaller adopters. Specifically, we find moderate evidence that access to information from spatially proximate adopters moderates the effect of smaller adopters. We also find that corporate size reduces the influence of smaller adopters. We suggest that this is because larger corporations have more resources to gather and disseminate information about new practices within the organization. The combined evidence provided by our main and ancillary predictions provides support for our theory.

Why do our findings differ from the preponderance of previous research? One explanation is that we purposely chose a setting that meets our conditions and where we therefore expected such an outcome: specifically, a setting where adoption is a visible act (because it is publicly certified) and actors expect the value of adoption to increase with organizational size. The contexts in which previous studies were conducted may not have fulfilled these conditions. Haunschild and Miner (1997), for example, explore adoption bandwagons in the context of investment banker choices for acquisitions and find that larger companies strongly influenced the choices of others. Baum *et al*. (2000) find that larger firms' location choices for chain acquisitions can sometimes set off bandwagons. In both of these empirical contexts, it is not clear that the value of adoption increases with organizational size, and smaller adopters may therefore have had little influence.

Another explanation is that the existence of published registries of ISO 9000 adopters may have reduced the relative visibility of larger adopters. Specifically, to the degree that previous studies found larger adopters to be more influential because of their greater visibility, this visibility effect may have been less pronounced in our context because published registries provide information on certified organizations of all sizes.

A principal implication of our study is that settings exist where theories of value-enhancing and information-revealing adoption make contradictory predictions. By analyzing these different settings, scholars may be better able to understand the mechanisms and import of the two theories. Do our findings suggest that information-revealing bandwagon processes are always more important than value-enhancing ones? Not at all. We may have considered a case in which previous adoption provides little change in the value of the practice and thus legitimacy concerns are relatively less important. ISO 9000 was widely considered to be legitimate from its very inception. ISO 9000 was created by the International Organization for Standardization in Geneva, which infused the standard with legitimacy. As a result, the size or status of previous adopters may not increase substantially the legitimacy of the standard. Moreover, our empirical approach may have underestimated legitimacy effects by only exploring *intra*-industry adoption processes of ISO 9000.[10]

Findings from at least one previous study are in line with ours and suggest that our results are not an isolated case. In a study of bandwagon effects in curriculum changes, Kraatz (1998) finds that larger previous adopters negatively affected program adoption and suggests that 'the legitimacy or status concerns at the heart of much theorizing on interorganizational imitation are not critical to program diffusion in the present context' (Kraatz, 1998: 632). One explanation for this finding is that

[10] We thank an anonymous reviewer for pointing out these explanations.

the substantial organizational changes associated with curriculum modifications caused colleges to consider primarily whether these modifications fit the colleges' existing operations, thereby making legitimacy considerations a secondary issue. As a result, similar adopters, rather than larger ones, may have been more influential. Interpreted from the perspective of our study, it also is possible that curriculum changes provided greater value to larger institutions, which would have decreased the influence of large adopters on subsequent adoption.

We believe that our findings (and those discussed above) suggest the need for more research on how conditions in adoption environments (e.g., managerial expectations, observability, initial legitimacy) affect the relative influence of different types of organizations. In conducting such research, scholars may benefit by identifying contexts that allow comparison of various theories. Our results suggest that multiple forces are often at play, and that scholarship should consider the contingencies that affect their relative strength and direction.

Our study opens some interesting avenues for future research. In this study, we have assumed that managers do not *systematically* misjudge the value of adoption. In future research, we hope to explore cases where the reliability of the information from previous adopters varies systematically as a function of different organizational and industry-level attributes.

Future research could also investigate patterns in abandonment subsequent to adoption. Rao *et al.* (2001) find that inference from a greater number of previous adopters causes systematic overestimation of adoption profitability and leads to subsequent abandonment. While our theory allows for such a process, we do not specifically address it in this study. A theoretical and empirical exploration of the conditions for systematically unprofitable adoption (and resulting abandonment of the adopted practice) would represent a substantial contribution to scholarship.

Need for further research also exists with respect to the moderating effect of additional information sources. We have argued that corporate size reduces the effect of observed adoption because larger corporations have the resources to provide their facilities with information about new practices. Using the number of facilities as a measure of corporate size, we found evidence for such a moderating effect in this study. However, we did not explore whether the degree to which corporations are diversified (i.e., have facilities in different industries) influences facility adoption behavior. It is conceivable that highly focused corporations use the information from observed within-industry adoption differently than broadly diversified corporations.

Insight on information-revealing bandwagons could furthermore be gained from direct measurement of managerial expectations about variations in the practice's profitability. For the purpose of this study, we chose a context in which previous studies had identified managerial expectations that matched the conditions of our theory, and we found that adoption behavior was consistent with stipulated expectations. However, when testing the applicability of our theory in other contexts, a direct measure of managerial expectations might allow a more differentiated view of the relationship between profitability expectations and adoption behaviors.

Finally, additional insights might be gained by testing our ideas across different adoption processes. Our study does consider the adoption process of ISO 9000 within multiple industries, and thus provides evidence that our ideas have explanatory power in different settings (so long as they meet the assumptions of our theory). However, our study only considers adoption of one practice, and thus care should be taken in extrapolating to adoption of different types of practices. In future research, we hope to explore our ideas in other empirical settings.

For practitioners, our study has important implications. In today's dynamic competitive landscapes, organizations must gather information from a variety of sources. Observation of others represents one important learning path to competitive advantage. Yet attention is a scarce resource, requiring managers to allocate carefully their consideration where it can be used best. While previous studies have emphasized the value of observing more salient or larger organizations, our study suggests that under some conditions managers should allocate more of their attention to the activities of smaller, less prominent organizations.

CONCLUSION

In this article, we contribute to theories of adoption bandwagons by investigating a case in which theories of information-revealing adoption predict that smaller organizations will have a stronger effect on future adoption than larger ones. Exploring this case proves valuable because it allows a means of distinguishing whether previous adopters spur bandwagons by revealing information about the value of adoption or by increasing the value of adoption. We argue and find evidence that when the profitability of a practice increases with organizational size—a relatively common case—smaller adopters, rather than larger ones, may have a greater influence on future adoption propensities because they allow observers better to infer that adoption will be profitable for their own organization. In support of this information story, we find that alternative information sources moderate the effect of smaller adopters.

We hope that our findings will encourage future research to advance further theories of adoption processes by exploring the effect of managerial beliefs on adoption patterns and by investigating the differences in the mechanisms underlying various bandwagons.

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APPENDIX

This Appendix provides a formal model of a bandwagon process that matches the one hypothesized in this paper. It also clarifies how we constructed our measure of *Bayesian Inference* and how we conducted robustness testing on this approach.

The model

Managers of facilities in an industry believe that the value of adoption varies with some attribute θ. In our specific example, θ is facility size. Managers also assume that there is a value of θ above which benefits exceed costs ($B(\theta) > C(\theta)$) and below which they do not. We call this value of θ the 'separating level' S_θ and index it with industry j. We assume that of the N facilities in the industry, some have diffuse priors for S_{θ_j} and some have private information about benefits and costs and know whether their facility i in industry j can profitability adopt ($B_j(\theta_i) > C_j(\theta_i)$). This private information is distributed among facilities in the industry so that each facility has a chance p of having such information. We also assume that facilities observe adopters once a year (for example, when McGraw-Hill publishes its updated data on adopters). We assume that facilities adopt when the probability of $B_j(\theta_i) > C_j(\theta_i)$ exceeds a threshold level ϕ_{ijt}. We assume, however, that not all facilities adopt immediately, because random differences in organizational schedules or contingencies cause managers to delay adopting even though $P(B_j(\theta_i) > C_j(\theta_i)_t) > \phi_{ijt}$.

In the first period, facilities with private information know the value of $B_j(\theta_i)$ and $C_j(\theta_i)$, and thus $P(B_j(\theta_i) > C_j(\theta_i)) = 0$ or 1. Other facilities have no information about benefits and costs and learn about them by observing previous adopters. Thus, in the first year of adoption in the industry ($t = 1$), only facilities with private information adopt. Facilities without private information observe these adopters at the end of the year and use Bayes' rule to update their inference.

For each industry j in year $t = 2$ with $\omega = 1$ to M possible facility-separating levels, Bayes' rule would predict that

$$P(S_{wj}|\{\gamma_{j1}\}) = \frac{P(\{\gamma_{j1}\}|S_{\omega j})P(S_{\omega j})}{\sum_{\omega=1}^{M} P(\{\gamma_{j1}\}|S_{\omega j})P(S_{\omega j})} \qquad (1)$$

with

$S_{\omega j}$ = separating level is at size ω in industry j $(B(\theta)_j > C(\theta)_j)$;
$\{\gamma_{jt}\}$ = set of observed adopters in industry j in year 1.

The probability that the focal facility is larger than the eventual smallest adopter (e.g., above the separating level) in industry j is

$$P(\theta_{\text{ij}} > S_{\omega j}) = \sum_{w<\theta_{\text{ij}}} P(S_{\omega j}|\{\gamma_j\}) \qquad (2)$$

where θ_i = size of the focal facility i and $P(\theta_{\text{ij}} > S_{\omega j})$ represents Bayes' estimation; i.e., it reflects the estimation of the focal facility $P(B_{ij} > C_{ij})$.

In years after the first ones, the inference process for non-adopters becomes slightly more complicated because any adopter may have private information (in which case its actions provide new information about the value of adoption) or it may be adopting based on its own inference from observing previous adopters (in which case its actions provide no new information). Since it is unlikely that managers know a priori the distribution of private information p, we assume that they must use observed behaviors to estimate whether observed adopters have private information. Because managers can estimate the information provided by previous adopters, they can also estimate the degree to which other managers could make such an inference. The probability that any observed adopter has private information is the probability that it is not adopting based on inferred information. For a facility of size θ in industry j observed adopting in year t, the probability that it has private information $= 1 - P(\theta_{\mathrm{ijt}-1} > S_{\omega j-1})$. In other words, it is the probability that it could not infer that $P(B_j(\theta_i) > C_j(\theta_i))$ given the information it had in the period before it adopted $(t-1)$.

Calculation

Programs were created in the C programming language to estimate $P(B_j(\theta_i) > C_j(\theta_i)$ for each facility, industry, and year. To simplify calculation each industry was discretized into 40 size levels (ω) that spanned all observed sizes for the industry. The size of the observing facility was updated for each year, but the size of the adopting facilities was held constant at their size in the year of adoption.

Robustness testing

To ensure the robustness of our system, we constructed the measure using different assumptions. We assumed that (a) all adopters were observed, (b) 90 percent were observed, (c) 75 percent were observed, and (d) 50 percent were observed. We also assumed that (i) observers knew the size of all adopters, and (ii) observers estimated the size of adopters with a normally distributed error ε. This error was set at $0.25s$, $0.5s$, and s, where s is the measured standard deviation for the size of our sample of facilities in that industry in that year. Robustness tests confirm sign and significance consistency for observed adoption $>$50 percent and for size error estimation $\leq$0.5 s.

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DISCUSSION PAPER

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Evaluating Voluntary Climate Programs in the US

Richard Morgenstern, William A. Pizer, and Jhih-Shyang Shih

1616 P St. NW
Washington, DC 20036
202-328-5000 www.rff.org

RESOURCES FOR THE FUTURE

Evaluating Voluntary Climate Programs in the US

Richard Morgenstern, William A. Pizer, and Jhih-Shyang Shih

Abstract

Voluntary programs are playing an increasingly important role in environmental management. Despite their growing importance, however, they have been subject to limited evaluation. As is well known, program evaluation in the absence of randomized experiments is difficult because the decision to participate may not be random and, in particular, may be correlated with the outcomes. The present research is designed to overcome these problems by measuring the environmental effectiveness of two voluntary climate change programs -- EPA's Climate Wise program,and DOE's Voluntary Reporting of Greenhouse Gases Program, 1605(b) -- with particular attention to the participation decision and how various assumptions affect estimates of program effects. For both programs, the analysis focuses on manufacturing firms and uses confidential Census data to create a comparison group as well as measure outcomes (expenditures on fuel and electricity).

Overall, we find that that the effects from Climate Wise and 1605(b) on fuel and electricity expenditures are no more than 10% and likely less than 5%. There is virtually no evidence of a statistically significant effect of either Climate Wise or 1605(b) on fuel costs. There is some statistically significant evidence that participation in Climate Wise led to a slight (3-5%) increase in electricity costs that vanishes after two years. There is also some statistically significant evidence that participation in 1605(b) led to a slight (4-8%) decrease in electricity costs that persists for at least three years.

Key Words:

JEL Classification Numbers:

Contents

Evaluating Voluntary Climate Programs in the US

Richard Morgenstern, William A. Pizer, and Jhih-Shyang Shih*

Introduction

Voluntary programs have been a key part of U.S. climate change policy since the early 1990s. Such programs figured prominently in President Bush's 2002 climate change policy announcement, referencing recent agreements with the semi-conductor and aluminum industries and leading to the creation of the Climate Leaders and Climate Vision programs (White House 2002, 2005). They were also the centerpiece of President Clinton's 1993 Climate Change Action Plan, which included Energy Star, Rebuild America, Green Lights, Motor Challenge, the Voluntary Reporting of Greenhouse Gases Program (required under Section 1605(b) of the Energy Policy Act of 1992), and Climate Wise. In fact, a number of these programs were initiated in the George W. Bush Administration. A 2005 survey identified 87 voluntary programs at the U.S. Environmental Protection Agency (EPA), up from 54 in 1999 and 28 in 1996 (U.S. EPA 2005). In fiscal year 2006, voluntary programs comprised 1.6% of EPA's operating budget. Dozens more programs operate at the U.S. Department of Energy (DOE) and other federal agencies and at the state level. While many of these programs focus on climate change and energy, others cover waste, water, toxics, and agriculture. Voluntary programs have figured prominently in the national climate policies of other countries as well, and continue to play a leading role in Japan.

Arguably, the explosive growth in voluntary environmental programs reflects changing societal attitudes about the environment and a growing optimism on the possibility of enhanced cooperation between government and business. It may also reflect the widespread frustration with the long and expensive battles often associated with new environmental regulations. In most cases, voluntary programs are being used to control pollutants that have not yet been regulated and for which legislative authority may be difficult to obtain. Unlike market-based approaches to environmental management, where the conceptual roots are largely academic, voluntary programs have emerged as a pragmatic response to the need for more flexible ways to protect the environment.

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* Authors are Senior Fellow, Senior Fellow, and Fellow, respectively, at Resources for the Future.

The prominence of voluntary programs begs the obvious question of whether or not these programs are effective in achieving the stated goals. For example, following the 2002 announcement by President Bush of voluntary efforts to achieve an 18% improvement in greenhouse gas intensity, recent data indicating that we are track to meet that 18% goal has been cited as evidence of the voluntary program's success (White House 2006). But is the data really evidence of the voluntary program's success, or does it simply reflect other coincident events?

The key issue considered in this research is whether or not these programs actually work as advertised. That is, do voluntary programs deliver the promise of significant environmental gains without the burdens associated with mandatory regulation? Do they improve environmental and conservation outcomes relative to a realistic baseline, or do they pave the way for other actions that do? Quantitatively, how large are the likely gains? Can such approaches serve as a substitute for mandatory requirements or should only modest gains be expected from these efforts? Unfortunately, the existing literature—which primarily emphasizes the motivation of firms to participate rather than the environmental accomplishments of the programs—provides only limited answers to these questions.

This research addresses these questions by conducting a detailed analysis of two early voluntary programs: the U.S. EPA's Climate Wise program, and the U.S. DOE's Voluntary Reporting of Greenhouse Gases Program, 1605(b). Although they are not the most recent voluntary initiatives, and did not benefit from potential improvements in voluntary program design that occurred over the past decade, the relatively long histories of these programs make them particularly amenable to statistical analysis. While 1605(b) is strictly a reporting program, both programs emphasize flexibility for the participants. Arguably, Climate Wise offers more 'carrots' in the form of technical assistance and public acknowledgement. It also imposes more 'sticks' in the sense of at least an implied expectation that participating firms will make larger emission reductions. Climate Wise is oriented entirely to non-electric utility firms, 1605(b) is open to a broader range of entities. However, because of the nature of our matching sample, (described below), our analysis of both Climate Wise and 1605(b) is limited to firms in the manufacturing sector.

Our focus is on the environmental effectiveness of these programs, with particular emphasis on the participation decision and how various assumptions affect estimates of program effects. As part of our effort to develop a credible baseline, we are fortunate to have access to confidential plant-level data files for the manufacturing sector collected by the U.S. Census Bureau. We consider two alternative approaches to evaluating outcomes, attempting to control for self-selection in joining the voluntary programs. In one approach we consider a model where program participation depends on both observed and unobservable variables that may be correlated with the outcome. In the other approach, we match participants to appropriate non-participants and consider pairwise differences. The latter method is referred to as propensity score matching.

Understanding the true effectiveness of these programs is important. Protagonists and antagonists of the trend toward voluntary approaches are increasingly at odds, sometimes drawing opposite conclusions about the same program. Protagonists, typically on the side of industry, see voluntary programs as a more practical, flexible approach to regulation. Antagonists, including some environmental advocates, often see voluntary programs as an obstacle to more stringent, mandatory programs. This polarization may be partly a consequence of poor information. While intuition and anecdotes may provide some reason for believing that a given program has or has not had a beneficial environmental impact, careful empirical analysis with peer review is much more convincing. The goal of this research is to help fill that void.

Background

In principle, voluntary programs offer opportunities for business to get hands on experience with new types of environmental problems without the straightjacket of regulation and, in the process, to enhance their environmental reputation with government, customers, investors, communities, employees, and other firms. In some cases, the firms' participation may represent an effort to shape future regulations or to stave-off mandatory requirements altogether. Some or all of these benefits may be reflected in the firms' bottom line over the short or long term.

Voluntary programs also provide opportunities for government agencies to gain experience with new problems and new industries. Most importantly, they provide opportunities to achieve environmental improvements more quickly, and with lower administrative costs, than otherwise possible and, sometimes, via more holistic approaches than the media-specific, end-of-pipe focus of most existing legislation. In the view of some observers, by encouraging proactive approaches from industry, voluntary programs may help foster a common understanding of both environmental problems and the mutual responsibilities to address them.

Notwithstanding the many potential benefits of voluntary approaches, the absence of deliberate price or regulatory signals to encourage fundamental changes in corporate or consumer actions or to stimulate demand for cleaner technologies is a clear limitation. The term "regulatory capture" applies when the targets established for the voluntary programs reflect only a business-as-usual scenario. Free riding, wherein some firms avoid any effort while other, proactive firms voluntarily address a problem and keep further regulation at bay, may be an issue with certain voluntary programs. Taking this a step further, voluntary approaches may represent a shift in emphasis from the "worst" polluters to those most willing to abate on their own initiative. Some, particularly in the environmental community, see voluntary programs as a distraction from the real work of taking mandatory action.

Since business is inherently dynamic, with firms constantly confronting new challenges, opportunities, and technologies, it is not sufficient to simply look at two distinct points in time to see if firms' environmental performance has improved. Rather, environmental gains must be assessed with reference to a credible representation of what would have happened otherwise. Defining such a baseline is, of course, quite difficult to do. One approach is to construct a business-as-usual forecast using the best available data. However, such an approach is limited by the large number of unpredictable influences on outcomes. An alternative is to compare participants to a suitably chosen group of non-participants. Still, biases may arise if participants and non-participants differ in some systematic way—for example, if participants are bigger, faster growing, or better managed. Unless the comparisons are carefully constructed, observed differences between participants and non-participants may reflect factors other than the effects of the program.

If we imagined a laboratory setting, the most transparent way to measure the environmental performance of a voluntary program—or any program—would be to conduct a scientific experiment to see whether firms randomly assigned to the program exhibited different outcomes than those randomly assigned to a control group. Because the two groups would be otherwise identical (due to randomization), this would yield an unbiased estimate of the effect of the voluntary program on environmental performance. In real life, we rarely see such randomized experiments and are instead left with either forecast baselines or imperfect control groups. This provides only limited evidence on the environmental performance of participating firms compared to what realistically would have happened otherwise.

Evaluating Voluntary Programs

The literature on voluntary programs contains a variety of descriptors to identify particular mechanisms: self-regulation, negotiated agreements, environmental covenants, business-led environmental strategies, and others. Nonetheless, a loose taxonomy has evolved, with three reasonably distinct bins based on how the parameters of the commitment are determined:

- *Unilateral agreements by industrial firms*. Business-led corporate programs fall under this heading, as do commitments or reduction targets chosen by firms or industry associations. Examples of such agreements include the Chemical Manufacturers Association's "Responsible Care" program for reducing chemical hazards and McDonald's replacement of its Styrofoam clamshell containers with paper packaging.
- *Public voluntary programs*, in which participating firms agree to protocols that have been developed by environmental agencies or other public bodies. Although the public agencies may promote the programs to industry, they generally do not negotiate over the specific terms. Eligibility criteria, rewards, obligations, and other elements are established by the public agencies. Examples of such programs in the United States include the 33/50 program, Climate Wise and 1605(b).
- *Negotiated agreements*, consisting of a target and timetable for attaining the agreed-upon environmental objectives, are created out of a negotiation between government authorities and a firm or industry group over specific terms. In some cases, participating firms receive relief from an otherwise burdensome tax, making the voluntary notion of the program somewhat hazy. Sometimes, firms are held liable for compliance on an individual basis while in others, such as Japan, industries generally are liable on a collective basis for the environmental performance stipulated in the agreements. The XL program is an example of a negotiated agreement.

Economic analysis suggests that since environmental mitigation typically is not costless and the benefits not appropriable by the firm, profit-maximizing firms have little incentive to undertake such activities unless mandated by government to do so. It is not surprising, therefore, that as measured by the number of articles or books published on the subject, by far the dominant issue in the academic literature on voluntary programs concerns the motivation for firms to participate in the programs. Extensive theoretical and some empirical work has focused on the importance of preempting regulatory threats; the potential to influence future regulations; the effects on stakeholder relations and the firms' public image; the importance (or unimportance) of technical assistance and financial incentives to the firms' participation decision; the economic efficiency of the programs; the role of competitive pressures; and the potential to bring about savings in transaction or compliance costs. Several studies have shown the importance of public recognition provided by participation in a voluntary program to be a key motivation for firms.[1]

While the literature on the motivation for firms to participate in voluntary programs is extensive, there are only a limited number of previous analyses of environmental performance. The largely theoretical work on the issue suggests that participation in voluntary programs does not guarantee an improvement in actual performance. While it may encourage the exchange of information about best practices, a key factor may be to provide insurance to firms against stakeholder pressure. Thus, by implication, it might be argued that participation in voluntary programs may actually reduce incentives to cut emissions if it is successful in staving off stakeholder pressure for more stringent actions. Theoretical studies have shown that improvements in actual environmental performance depend on the extent to which voluntary programs lead to lower abatement costs relative to mandatory regulation; the likelihood that regulation will be imposed even if the program is not effective; the extent to which the regulator is willing to subsidize pollution reduction; the willingness of consumers to pay for green products; and other factors.

In considering environmental performance of voluntary programs it is useful to distinguish between those programs that focus on the adoption of particular technologies (e.g., Green Lights, now part of the Energy Star Program) and those that focus directly on environmental performance (e.g., 33/50, Climate Wise, 1605(b), or various audit-based programs). In the former, success is measured as adoption of specific technologies. In the latter, it is measured as a reduction in emissions. In both cases, there is the need to define a baseline: Measured over the same period, how many firms (or households) would have installed the technologies, or how much would emissions have been reduced, even without the voluntary program?

Technology programs can be difficult to evaluate because of the general absence of comprehensive databases on the performance of facilities that have not adopted the particular technologies. Despite this limitation, a number of these programs have been subject to at least some evaluation. The Green Lights Program is an innovative, voluntary, pollution-prevention program sponsored by the U.S. EPA focused on the installation of energy-efficient lighting

[1] For reviews of this literature see Khanna (2001) and Lyon and Maxwell (2002); see also Arora and Cason (1995, 1996), Celdren et. al. (1996), and Khanna and Damon (1999).

where profitable and where lighting quality can be maintained or improved. DeCanio (1998) finds that the energy-efficiency investments carried out under this program yielded annual real rates of return averaging 45%. DeCanio and Watkins (1998) find that specific characteristics of firms affect their decision to join Green Lights and commit to a program of investments in lighting efficiency.

Energy Star is a voluntary labeling program designed to identify and promote energy-efficient products to reduce greenhouse gas emissions. Dowd et al. (2001) cite specific product-purchase decisions being influenced by Energy Star, including a number of favorable “soft” and “dynamic” effects associated with the program. After reviewing the evidence on Green Lights and Energy Star, Howarth et al. (2000) concluded that “voluntary agreements between government agencies and private sector firms can … lead to improvements in both technical efficiency of energy use and the economic efficiency of resource allocation”. Unfortunately, none of these studies was able to distinguish between the improvements attributable to the voluntary programs and those changes that likely would have taken place even without the programs.

The empirical evidence is more extensive, though still mixed, when we look at programs focused explicitly on environmental performance as opposed to technology adoption, particularly with regard to toxics where there has been extensive analysis using TRI data. What is probably the gold standard in the field is an in-depth analysis of the 33/50 program by Khanna and Damon (1999), who jointly modeled the decision to participate in the program as well as the actual outcomes. They first recognize that a firm’s decision about the quantity of covered releases to emit will likely depend on both its participation in 33/50 and such factors as stakeholder pressure, output levels, and others. They then allow for the participation decision to both depend on these same variables and to be correlated with the volume of releases. Using publicly available firm-level data, they found a statistically significant impact of the program on toxic releases, as well as on firms’ return on investment and long-run profitability. Khanna and Damon hypothesize that the incentives for participation arise from three sources: program features, the threat of mandatory environmental regulations, and firm-specific characteristics.

Focusing on the period 1988–1995, Sam and Innes (2005) also found that participation in 33/50 lowered releases of the covered chemicals, particularly in 1992. Further, they found that participation in 33/50 was associated with a significant decline in EPA inspection rates for the years 1993–1995. A study by Gamper-Rabindran (2006) found that while the effects varied by industry, in the case of the largest participating industry, namely the chemical industry, the positive results that 33/50 reduced toxic releases (reported by Khanna and Damon (1999)) are actually reversed when the analysis excludes two ozone-depleting chemicals whose phase-out was mandated by the Clean Air Act.

King and Lenox (2000) analyzed the environmental impact of firms participating in Responsible Care, an industry-sponsored effort to cut toxic releases distinct from the government-sponsored 33/50. Using pooled and panel data for the period 1991–1996, they find that participants were reducing their releases more slowly than non-participants. Their fixed-effect model shows that Responsible Care had an insignificant effect on environmental performance. That is, despite the improved performance of the chemical industry over the studied period, the rate of improvement was not greater than in pre-program years and, most surprisingly, it was slower for participants in Responsible Care than for non-participants.

A paper by Dasgupta, Hettige and Wheeler (1997) focused on the adoption of ISO 14001 management practices by Mexican firms. They found a significant improvement in the (self-reported) compliance status of participating firms. They also found that explicit environmental training programs for non-environmental workers led to an improvement in the compliance status of the firms.

Turning to energy and climate change, an analysis of the U.S. Department of Energy's Climate Challenge Program on CO2 emissions focused on the largest 50 electric utilities east of the Rocky Mountains from 1995–1997 (Welch, Mazur, and Bretschneider 2000). Despite a number of intriguing results about the motivation of firms to participate in Climate Challenge, the authors find that adoption of the program seems to have no effect on emissions. In fact, those firms predicted to volunteer higher reduction levels were found to reduce their CO2 emissions less. The authors hypothesize that the poor program performance is associated with the lack of at least a tacit regulatory stick of the type present in 33/50. A recent paper examined the performance of electric utilities participating in the 1605(b) program (Lyon and Kim 2007). They use a two-stage model to account for both participation and environmental outcomes. The authors find that participants tend to be larger, with higher and more rapidly increasing emissions than non-participants. However, they also find that participation had no measurable effect on a firm's carbon intensity. They conclude that participation may be a form of greenwash, that is, an attempt to appear more environmentally friendly than is really the case.

Overall, the literature is characterized by a paucity of empirical studies on the actual environmental performance of voluntary programs and, equally important, an almost exclusive focus on toxics as opposed to energy- or climate-related programs. As is well known, energy issues differ from toxics in many ways, including the extent to which financial incentives are already in place to reduce emissions. That is, market forces already encourage conservation and energy efficiency, whereas no such forces exist to reduce toxic emissions. Thus, the potential for voluntary programs to achieve reductions in energy-related carbon dioxide emissions may be more limited than the potential associated with toxics. A key motivation for this research is to increase the attention paid to the rigorous study of program results and to emphasize rapidly growing interest in energy- and greenhouse-gas-related programs.

The Climate Wise Program

Officially established by the U.S. Environmental Protection Agency (EPA) in 1993, Climate Wise is a voluntary program focusing on the non-utility industrial sector to encourage the reduction of carbon dioxide (CO2) and other greenhouse gases (GHGs) via adoption of energy efficiency, renewable energy and pollution prevention technologies. Climate Wise remained in operation until 1999-2000 when it was renamed and placed under the Agency's Energy Star umbrella. Unlike Green Lights or EPA's other technology-based programs which require the adoption of particular technologies, Climate Wise members had the flexibility to use whatever technologies or strategies they chose to reduce their emissions. The basic requirements of Climate Wise were that a participating firm develop baseline emission estimates of its GHGs, pledge forward looking emission reduction actions, and make periodic progress reports. As part of the program operations, Climate Wise provided public recognition and certain types of technical assistance to its members. At its peak, Climate Wise had enrolled more than 600 industrial firms covering several thousand facilities nationwide. More recently, Climate Leaders, a program noted above with some design features similar to those of Climate Wise, has been embraced by the Bush administration as a key element of its climate change initiative. Although EPA has developed estimates of the emission reductions associated with Climate Wise, there has been little outside evaluation of the program.

As stated in the Program's 1998 Progress Report the four broad objectives of the Climate Wise Program are to:

- Encourage the immediate reduction of greenhouse gas emissions in the industrial sector through a comprehensive set of cost-effective actions;
- Change the way companies view and manage environmental performance by demonstrating the economic and productivity gains associated with 'lean and clean' manufacturing;

- Foster innovation by allowing participants to identify the actions that make the most sense for their organization; and
- Develop productive and flexible partnerships within government and between government and industry. (EPA 1998 page 2)

Climate Wise consists of three interrelated components. First, the pledge component asks firms to commit to taking cost-effective, voluntary actions to reduce greenhouse gas emissions. Second, the tailored assistance efforts are designed to facilitate companies' emission reducing efforts via a clearinghouse, workshops, and seminars. Finally, communication activities provide public recognition for actual progress in reducing emissions.

To join Climate Wise, a firm has to develop a baseline estimate of its direct emissions of CO2 (and other greenhouse gases) for the year it joined the program or any prior year of its choice since 1990. Since an estimate of baseline emissions estimate does not involve the detailed accounting information required for a full emissions inventory, the burden on the firm was relatively modest.

In addition to establishing a baseline, a firm was required to identify specific actions it proposed to undertake to reduce its emissions and, for each action, to indicate whether this is a 'new,' 'expanded,' or 'accelerated' initiative. To encourage consideration of substantial reductions, EPA provided a checklist of major actions to improve equipment and processes, including those involving boiler efficiency, air compressor systems, steam traps, and piping and heat generating equipment. Also included were fuel switching and best management practices, as well as the further integration of energy efficiency in new product design and manufacturing. Firms were strongly encouraged, albeit not required, to select at least some of their proposed actions from this list. The only formal requirement was for a firm to establish an emissions goal for the year 2000, and to provide a progress report directly to EPA. Participants were also encouraged, but not required, to report their progress to the U.S. Department of Energy through the 1605(b) registry program.

EPA provided several types of technical assistance to participating firms, including a guide to industrial energy efficiency, various government publications on energy efficiency and related issues and, most importantly, free phone consultation with government and private sector energy experts retained as consultants by the Agency. Information about financial assistance to support emissions reducing actions was also made available to participants, including via Small Business Administration guaranteed loans, low interest buy-downs from state providers, utility programs, and others. Further, EPA set up an annual event open to the public to recognize the performance of outstanding Climate Wise participants.

Although the focus of the Climate Wise program is on energy efficiency and the reduction of CO2 emissions, a number of firms did propose to reduce emissions of non-CO2 greenhouse gases as well. Reportedly, the most substantial reductions of the non-CO2 gases were in the chemical industry, where relatively large amounts of nitrous oxide (N2O) emissions were released in the manufacture of adipic acid. Significant amounts of methane (CH4) were also included in the action plans of several firms, especially in the beer industry.

The 1605(b) Program

Unlike Climate Wise, which was initiated entirely by the EPA, section 1605(b) of the Energy Policy Act of 1992 (EPACT) directed the DOE to develop a program to document voluntary actions that reduce emissions of greenhouse gases or remove greenhouse gases from the atmosphere. The Voluntary Reporting Program was to be administered by the U.S. Energy Information Administration (EIA). The EPACT mandated that EIA issue guidelines for reporting, establish suitable procedures, ensure confidentiality of trade secrets, commercial and financial information, and establish a publicly available database. It also mandated consultation with the EPA. The first reports covered the year 1994.

Although it involves fewer programmatic activities than Climate Wise, the 1605(b) program does provide recognition for entities that reduce greenhouse gas emissions or sequester carbon voluntarily, and it attempts to identify innovative and effective ways of reducing emissions. Most of the reporters to the Voluntary Reporting Program are affiliated with one or more EPA or other government-sponsored voluntary programs.

As originally developed, the 1605(b) program is extremely flexible. Both direct and indirect emissions, including sequestration, can be included. Voluntary reporters can define the boundary of the entity or the project, and can choose to report reductions at the entity or the project level. Reporters can select a 'basic' reference case as any single year between 1987 and 1990, or an average of those years. Alternatively, reductions can be reported against a 'modified' or hypothetical reference case, reflecting what emissions (or sequestration) would have been in the absence of the project. Further, reporters can measure their reductions in either absolute terms or on the basis of emissions intensity.

Since its inception in 1994, activities reported under 1605(b) have increased dramatically: the number of reporting entities has doubled from about 100 per year to more than 200 per year;

the number of projects has more than tripled from about 600 per year to more than 2000 per year; and reported reductions in direct emissions have more than quadrupled from 63 million metric tons in 1994 to 277 million metric tons in 2004. Overall, the electric power sector reported more entities, projects and tons of emissions reduced than any other sector in the database. Effective June 1, 2006, the program was revised and the reporting flexibility was reduced somewhat. However, the analysis presented in this research is based on the data firms reported to the program during 1994-2000.

The 1605(b) Program differs from Climate Wise and most other voluntary programs initiated during the early 1990s in its diversity of project types, participation, and approaches. The program's database offers abundant examples of the types of concrete actions that organizations report to reduce greenhouse gas emissions. The EIA notes some of the most important benefits of the 1605(b) Program as follows (EIA 2002 pp 1-2):

- The program has served to teach staff at many of the largest corporations in the United States how to estimate greenhouse gas emissions and has educated them on a range of possible measures to limit emissions.
- The program has helped to provide concrete evidence for the evaluation of activities reported to the many government voluntary programs launched since 1993.
- Reporters have been able to learn about innovative emission reduction activities from the experiences of their peers.
- The program has created a "test" database of approaches to emission reductions that can be used to evaluate future policy instruments aimed at limiting emissions.
- The program has helped to illuminate many of the poorly appreciated emissions accounting issues that must be addressed in designing any future approaches to emission limitations.

Data

For both Climate Wise and the 1605(b) program we combine participation data from the relevant government agencies with outcome data (and control observations) drawn from Census data. As noted, we focus exclusively on the manufacturing sector.

The Climate Wise Program

For EPA's Climate Wise Program data, a list of voluntary program participants was obtained from EPA describing who joined Climate Wise in each of its operational years from 1994 to 2000. This list includes name, zip code and join date data for two different types of participants, those who joined at the corporate level and those who joined as individual plant participants. There were a total of 671 participants with complete data. Table 1 displays the distribution of both types of participants over time. As shown, the number of corporate participants reached a peak in 1996 and gradually dropped to zero in 2000. However, the number of plant participants continued to increase until 2000.

This information on program participation then was linked to detailed data at the Census Bureau using name and, for plant participants, zip code information. We succeeded in linking a total of 377 out of 671 participants, including 228 corporate participants and 149 plant participants. To some extent, the failure to link participants to the Census data reflects the fact that Census data only includes manufacturing establishments, while the Climate Wise program includes both manufacturing and non manufacturing participants (e.g., municipalities, commercial buildings, etc. – despite its programmatic focus on manufacturing).

These 377 linked participants from the original Climate Wise list translate into 2311 facilities because corporate participants can have multiple associated facilities. The data are displayed in Table 2.

Summary statistics for the linked sample, as well as the entire Census database, are given in Table 3. Here we see the principal differences among participants and the broader universe of plants in the Census data: The participants are considerably larger. Our participant sample is also a very small fraction of the plants in the Census database—roughly 1%. This suggests that the full Census sample is unlikely to be an appropriate control group as a whole, and that there are a large number of plants from which to choose a more appropriate sub-group of controls.

It is worth noting that the linking Climate Wise and Census data has important consequences for our ability to evaluate the effect of program participation over longer horizons. As we are attempting to study behavior 2 or 3 years after joining, we are forced to drop plants that joined in 2000 and 1999, respectively, because our Census data ends in 2001. As noted, corporate participants provide the overwhelming majority of participant observations because they match to multiple facilities. Given the steep drop off in new corporate participants after 1998, we do not sacrifice many observations by looking 2 to 3 years out. However, trying to discern effects 4 years after joining, with only participants who joined between 1994 and 1997, we have noticeably fewer observations and noisier estimates. Thus, we do not attempt to look at effects more than 3 years after participants join the program.

The 1605(b) Program

For DOE's Voluntary Reporting of Greenhouse Gases (1605(b)) Program, a list of reporting entities, sectors, years reported, and form type used was obtained for the years between 1994 and 2001. The reporting entities are distributed among six sector categories: Agriculture, Alternative Energy, Electric Power, Industry, N/A and other. Most of the participants are in the energy relevant sectors. For example, the electric power sector accounts for more than one third of total reporting entities (130 out of 383). In this research, we are most interested in manufacturing participants which account for only 18% of the all reporting entities. In Table 4, we provide sector distribution information for all the reporting entities.

Unlike EPA's Climate Wise program, DOE 1605(b) data does not have join date information. However, as noted, the year and type of form reported for program participants are available in the database. Thus, we use the first reporting year as the join year and assume that the participants continue in the program after that, even though individual entities may not have continuous reporting years. Table 5 displays the join year information based on either firm or plant participation.

A separate entity file was also obtained from EIA. It contains entity identification number, name, street, city, state, contact, internet address and sector information. Using this information, we were able to match participation data with Census data. In Table 6, we show the sector distribution for DOE 1605(b) and LRD matching results. For the industrial sector, the matching rate is about 77%. For sector classified as N/A, we were able to match 36% of them. For others, the matching rate is only 13%, because most of the others are electricity and energy relevant entities which do not fall into the manufacturing category. Due to the small number of observations, items marked with D* are included in the 'Other' category.

After excluding missing join year and others, we were able to link 83 out 383 participants, including 67 corporate participants and 17 plant participants. We have a much lower matching rate for the DOE 1605(b) program because it includes both manufacturing and non manufacturing sectors. In fact, more than 50% of the participants are in the electric power and alternative energy sectors, which are not in the Census data. These 83 linked participants from the original DOE 1605(b) list corresponds to 1791 LRD facilities because corporate participants can have multiple facilities. Table 7 summarizes the matching of the 1605(b) data to Longtitudinal Research Database (LRD).

Table **8** provides summary statistics for the linked sample, as well as the entire Census database for the DOE 1605(b) voluntary program.

Models and Econometric Method

With the linked Census data described in the preceding section, we have access to variables indicating energy expenditures (separately on fuels and electricity), size (measured by the total value of shipments), location, and industry, for a large sample of manufacturing plants over a range of years from 1992 until 2000. We also have linked information on which plants participated in each of our two programs and what year they first participated. We now consider two alternative approaches to evaluating outcomes, attempting to control for selection based on observables in one and unobservables in the other. In each case we can imagine two outcomes Y_i for every observed plant i: the value associated with participation, $Y_i(1)$, and the value associated with non-participation, $Y_i(0)$. Here, $Y_i(D_i)$ is the outcome associated with either treatment, D_i = 1, or non-treatment, D_i = 0, and is either the cost of fuels or electricity measured in natural logarithms. The ideal study would measure the treatment effect,

$$Y_i(1) - Y_i(0)$$

for each plant i, that is, the percent change in energy expenditures when a plant joins the program. The obvious problem is that for every plant we observe either $Y_i(1)$ or $Y_i(0)$, but never both. The problem, viewed this way, is one of missing data and the selection process determining which data are observed and which are missing (that is, who participates).

The simplest solution, and the one appropriate for randomized experiments, is to assume that the missing observations are *missing at random* (Rubin, 1974). Another way to say this is that the selection mechanism determining which outcomes are observed is *ignorable*. Under this assumption, formally $D_i \perp Y_i(1), Y_i(0)$, we can measure the *average treatment effect* as

$$E\left[Y_i(1) - Y_i(0)\right] = \frac{\sum_{D_i=1} Y_i(1)}{\sum_{D_i=1} 1} - \frac{\sum_{D_i=0} Y_i(0)}{\sum_{D_i=0} 1}$$

That is, the average outcome among those participating minus the average outcome among those not-participating. Or from a simple regression model,

$$Y_i\left(D_i\right) = \beta_0 + \beta_1 D_i + u_i$$

where by assumption u_i is uncorrelated with D_i and the treatment effect is the estimated value of β_1. Of course, in reality, missing at random is unlikely and hence we proceed to our two approaches.

In our first approach, we follow Heckman and Hotz (1985) and instead consider a model where program participation depends on both observed and unobservable variables that may be correlated with the outcome.

$$D_i \perp Y_i\left(1\right), Y_i\left(0\right) \middle| X_i, u_i$$

with u_i being an unobserved variable. We build a structured model where, even though selection D_i is dependent on an unobserved variable, we can still consistently estimate the treatment effect. Specifically, we assume an outcome model of the form

$$Y_i = \beta_0 + \beta_1 \cdot X_i + \beta_2 \cdot D_i + u_i \tag{1}$$

where we have allowed for covariates. We still must deal with the problem that Y_i and D_i are not independent, even conditioning on X_i. In particular, we assume u_i and D_i to be correlated, thus violating a key assumption for unbiased estimation in an OLS model (that the error must be *uncorrelated* with all of the right-hand side variables). The solution is to specify a model for participation D_i and thereby parameterize the correlation with u_i.

In particular, we specify a selection model

$$D_i^* = \delta \cdot Z_i + v_i$$

where $D_i = 1$ if $D_i^* > 0$ and $D_i = 0$ otherwise, and Z_i is a set of covariates with at least one additional covariate not included in X_i (referred to as “excluded variables”). This condition is necessary for identification, and intuitively reflects the presence of a variable that influences the decision to participate in the voluntary program but does not directly influence the emission outcome. For example, if we find that in some years individual programs were more aggressively marketed than others, we could create a variable indicating whether firms joined in particular years. This variable would be precisely the kind that would help identify participation but not directly influence the emissions outcome.

If we assume (u_i, v_i) are jointly normal, it is easy to show that

$$E\left[v_i \middle| D_i, Z_i\right] = \lambda\left(D_i, Z_i\right) = \begin{cases} \dfrac{\phi\left(-\delta \cdot Z_i\right)}{1-\Phi\left(-\delta \cdot Z_i\right)} & D_i = 1 \\ \dfrac{-\phi\left(-\delta \cdot Z_i\right)}{\Phi\left(-\delta \cdot Z_i\right)} & D_i = 0 \end{cases}$$

If we then specify the outcome equation as

$$Y_i = \beta_0 + \beta_1 \cdot X_i + \beta_2 \cdot D_i + \alpha \cdot \lambda\left(D_i, Z_i\right) + \varepsilon_i \tag{2}$$

where $u_i = \alpha \cdot \lambda\left(D_i, Z_i\right) + \varepsilon_i$, the error ε_i is no longer correlated with D_i because $\alpha \cdot \lambda\left(D_i, Z_i\right)$ reflects the expectation of u_i given D_i. Note the intuition for the identifying assumption that there must be at least one variable in Z_i excluded from X_i: Except for the non-linearity in the function λ, the right-hand side variables would be co-linear if X_i included all the variables in Z_i.

Our dependent variable in this model is the change in logged energy expenditures (fuel and electricity) over different time horizons after a given year when plants join the voluntary program. When we estimate this model, we include linear and quadratic values of our key variables as controls X_i: logged and lagged value of shipments, electricity costs, and fuel costs. We also include the change in logged value of shipments over the given time horizon as a control variable. While this is arguably endogenous, we believe controlling for growth is critical: we observe that faster growing plants are more likely to join voluntary programs. It seems unlikely that this growth is *caused* by joining; therefore, we need to control for it.

We also include dummy variables for Census region and two-digit industry classification. Our Z_i variables include two variables we believe are likely to influence participation but not the outcome – distance to the nearest regional EPA office and local membership rates in a national environmental organization.[2] We discuss the results of this approach in the results section that follows.

Our second approach is based on work by Rosenbaum and Rubin (1983) and more recently used by List et al (2003) and Dehejia and Wahba (2002). This approach makes an alternative assumption that participation decision is ignorable conditional only on observed covariates, or

$$D_i \perp Y_i\left(1\right), Y_i\left(0\right) \middle| X_i$$

[2] Many thanks to the National Wildlife Federation for supplying this data.

This could be accomplished via a model such as (1), except that it requires a correct specification of the X_i dependence – otherwise the estimated effect of the program remains mingled with covariates. Instead, Rosenbaum and Rubin (and others) match participants to appropriate non-participants and consider the pairwise differences. While the Heckman and Hotz approach attempts to control for selection on additional, unobserved effects correlated with outcome, it requires both on a correct specification and identification of one or more excluded variables. This approach, while not controlling for such effects, relaxes the specification assumption and does not require excluded variables.

While the general problem of creating a set of matched, non-participating observations is quite challenging (there are many observable variables – in our case describing location, industry, size, energy intensity, and growth – that we would want to match), the important result based on Rosenbaum and Rubin is that we only need to match the expected likelihood of participation. That is, we simplify the difficult problem of matching all these different variables to a much simpler one of matching a summary variable describing the propensity to join the program. This approach is referred to as propensity score matching.

Our model of propensity score – the likelihood of joining the voluntary programs – is similar to our model of outcome in (2). It depends on linear and quadratic terms involving value of shipments, cost of fuels, and cost of electricity (all in logarithms), as well as dummy variables for Census region and 2-digit industry classification. As before, we also include a term for growth in value of shipments over a given horizon h, as this turns out to be an important determinant of participation. As it seems unusual to imagine participation causing growth, we take this as a proxy for expected growth over the given horizon. We use samples matched with different horizons h to estimate program effects over similar horizons.

Because each of the voluntary programs lasted a number of years, it seems more natural to think about the decision to join in a duration model framework. That is, in each period, conditional on not having joined there is a given probability of joining based on the noted covariates and time. This allows us to combine data across years in estimating our model.[3] We therefore estimate a Cox proportional hazard model of the form:

[3] Note that while the participants have an obvious join-year associated with them, non-participants do not. That is, there are different years when plants begin participation, but not when they begin non-participation. Outside of a duration model, it does not seem possible to combine the data. In the previous approach, we estimate effects for different cohorts of participants separately for this reason.

$$\begin{array}{c}\text{probability of joining in year } t\\ \text{(assuming plant } i \text{ has not yet joined)}\end{array} = h(t)\exp\begin{pmatrix}\beta_{size}\ln TVS_{i,t-1}+\beta_{elec}\ln EE_{i,t-1}+\beta_{fuels}\ln CF_{i,t-1}\\ +[\text{all quadratic combinations of size, elec, fuels}]\\ +\beta_{growth}\left(\ln TVS_{i,t+h}-\ln TVS_{i,t-1}\right)\\ +\sum_{\text{industries } j}\beta_j 1(M_i=j)+\sum_{\text{region } k}\beta_k 1(G_i=k)\end{pmatrix}$$

Once estimated, we predict hazard rates for participants in the year they join and match them to the nearest valued non-participant in that year. We then examine the difference in changes in cost of fuels and electricity across each pair; this difference-in-differences forms the estimate of our program effect.

Results

Table 9 through

Table **12** present results for the first, Heckman-Hotz approach for the DOE 1605(b) and EPA Climate Wise programs, and both cost of fuels and cost of electricity as outcome variables, respectively. We report only the results for a "two-year" horizon; that is, the dependent variable measuring the change between the year before a group of participants join the program (cohort) and two-years later; the results are broadly similar at one- and three-year horizons. We have reported the results with and without the selection correction term, $\lambda(D_i, Z_i)$ in (2). The results without the correction term (first column) reflect the simplest model, with the outcome depending only on covariates (value of shipments, cost of fuels, and cost of electricity, growth in value of shipments, as well as region and industry dummies) and the dummy variable indicating whether a firm joins the program in a given year.

Among the results for this simple model in the first column of each table, without any correction for possible selection bias, we generally estimate small, statistically insignificant effects of less than 10%. The three exceptions are a statistically significant 9% decline in electricity costs among 1605(b) participants in the 1994 cohort, a 6% increase in electricity costs among Climate Wise participants in the same cohort, and a *55% increase* in fuel costs among Climate Wise participants in the 1999 cohort. The first two effects are not inconsistent with our observations below, that electricity might increase in Climate Wise if efforts to reduce direct emissions lead to more electricity use and higher indirect emissions. Similarly, a positive electricity effect could reflect a combination of specification error and the fact that larger / faster growing firms tend to participate in voluntary programs. The latter, 55% effect likely reflects an outlier in the rather small sample (96 participants) for that year and/or specification error.

The preceding results ignore the potential for selection bias, which is the main purpose of this exercise. The second column presents results where first we estimate the probability of selection, and then include the selection correction term, $\lambda(D_i, Z_i)$ in (2), in the original outcome regression. For simplicity, we have not reported the results of the first stage regression. However, an important observation in these results is that the excluded variables are *almost never* statistically significant.[4] Empirically, it is difficult to see a difference in the distribution of either variable among participants and non-participants, suggesting this approach may be problematic given available data.

When we look at the results across the four program / outcome variable combinations, the results are indeed problematic. We also see much larger standard errors on the estimates, compared to the simple estimates in column one. This reflects the likely multi-collinearity between the correction term and the right-hand-side variables, where it may mostly be the nonlinearity of the $\lambda(D_i, Z_i)$ function identifying the parameters rather than the excluded variables. In any case, five of 24 estimates are statistically significant, ranging from a -1.42 (0.71) estimated effect on electricity costs in the 1999 participant cohort of the EPA Climate Wise program, to a +0.60 (0.09) estimated effect on electricity costs in the 1994 cohort of the same program (this would suggest an effect ranging from -76% to +82% across different years). Given that such a divergent range driven by the participation year seems implausible, and the noted problem with the excluded variables, we tend to distrust this approach.

Instead, we now turn to the results from the propensity score matching approach in

Table **13** through

Table **16**. As noted in the methods section, we estimate duration model for whether or not facilities join, using a variety of specifications. These specifications differ based on whether dummies are included for industry and region, and whether or not quadratic terms are included, as indicated in the top three rows of each table. For each specification, we consider effects over 1, 2, and 3 years; we pool across all cohorts of matched pairs, and report both the mean and median across pairs.

As with the simple model (column 1 of Table 9 through

[4] Distance to EPA regional office is significant in the 1997 cohort. Note that we experimented with various specifications of the excluded variable with no appreciable difference. The reported specification is based on logged distance to EPA regional office and county environmental group membership as a share of total county population.

Table **12**), all of the estimates suggest effects of less than 10%. We focus our discussion on the median estimates in the bottom half of each table because they are more robust to outlying observations of paired differences. Only 4 of these 72 median estimates are larger than 5% in magnitude, suggesting any effect is probably even smaller than 10%. There is generally more statistical significance among the electricity cost estimates (6 of 36) versus fuel cost estimates (1 of 36). Interestingly, the 1605(b) program seems to have a negative effect of perhaps several percent (

Table **14**, where 17 of 18 median estimates are negative), while Climate Wise appears, if anything, to have a slight positive effect (

Table **16**, where 14 of 18 median estimates are positive). The positive effect in Climate Wise is not present in our most general matching model (

Table **16**, where median estimates in column 1 are not significant); the negative in 1605(b) is present (

Table **14**, where median estimates in column 1 are signficant). Further, there is no evidence of persistence in the Climate Wise results (effects at 3 year horizon are all lower than at 2 years; see bottom 2 rows of

Table **16**). Meanwhile 1605(b) estimates in 4 out of 6 models are largest for the longest horizon (bottom row of

Table **14**).

Putting this all together, we have several key observations based on the simple results (column 1 in Table 9 through

Table **12**) and propensity score matching approach (

Table **13** through

Table **16**). As noted earlier, we tend to distrust the Heckman-Hotz results.

1. Voluntary program effects from Climate Wise and 1605(b) on fuel and electricity expenditures are no more than 10% and likely less than 5%.
2. There is virtually no evidence of a statistically significant effect of either Climate Wise or 1605(b) on fuel costs.
3. There is some statistically significant evidence that participation in Climate Wise led to a slight (3-5%) increase electricity costs that vanishes after two years.

4. There is some statistically significant evidence that participation in 1605(b) led to a slight (4-8%) decrease in electricity costs that persists for at least three years.

Among these results, the transient, slight increase in electricity costs under Climate Wise is certainly anomalous. Two explanations come to mind. First, participating plants may have pursued direct emission reductions that required increased electricity use. Ignoring the indirect emissions associated with electricity use, this technically reduces emissions as defined by the program goals – but with the unintended consequence of higher indirect emissions from electricity use. Lower direct emissions might be not show up in the cost of fuel measure because fuel switching among purchased fuels – for example, a shift to biomass or from coal to gas – might reduce emissions without changing expenditures. Or plants may have pursued non-energy-related emission reductions -- such as N_2O emissions at chemical plants, methane emissions at refineries, or CO_2 process emissions at cement or other industrial sources – that is not reflected in a lower cost of fuels.

A second explanation for a positive effect on electricity is that it may reflect a failure to adequately control for growth. While we match, in part, on growth in the value of shipments, the tendency of faster growing firms to join remains troubling. For example, we have no way of knowing about the underlying prices and quantity changes – participants might experience changes in quantities while those matched from the Census database might experience changes in prices; we cannot tease out controls that have that same pattern because there is no available detail on prices and quantities. If the estimated electricity expenditure growth effect is really reflecting an underlying and uncorrected difference in growth between participants and controls, then (presumably) fixing it would raise the growth rate of the control group and make the estimated program effect on electricity and fuel costs more negative.

Conclusions

Thus far, the rigorous assessment of the environmental performance of voluntary programs, especially climate-related programs, has been quite limited. The key challenge is to measure performance relative to a realistic baseline. The present research, which examines both a DOE- and an EPA-sponsored program, relies on confidential plant-level data for the manufacturing sector collected by the U.S. Census Bureau to develop such a baseline based on a comparable set of non-participant controls, focusing on activities through 2001 when available Census data ends. We consider two alternative approaches to evaluating outcomes, attempting to control for selection in joining the programs based on both observable as well as unobservable characteristics. In one approach we consider a structural model where program participation depends on both observed and unobservable variables that may be correlated with the outcome. In the other approach, we match participants to appropriate non-participants based on observable characteristics only, and consider pairwise differences – a method known as propensity score matching. The results are sobering.

In contrast to the claims of relatively large emission reductions reported by the sponsoring agencies, our analysis suggests more modest reductions are attributable to the programs studied. Overall, we find that that the effects from Climate Wise and 1605(b) on fuel and electricity expenditures are no more than 10% and likely less than 5%. There is no evidence of reductions in direct emissions from fossil fuels attributable to the voluntary programs; however, there is some statistically significant impacts on the use of electricity. In particular, there is some statistical evidence that participation in 1605(b) lead to a slight decrease in electricity expenditures, on the order of 4-8 percent. This decrease persists for at least three years. The statistically significant evidence on Climate Wise is that the program may be associated with a slight *increase* in electricity expenditures, although that effect vanishes after two years. Given the limitations of the analysis, we tend to discount these findings and conclude, instead, that in all likelihood, participation in Climate Wise has at most a negligible effect on emissions.

The findings of modest, albeit statistically significant, reductions in electricity expenditures for 1605(b) reporters may have implications for other government-sponsored voluntary programs as well. Recall the EIA observation that most of the entities reporting under 1605(b) are also affiliated with one or more other government-sponsored programs. Thus, the observed emission reductions for the 1605(b) reporters may reflect the influence not only of the 1605(b) program itself but also that of other programs. While our separate assessment of Climate Wise suggests that participation in that program is not likely associated with significant emission reductions, other larger programs, e.g., EPA's Energy Star Program, may be more effective. Unfortunately, the EIA reporting form does not require disclosure of the name of any of the other individual programs in which the firm participates.

Methodologically, our research highlights the inevitable complexity of assessing voluntary programs. Our research reinforces the work of others in emphasizing the importance of distinguishing between the participation decision and the environmental outcomes achieved. Our work also points to the value of working with micro-level data, and the particular need to take special care in matching otherwise disparate samples to obtain a credible control group. This process is all the more difficult in our case, where the samples were not coded via a uniform system. In terms of estimation, we have applied two distinct methods to evaluating outcomes.

One based on the work of Heckman and Hotz (1985), assumes that program participation depends on both observed and unobservable variables that may be correlated with the outcome. The other, propensity score matching, based on the work of Rosenbaum and Rubin (1983), matches participants to appropriate non-participants and considers pairwise differences. Because the Heckman and Hotz approach requires both a correct specification and identification of one or more excluded variables, it is more demanding than the Rosenbaum and Rubin approach which relaxes the specification assumption and does not require excluded variables (but does not allow for correlated, unobserved errors in the selection and outcome model). Because of our difficulty identifying excluded variables in the former method, our results seem more plausible with use of the latter approach, and we think such an approach may have wider application in the future evaluation of voluntary programs.

Overall, the evaluation of environmental programs seeks to determine what works and what does not. Our findings of at most a small effect should not be all that surprising. Energy-related greenhouse gas emissions are quite different than many other types of emissions, e.g., un-priced industrial byproducts such as toxics with no near-term localized effects whose existence was widely ignored until the 1980s and 1990s. With no practical opportunity for end-of-pipe abatement, reductions in energy-related greenhouse gas emissions often amount to reductions in energy use itself – something that has been picked over for some time. Given the underlying positive price on energy, there is *always* an incentive to reduce energy use. The existence of such underlying incentives, in turn, implies a far greater challenge for government in designing effective voluntary programs for industry.

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Tables

Table 1: Join Data for Climate Wise Participants

Join year	Corporate	Plant	Subtotal
1994	8	0	8
1995	30	7	37
1996	141	38	179
1997	101	37	138
1998	70	36	106
1999	17	72	89
2000	0	144	144
Subtotal	367	304	671

Table 2: Matching of Climate Wise (CW) to Longtitudinal Research Database (LRD)

	CW List	LRD Plants	LRD plant-year observations (1992-2001)
Corporate participants with multiple plants	135	2,053	11,503
Corporate participants with a single plant	93	95	316
Plant-level participants	149	163	946
Total	377	2,311	12,765

Table 3: Sample Statistics, LRD and Program Participants

Variable	Summary Statistics	Full LRD sample (1992-2001)	Program Participants
ln(*TVS*)	Mean	7.61	10.87
(total value	Standard deviation	2.30	1.81
of shipments)	Plant-year observations	1,157,606	12,605
ln(*CF*)	Mean	2.54	5.31
(cost of	Standard deviation	2.12	2.23
fuels)	Plant-year observations	839,934	11,280
ln(*PE*)	Mean	3.17	6.31
(purchased	Standard deviation	2.21	1.83
electricity)	Plant-year observations	1,019,042	12,377
	Number of Plants	515,189	2,311

Table 4: The Sector Distribution for DOE 1605(b) Reporting Entities

Sector	Counts
Agriculture	12
AlternativeEnergy	63
ElectricPower	130
Industry	69
N/A	94
Other	15
Total	383

Table 5: Join Year for DOE 1605(b) Participants

Join Year	Plant	Firm	Total
.	7	36	43
1994	0	105	105
1995	0	37	37
1996	3	23	26
1997	2	15	17
1998	8	53	61
1999	2	33	35
2000	6	53	59
Total	28	355	383

Table 6: The Sector Distribution for Matched DOE 1605(b) and LRD Data

Sector	Counts
Agriculture	D*
AlternativeEnergy	D*
ElectricPower	D*
Industry	53
N/A	34
Other	13
Total	100

Note: Items marked with D* included in "Other."

Table 7: Matching of DOE 1605(b) to Longtitudinal Research Database (LRD)

	1605(b)	LRD Plants	LRD plant-year observations (1992-2001)
Corporate participants with multiple plants	54	1762	8724
Corporate participants with a single plant	13	13	63
Plant-Level participants	16	16	122
Total	83	1791	8909

Table 8: Sample Statistics, LRD and Program Participants

Varibale	Summary Statistics	Full LRD sample (1992-2001)	Program Participants
ln(TVS)	Mean	7.80	10.99
(total value of	Standard Deviations	2.34	2.17

Table 9: DOE 1605(b) program, effect of program on logged cost of fuels after 2 years, Heckman-Hotz approach

Cohort	w/o correction	with correction	sample	participants
1994	-0.05 (0.05)	0.00 (0.24)	14686	343
1995	-0.06 (0.08)	0.30 (0.36)	24369	193
1996	-0.06 (0.20)	-0.55 (0.49)	22480	28
1997	-0.14 (0.08)	-0.79 (0.44)	13146	192
1998	-0.03 (0.09)	-0.51 (0.37)	21107	164
1999	0.09 (0.11)	-0.05 (0.48)	17667	162

Table 10: DOE 1605(b) program, effect of program on logged cost of electricity after 2 years, Heckman-Hotz approach

Cohort	w/o correction	with correction	sample	participants
1994	-0.09 (0.03)*	-0.86 (0.14)*	15319	343
1995	0.06 (0.06)	-0.71 (0.23)*	26123	193
1996	-0.17 (0.14)	-0.52 (0.35)	24089	28
1997	0.04 (0.05)	0.29 (0.24)	13754	192
1998	0.04 (0.06)	-0.25 (0.24)	22536	164
1999	0.05 (0.07)	0.29 (0.32)	18768	162

Table 11: EPA Climate Wise program, effect of program on logged cost of fuels after 2 years, Heckman-Hotz approach

Cohort	w/o correction	with correction	sample	participants
1994	0.06 (0.03)	0.20 (0.14)	18788	809
1995	0.06 (0.06)	0.08 (0.20)	32768	335
1996	0.04 (0.05)	0.26 (0.33)	29111	656
1997	-0.04 (0.05)	-0.33 (0.29)	16706	835
1998	-0.04 (0.04)	-0.49 (0.29)	28658	1063
1999	0.55 (0.14)*	0.41 (0.96)	18702	96

Table 12: EPA Climate Wise program, effect of program on logged cost of electricity after 2 years, Heckman-Hotz approach

Cohort	w/o correction	with correction	sample	participants
1994	0.06 (0.02)*	0.60 (0.09)*	19627	809
1995	0.04 (0.04)	-0.16 (0.14)	34880	335
1996	0.02 (0.03)	0.36 (0.21)	31253	656
1997	-0.02 (0.03)	-0.29 (0.18)	17534	835
1998	0.01 (0.02)	-0.75 (0.16)*	30693	1063
1999	0.05 (0.12)	-1.42 (0.71)*	33971	96

Table 13: DOE 1605(b) program, effect of program on logged cost of fuels over different horizons and pooled across cohorts (difference-in-difference based on propensity score nearest neighbor matching)

MATCHING MODEL (all models include logged value of shipments, cost of fuels, cost of electricity, and growth in shipments)							matched sample
Industry	x	x				x	
Region	x	x			x		
Quadratic	x			x	x	x	
MEAN							
1-year effect	0.02	0.03	0.04	0.07	0.04	0.04	547
	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	
2-year effect	-0.06	-0.04	0.02	-0.03	-0.11	0.01	349
	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)	
3-year effect	-0.08	-0.01	-0.07	0.00	-0.09	-0.05	298
	(0.07)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	
MEDIAN							
1-year effect	0.02	-0.01	0.03	0.01	-0.03	0.02	547
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	
2-year effect	0.03	0.01	0.03	0.04	-0.02	0.03	349
	(0.03)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	
3-year effect	-0.05	-0.01	-0.07	-0.02	-0.07*	-0.02	298
	(0.06)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	

Table 14: DOE 1605(b) program, effect of program on logged cost of electricity over different horizons and pooled across cohorts (difference-in-difference based on propensity score nearest neighbor matching)

MODEL (all models include logged value of shipments, cost of fuels, cost of electricity, and growth in shipments)							matched sample
Industry	x	x				x	
Region	x	x			x		
Quadratic	x			x	x	x	
MEAN							
1-year effect	-0.04*	0.00	-0.01	-0.02	0.00	-0.04	581
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	
2-year effect	-0.03	-0.03	-0.10*	0.00	-0.08	-0.05	388
	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	
3-year effect	-0.07	-0.11*	-0.04	-0.03	-0.01	0.05	336
	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	
MEDIAN							
1-year effect	-0.04*	-0.01	-0.03	-0.03	-0.02	-0.03*	581
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	
2-year effect	-0.03	-0.04	-0.05	-0.01	-0.05	-0.03	388
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	
3-year effect	-0.05*	-0.08*	-0.05	-0.04	-0.03	0.01	336
	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.02)	

Table 15: EPA Climate Wise program, effect of program on logged cost of fuels over different horizons and pooled across cohorts (difference-in-difference based on propensity score nearest neighbor matching)

MODEL (all models include logged value of shipments, cost of fuels, cost of electricity, and growth in shipments)							matched sample
Industry	x	x				x	
Region	x	x			x		
Quadratic	x			x	x	x	
MEAN							
1-year effect	-0.06	-0.03	-0.04	-0.05	-0.05	-0.02	949
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	
2-year effect	0.04	0.02	0.00	0.02	-0.02	-0.04	830
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	
3-year effect	-0.02	-0.06	-0.09	-0.07	-0.07	-0.10	764
	(0.04)	(0.05	(0.04)	(0.04)	(0.05)	(0.05)	
MEDIAN							
1-year effect	-0.01	0.00	-0.02	-0.02	-0.01	0.00	949
	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	
2-year effect	0.03	0.03	0.02	0.01	-0.01	-0.03	830
	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	
3-year effect	-0.01	0.01	-0.10	0.01	-0.04	-0.04	764
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	

Table 16: EPA Climate Wise program, effect of program on logged cost of electricity over different horizons and pooled across cohorts (difference-in-difference based on propensity score nearest neighbor matching)

MODEL (all models include logged value of shipments, cost of fuels, cost of electricity, and growth in shipments)							matched sample
Industry	x	x				x	
Region	x	x			x		
Quadratic	x			x	x	x	
MEAN							
1-year effect	0.05*	0.06*	0.06*	0.04	0.04	0.08*	1004
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	
2-year effect	0.04	0.05*	0.05	0.03	0.05*	0.01	888
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	
3-year effect	-0.01	0.01	0.00	0.03	0.02	-0.02	837
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	
MEDIAN							
1-year effect	0.00	0.02	0.03	0.01	0.01	0.02	1004
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
2-year effect	0.02	0.05*	0.03	0.03*	0.01	0.02	888
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
3-year effect	-0.01	-0.01	-0.01	0.02	0.00	-0.02	837
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	

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Voluntary Agreements to Improve Environmental Quality: Are late joiners the free riders?

Magali A. Delmas * Maria J. Montes †

*University of California, Santa Barbara
†Carlos III University

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Within the context of environmental voluntary agreements (VAs), this paper analyzes how free riding affects the effectiveness of collective corporate political strategies that aim at shaping government policy. We demonstrate that substantive cooperative strategies are more likely to be pursued by firms that enter a VA at its initiation while free riding or symbolic cooperation is more likely to be adopted by late joiners. We demonstrate that late joiners and early joiners within VAs adopt different cooperative strategies because they face different institutional pressures. We also find that late joiners that cooperate only symbolically may endanger the overall effectiveness of a VA. Our analysis is based on the strategies of firms participating in the Climate Challenge Program established in 1995 by the U.S. Department of Energy (DOE) and the representatives of the national electric utilities to reduce greenhouse gas emissions.

VOLUNTARY AGREEMENTS TO IMPROVE ENVIRONMENTAL QUALITY:

ARE LATE JOINERS THE FREE RIDERS?

Magali Delmas*
Donald Bren School of Environmental Science and Management.
University of California,
Santa Barbara, CA 93106-5131
Tel: 805-893-7185
Email: delmas@bren.ucsb.edu

Maria J. Montes-Sancho.
Department of Business Administration
Carlos III University
Madrid (Spain)
Tel: (+34) 91 624 8639
Email: mmontes@emp.uc3m.es

* Corresponding author. The authors acknowledge financial support from the following three sources: US Environmental Protection Agency Star Program grant #GR829687-01-0, the University of California, Santa Barbara, and the Spanish Ministry of Education and Science grant # SEC2001-1578-C02-01 and SEJ04-07877-C02-02.

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Within the context of environmental voluntary agreements (VAs), this paper analyzes how free riding affects the effectiveness of collective corporate political strategies that aim at shaping government policy. We demonstrate that substantive cooperative strategies are more likely to be pursued by firms that enter a VA at its initiation while free riding or symbolic cooperation is more likely to be adopted by late joiners. We demonstrate that late joiners and early joiners within VAs adopt different cooperative strategies because they face different institutional pressures. We also find that late joiners that cooperate only symbolically may endanger the overall effectiveness of a VA. Our analysis is based on the strategies of firms participating in the Climate Challenge Program established in 1995 by the U.S. Department of Energy (DOE) and the representatives of the national electric utilities to reduce greenhouse gas emissions.

Keywords: Free Riding, Collective Action, Institutional Theory, Symbolic Action, Environmental Voluntary Agreements, Public Good, Non-Market Strategy

INTRODUCTION

The literature on corporate political strategy focuses on the strategies used by firms to shape government policy (Baron, 1995; Baysinger, 1984; Hillman, Keim, & Schuler, 2004; Keim & Baysinger, 1988; Keim & Zeithaml, 1986). This line of research makes important strides to explain the rationales behind firms' political strategies, such as hiring lobbyists and forming political action committees (Baron, 2005; Hillman & Hitt, 1999). An important task for scholars and practitioners is to assess the degree of effectiveness of corporate political strategies. Corporate political activity represents a classic problem of collective action because legislative and regulatory decisions are not selective and affect all firms, even if they do so unevenly (Olson, 1965). Therefore, the benefits that firms seek from their corporate political activity will accrue, to some degree, to other firms regardless of each firm's contribution. Because of this, firms may be tempted to behave opportunistically and free ride on the corporate political activity of others (Yoffie, 1987). This is particularly true for collective strategies that engage several firms (Hillman & Hitt, 1999). Due to this potential for opportunistic behavior, collective political strategies are risky. If too many firms free ride, their effectiveness may be undermined. It is important for both firms and policy makers and to assess the risks and to understand under what conditions collective strategies could be attractive options.

However, this task has proven difficult both theoretically and empirically (Schuler, 2002). One of the research challenges is to assess effectiveness when firms' political strategies are carried out collectively via coalitions, partnerships and through trade associations. Collective political action complicates the analysis of a single firm's political action because it is difficult to identify each firm's contribution (King & Lenox, 2000; Schuler, 2002). Another complicating factor is that individual contributions may vary over time (Lenway & Rehbein, 1991).

In this paper we address these challenges with the analysis of the effectiveness of collective political strategies in the context of the natural environment. We examine firms' participation in the Climate

Challenge Program, a Voluntary Agreement (VA) established in 1995 by the U.S. Department of Energy (DOE) and representatives of the national electric utilities, to reduce greenhouse gas emissions and potentially mitigate the need for regulation in this arena. Our objective is to understand whether participants in the program reduced their emissions significantly more than non-participants and to understand differences in levels of cooperation within participants of the program. We hypothesize that firms' level of participation in the program vary with the timing of entry into the program and that early joiners are more likely to contribute substantially to the program than late joiners. We argue that these different types of cooperation are explained by the different institutional pressures and incentives that early and late entrants experience. Through an analysis of levels of cooperation within the Climate Change Program, this study contributes to the corporate political strategy literature by expanding the understanding of free riding and potentially the effectiveness of collective corporate political strategies. Further, by focusing on how institutional mechanisms, and political pressures frame selective incentives, our study combines previously separate theoretical perspectives to provide an explanation of various strategic behaviors within collective corporate actions, as well as how these vary over time.

EARLY AND LATE JOINERS OF COLLECTIVE POLITICAL STRATEGIES

Building on collective action theory, the corporate political strategy literature argues that firms participate in collective corporate strategies primarily for material rewards rather than for the collective or public good that is at issue (Lenway & Rehbein, 1991; Yoffie, 1987). For example, Lenway and Rehbein use a cost benefit framework to predict a firm's involvement (Lenway & Rehbein, 1991). Thus the primary mechanism for participation has been shown to be economic. Other scholars have identified additional types of rewards for acting collectively which can include social rewards (such as enhanced reputation) and purposive rewards (doing the right thing) (Wilson, 1973). For instance, firms acting collectively in the context of the natural environment want to convince regulators that their voluntary practices can be legitimately considered within a "generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs and definition" (Suchman, 1995: 574). Therefore the rewards that firms are seeking may be influenced by the social context in which the collective action initiative is implemented, a context that may vary geographically but also over time. For example, regulators and other organizations may find voluntary activities more legitimate once they have diffused among a larger set of firms. While the corporate political strategy literature has identified how differences in national institutional environments across countries drive differences in firms' political action, this stream of research still pays little attention to the social context in which firms operate and to the importance of changes over time (Bonardi & Keim, 2005; Hillman, 2003). Furthermore, collaborative behavior is often treated as a dichotomous variable with "participation" in collective action, becoming, with "non participation," the only alternatives when, in reality, collective behavior is much more nuanced. This is because firms' can adopt various levels of participation within collective action and also because behavior may change over time. Several scholars within the tradition of corporate political strategy research have begun to identify the selective incentives and mechanisms that trigger different levels of cooperation and how these vary temporally (Lenway & Rehbein, 1991; Yoffie, 1987).

The institutional literature provides an interesting, complementary approach to understand how social context shapes organizations' behavior. Institutionalists have argued that early adopters and late adopters of management practices and technologies face different pressures from their institutional environment and therefore may implement the same practice differently (Tolbert & Zucker, 1983; Westphal, Gulati, & Shortell, 1997). Using the case of the diffusion of civil service reform, Tolbert and Zucker demonstrate that first movers are mainly interested in the technical efficiency of a practice while followers are more subject to institutional pressure. They argue that first movers adopt management practices because "of real needs." They also find, in contrast, that followers do not implement a practice because of its merits but because other organizations do. Westphal, Gulati and Shortell also show that early adopters of total quality management practices in hospitals seek efficiency gains while later adopters aim at increasing their legitimacy (Westphal et al., 1997). In addition, institutionalists contend that symbolic adoption, or decoupling of formal organizational structures from actual practices in the organization, is more likely when institutional forces are present and when a practice is adopted for legitimacy (Meyer & Rowan, 1977) rather than efficiency reasons. The institutional literature shows that managers can increase the legitimacy of their organization by adopting governance structures without changing actual practices, and that late joiners are more likely to act in this way (Westphal & Zajac, 1994; Zajac & Westphal, 1995).

In this paper, we combine corporate political strategy theory with institutional theory to propose a model of collective corporate political activity where private incentives are institutionally shaped. We show that private incentives vary with the timing of joining collective corporate activity and that symbolic cooperation is more likely with late joiners than with early joiners of collective corporate political activity. In this endeavor, we follow the path of Oliver, who argued for the integration of institutional theory with research on strategic motives (Oliver, 1991). Our model differs significantly from previous analyses and yields new findings on the effects of institutional and political pressures on corporate political strategies. While in previous studies institutional pressures lead to isomorphism or conformity, in our model, institutional pressures could lead to strategic behavior and manipulation. In addition, we build on the work of Bansal who challenged the institutional assumption that institutional pressures are only present in the later stages of the adoption of a management practice (Bansal, 2005). We propose that early joiners may not just seek technical efficiency but may respond to institutional pressure while late joiners may not seek only legitimacy but may want to take advantage of the technical benefits of participation.

CORPORATE POLITICAL ACTIVITY THROUGH ENVIRONMENTAL VOLUNTARY AGREEMENTS (VAS)

In this study, we focus on collective corporate political strategies through environmental voluntary agreements (VAs) between firms and regulatory agencies. We examine the cooperative strategies of firms within the Climate Challenge Program, a VA established in 1995 by the U.S. DOE and national electric utilities to reduce greenhouse gas emissions. VAs are "collaborative arrangements between firms and regulators in which firms voluntarily commit to actions that improve the natural environment" (Delmas & Terlaak, 2001: 44). VAs vary in objectives and designs, and, as a result, offer different kinds of strategic opportunities for participating firms to influence political outcomes (Lyon & Maxwell, 2004). VAs can be designed to preempt regulation as a response to a regulatory threat, to provide flexibility with the implementation of existing regulation, and/or to influence the form of future regulation (Decker, 1998; Delmas & Terlaak, 2001; Maxwell & Decker, 1998; Segerson & Miceli, 1998). The Climate Challenge Program, created by the electric utility industry to pre-empt legislation relating to climate change, is a form of VA also known as a "negotiated agreement," one typically negotiated by an industry trade association (Delmas & Terlaak, 2001; Maxwell, Lyon, & Hackett, 2000), and therefore a type of collective corporate political strategy.

VAs differ from other political strategies identified in the literature such as information-based strategies, financial-incentives strategies, and constituency-building strategies (Hillman & Hitt, 1999). For example, although VAs might include an exchange of information between firms and regulators, this is not their main objective. VAs represent a quid pro quo where firms commit to provide a public good voluntarily in return for a potential private benefit. VAs also differ from self-regulation strategies that represent collective political strategies undertaken without government involvement (Bonardi & Keim, 2005; King & Lenox, 2000). There are two different forms of cooperation at work within VAs. The first one is among firms within the industry who jointly decide to reduce their environmental impact voluntarily. This type of cooperation is usually orchestrated by the trade association. The second form of cooperation occurs between firms and government where they agree on a mutually acceptable arrangement.

The last decade, has seen an increase in the use of such agreements with more than 300 VAs in place in the European Union (Borkey & Leveque, 1998), and around 200 VAs launched in the U.S. (Darnall & Carmin, 2005). However, because most of these agreements lack explicit measures to sanction free riders, there are concerns that firms may enter a VA and cooperate only in a token fashion rather than undertake effective actions to reduce their impact on the environment (King & Lenox, 2000; Rivera & DeLeon, 2004).

Because VAs are a relatively recent phenomenon, "there are relatively few empirical studies assessing the specific impacts of VAs on emissions reductions, compared to business-as-usual emissions abatement" (Baranzini & Thalmann, 2004: 28). Indeed, rare are the analyses investigating whether participating firms actually meet the requirements of the programs (Arora & Cason, 1996; Khanna & Damon, 1999; King & Lenox, 2000; Rivera, 2002; Videras & Alberini, 2000; Welch, Mazur, & Bretschneider, 2000). Most importantly, these studies seldom investigate differences in cooperative behavior within VAs that may explain why or why not requirements are met.

Firms face three choices of participation in a VA: first, participation and -cooperation where they improve their environmental performance. In undertaking actions to improve their environmental performance, these participating firms must accomplish organizational or technological changes that could lead to such improvement. Thus, for these firms, participation in a VA is coupled with practical changes at the operational level. We refer to this type of participation as substantive cooperation. Second, firms can refuse to participate in the collective activity and free ride on the behavior of other members of the industry who participate fully in the VA. Although the literature has focused mostly on these two options, we take up the argument that there is a third: participation in the VA without substantive implementation of the VA's requirements. That is to say, firms might participate without actually improving their environmental performance. In this sense, participation in VAs may be only symbolic as firms decouple their practical actions from formal organizational structures (Meyer & Rowan, 1977). Consequently, we refer to participation in a VA without performance improvement as symbolic cooperation. In addition to non-participants, firms that undertake symbolic cooperation are also free riding on the effort of firms that undertake substantive cooperation.

THE CLIMATE CHALLENGE PROGRAM

The Climate Challenge Program was a VA between the U.S. DOE and electric utility industry representatives to reduce, avoid or sequester greenhouse gas emissions through voluntary commitment.[1] The Program was initiated just after President Clinton launched, in 1993, the Climate Change Action Plan (CCAP), where he announced the nation's commitment to reducing U.S. emissions of greenhouse gases to their 1990 levels by the year 2000. At the time, the Clinton Administration was investigating the possibility of implementing a tradable credit system, where firms that exceeded the limits, or "caps," on emissions could buy emissions credits from entities that were able to stay below their designated limits. The issue of greenhouse gases emissions had become a widely salient issue--a public policy likely to be of interest to a large segment of likely voters and to receive considerable attention (Bonardi & Keim, 2005). As they were among the leading generators of greenhouse gases in the U.S., electric utilities were particularly worried about the possibility of new regulations being implemented.[2] The Climate Challenge Program was clearly an attempt by the industry to promote voluntary approaches and negate the need for

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[1] The industry representatives were Edison Electric Institute, American Public Power Association, National Rural Electric Cooperative Association, Large Public Power Council and Tennessee Valley Authority.

future greenhouse gas regulations. The Edison Electric Institute, the trade association for U.S. shareholder-owned electric companies, was instrumental in the creation of the Program, aiming to demonstrate that emissions reductions could be achieved voluntarily rather than through mandated regulation. Tom Kuhn, president of the Edison Electric Institute, made this clear in a statement to the press one year after the start of the Program: "Our industry has demonstrated that a vigorous, voluntary approach toward curbing greenhouse gas emissions is the way to go. We will continue to put these programs in place while opposing government and international mandates that would cost the U.S. economy thousands of jobs. Utilities have met the challenge and are continuing their leadership role in working with the Government to find creative and effective ways to improve the environment." [3] The U.S. DOE also explicitly stated on the Climate Challenge website that: "an effective voluntary effort may negate the need for legislation or regulation" and that "emission reductions could possibly be used for 'credit' against future mandatory requirements."[4]

The Climate Challenge Program consisted of (i) a general Memorandum of Understanding signed by the national electric trade organizations and the DOE on Earth Day 1994 and (ii) individual agreements signed by the utilities from 1995 to 1999. In these agreements, each participating firm committed to (1) reduce, avoid or sequester greenhouse gas emissions, (2) report annually its achievement and activities and (3) confer periodically with the DOE over evaluations of its progress and discussions of the adjustment. Each participating firm had to establish the level and detail of its commitment to be reached by the year 2000. Such commitments included efficiency improvement in generation, fuel switching to lower the use of carbon fuels such as natural gas, and increased generation using non-carbon sources such as renewable

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[2] About 40.5 percent of the U.S. CO_2 emissions were attributed to the combustion of fossil fuels for the generation of electricity in 1998 (DOE/EIA-0573(98), 1999).

[3] Newswire Association 1996 "U.S. Electric Utility companies are not waiting to reduce greenhouse gas emissions" April 12, 1996, Financial News.

energy and nuclear power. In 2000, at the end of the Program, 124 participation agreements had been signed. The signatories represented approximately 60% of the 1990 U.S. electric utility generation and utility carbon emissions (DOE/FE0355, 1996).

There were no direct sanctions for firms that did not participate in the Program or that participated only symbolically. Even though each participating utility was subject to requirements to provide information about its greenhouse gas emissions, no limits were set on such emissions. Although the DOE reviewed the participants' annual, self-reported information during the course of the Program, no penalties were imposed on firms that did not meet their commitments. Furthermore, the initial Memorandum of Understanding stipulated that utilities would be allowed to quit the Program whenever they chose "without penalty and without being subject to remedies at law or equity." [5]

The Climate Challenge Program exhibits features that make it particularly appealing to study the differences over time in cooperative strategies among participants and between participants and non-participants. The Program permitted firms to enter the VA at various dates during its operation. This allows us to compare the cooperative behavior of early and late joiners. Furthermore, approximately half of the investor-owned electric utilities joined the Program. This enables a comparison of cooperative behavior between participants and non-participants.

Welch, Mazur and Breschneider evaluated the effectiveness of the Climate Challenge Program during its early years (Welch et al., 2000). According to their results, participating firms did not reduce their emissions significantly more than non-participants during the 1995-1997 period. The authors warned that these results have to be viewed with caution based as they are on a study of only the first two years of the Program and only the top 50 utilities. In contrast, our study focuses on the entire life of the Program,

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[4] See http://www.climatevision.gov/climate_challenge/factsheet.htm last accessed on March 2006.

through 2000, allowing us not only to assess differences between late and early joiners, but also to consider a longer time period when evaluating the results of firms' CO_2 reduction efforts. In addition, we include a larger and more representative sample of firms (133 utilities), incorporating more variability in firm characteristics. The firms in our sample produced 61% of the U.S. electricity generated from 1995 to 2000 and 75% of the CO_2 emissions emitted by the electricity sector during that period. Moreover, we sought not only to analyze the overall effectiveness of the Climate Challenge Program but also to understand which firms within the Program were free riding and which ones undertook substantive cooperation.

HYPOTHESES

We develop below a model based on the concepts from institutional theory and the corporate political strategy literature to explain substantive and symbolic collective corporate strategy. We argue that first movers and late joiners face different institutional pressures that impact the type of cooperative behavior they will pursue within VAs. We first develop hypotheses on the institutional pressures that drove a firm's decision to participate early in the Climate Change Program, to participate late, or to remain a non-participant. We focus on the two major constituents of the institutional environment of utilities: namely the Government and the industry association and on how utilities' relationship with these prior to the Program can explain collective cooperative behavior.

Political Pressure

Even though the creation of a VA might help an entire industry avoid potential future regulations, not all firms will experience the same level of threat from these potential regulations and therefore neither the same benefits from pre-empting regulation. The corporate political activity literature shows that firms'

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[5] See http://www.climatevision.gov/climate_challenge/cc_accordxNSTATESP.htm

incentives to undertake corporate political activity vary according to the national regulatory environment in which they operate (Hillman, 2003; Hillman & Wan, 2005; Murtha & Lenway, 1994). Within a single country, states and smaller areas with governmental authority issue different rules and regulations. We argue that differences in sub-national politics will impact the likelihood that firms will undertake corporate political activity at the national level. In the U.S. context, for example, environmental legislation at the federal level is usually implemented by states. So firms located in states with more stringent regulations will be under more pressure to undertake reductions in emissions, and will have more incentive to participate in corporate political strategies. Regardless of federal standards, companies also face a complex set of environmental standards which again vary by state. A program that demonstrates the effectiveness of voluntary practices at the national level could also help influence future regulation at the state level.

Furthermore, in a federal context, firms may try to influence state congressional representatives by participating in VAs. These representatives may pay more attention to strategies undertaken by companies in their district. When congressional representatives are more prone to vote positively on more stringent environmental regulation, firms have more incentive to show them that improved environmental performance can be achieved voluntarily.

Additionally, there may be firm-specific characteristics that tend to make a firm subject to greater levels of political pressure (Bansal, 2005). For example, some firms may be temporarily or permanently more dependent than others on governments to obtain licenses to operate. In the electric utility sector, this may happen when firms are undergoing rate changes or when they want to bring new plants online (Bonardi, Holburn, & Vanden Bergh, 2006).

We argue that firms subjected to greater political pressure were more likely to have participated in the early stages of the Climate Challenge Program because the potential individual benefits they would derive from the VA would outweigh the costs of organizing a collective effort. These firms might have helped to create the VA regardless of the action of other firms. In that sense, their decisions to participate in the VA resemble individual decisions rather than a collective decision (Hillman & Hitt, 1999). Timing is important for firms subjected to a great deal of political pressure. They need to move as early as possible to pre-empt the evolution of the political issue at stake into a potentially more costly regulation (Baron, 2003; Bonardi & Keim, 2005). This is because it is usually more difficult for firms to advance their agendas once issues have become widely salient (Bonardi & Keim, 2005). In summary, firms subjected to greater levels of political pressure within the state in which they operated were more likely to be early joiners of the Climate Challenge Program than firms that did not face such levels of pressure. It follows that firms operating in states with lower levels of political pressure would not have experienced the same desire to participate in a program at its initiation, and would have been more likely to wait and see what others do.

We therefore hypothesize as follows:

> *Hypothesis 1a. Early participants in the Climate Challenge Program were subjected to greater political pressure than late joiners and non-participants.*
>
> *Hypothesis 1b Early participants in the Climate Challenge Program were more dependent on local and federal regulatory agencies than late joiners and non-participants.*

Links with the Industry Association

Scholars have shown that the structure of communication networks influences the order in which potential adopters receive information about innovations and therefore the order in which they adopt them (Abrahamson & Rosenkopf, 1997; Westphal et al., 1997). For example, Westphal, Gulati, and Shortell (1997) showed that in earlier stages of the diffusion process, communication ties may help match innovations to organizations' unique efficiency needs. In the context of corporate political strategies, trade associations have been shown to play a central role in facilitating the emergence of such strategies (King & Lenox, 2000). Trade associations constitute industry networks that provide a central forum for communication about political issues at stake (Rees, 1997). Firms participating in a trade association are therefore more informed about the impact of potential regulations on their activities than firms that do not participate in the association. They are also more likely to be informed about the negotiations that lead to the creation of a VA.

Firms participating in a trade association are also more likely to be exposed to normative pressure exerted by their peers as divergence of opinion may be more difficult in a context of continuous relations. Furthermore, because firms pay significant fees to join an association, firms that choose to join may do so because they agree with the policy of the association. Firms that are part of a trade association are therefore more likely to be the first participants in an action initiated by the association. We therefore propose the following:

Hypothesis 2. Early participants in the Climate Challenge Program were more likely to be members of the industry trade association than late joiners and non-participants.

Firms' Previous Environmental Investment

Firms' resources and the ability of a firm to sustain the cost of collective action have been shown to be important explanatory factors in firms' involvement in such action (Lenway & Rehbein, 1991; Meznar & Nigh, 1995; Schuler & Rehbein, 1997). There are two competing arguments about the relationship between resources and firms' involvement in collective corporate political actions such as VAs: first, that firms with a high level of resources or slack resources will be able to afford political action; second, that firms with fewer resources will seek a political solution to their limited resources.

In our case, the levels of investment in environmental performance improvements prior to the initiation of the VA may have had an impact on the potential benefits of participating in a voluntary program. "Greener" firms, ones that have already invested in reducing their environmental impact before the initiation of a related VA, could be more likely to join one provided that it gives credit for their earlier efforts. On the other hand, "browner" firms, those that have not invested in reducing their environmental impact prior to a VA, may use the agreement to improve their reputation as they need such improvement more than the others. Because there are rationales for both greener and browner firms to join a VA, the empirical evidence is mixed. One set of empirical studies shows that firms with larger percentages of emission reductions prior to making their participation decisions were more likely to participate in voluntary activities mainly to publicize their efforts (Arora & Cason, 1996; Khanna & Damon, 1999). In contrast, other studies show that firms with a lower environmental performance are more likely to undertake voluntary activities largely because they were under more pressure to do so (Bansal and Hunter, 2003; Konar & Cohen, 1997; Videras & Alberini, 2000). We argue below that both greener and browner firms had incentives to participate in the Climate Change Program but as affected by circumstances that varied over time.

Companies that have taken early steps on voluntary reductions of their emissions may find it advantageous to compel other, less committed competitors to follow suit (Hoffman, 2005). Scholars have suggested that chemical companies that had undertaken investments in safety and environmental improvements were behind the origin of the industry program Responsible Care, and that these companies, among other things, were looking to impose a cost on their competitors (King & Lenox, 2000; Reinhardt, 2000). In addition, in the case of the Climate Challenge Program, the DOE suggested that participating firms could potentially get future "credits" for their emissions reductions in the event that a tradable permit system were put into place. This provided an incentive for greener firms to participate, and to put their efforts on the record as soon as possible. Assuming that a future regulatory target would require a firm to reduce its emissions by a percentage from some base year, firms that act early to reduce CO_2 yet fail to register those reductions early under a voluntary scheme are in danger of being penalized.[6] In summary, firms that have already started efforts to reduce their emissions are more likely to benefit from a program that gives them credit for their past experience, regardless of what other firms contribute.

In such a context, it seems logical that firms that have not yet undertaken efforts to reduce their emissions would resist the costs associated with initiating such a program. However, such firms could still benefit from participating in a program if it allowed them to be associated with greener firms. Researchers have highlighted how the nature of early adopters of a technology or a management practice can impact future adoption (DiMaggio & Powell, 1983; Rosenkopf & Abrahamson, 1999). In particular, Rosenkopf and Abrahamson show that initial adopters with good reputations can pressure other organizations to adopt a practice (Rosenkopf & Abrahamson, 1999). Principally, followers might want to be associated with "high-quality" first adopters to increase their external legitimacy. While late joiners may not have been subjected to the same political pressure to participate in a VA as early joiners, as time passes non-participants could become singled out as the black sheep of the industry, especially if their environmental performance is poorer. This situation arose with the Climate Challenge Program when non-participant firms where identified by some NGOs as bad performers. For example, nine months after the creation of the Program and the main meeting where the majority of participants agreed to participate, a report by the Council on Economic Priorities (CEP), a non-profit organization, put the utility Virginia Power on a list of the nation's worst polluters for "failing to participate in the U.S. Dept. of Energy's Climate Challenge Program for reducing greenhouse gases, and for Virginia Power's lack of a formal environmental policy."[7]

Therefore, we hypothesize that the level of environmental effort undertaken by a firm prior to the start of the Climate Challenge Program impacted not only the firm's participation decision but also the timing of

[6] "Baseline protection" is the term of art used by firms and regulators to describe this phenomenon.

its participation. While firms that undertook environmental efforts prior to the creation of the Program had incentives to participate early to influence competition, the incentives for firms that had not yet undertaken such efforts became stronger for late joiners after a "critical mass" of participants had joined. This leads us to propose:

Hypothesis 3. Late joiners of the Climate Challenge Program were less likely than early joiners and non-participants to have undertaken efforts to reduce their emissions prior to the start of the Program.

Substantive Versus Symbolic Cooperation

Because firms' incentives are shaped by different institutional pressures that can vary over time, we argue that early joiners are more likely to undertake substantive actions to reduce their environmental impact and that late joiners are more likely to participate only symbolically in a program. Greater political pressure and strong trade association connections put early joiners under more scrutiny than late joiners. Additionally, if early joiners wish to impose a cost on competition, they need to provide evidence to their competitors that they are undertaking substantive action in order for their claim of reducing their emissions to be credible.

Institutional studies have found that firms might engage in symbolic management as a means of responding to institutional pressure (e.g., Edelman, 1992; e.g., Westphal & Zajac, 1998). As Oliver (1991: 155) notes, "from an institutional perspective…the appearance rather than the fact of conformity is often presumed to be sufficient for the attainment of legitimacy." In this way, firms adopting symbolic practices are "conforming" but to a lesser extent. However, while institutional pressures lead to isomorphism, symbolic participation could be seen as a departure from isomorphism. Thus an explanation of symbolic

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[7] Southeast Power Report (1995): "Southern Company, Dominion Resources Dismiss 'Worst Polluter Allegations" Dec. McGraw-Hill, Inc: 13.

participation based on legitimacy does not explain specifically why the firms with worse performance are the ones seeking symbolic participation.

Indeed, symbolic participation could also been seen as manipulation by corporations that do not want to conform but use the institution to a different strategic end than conformity with the aims of the program, that of deflecting institutional pressures. Thus, firms could decide to participate in the Climate Challenge Program to avoid criticism for not joining, but without adopting any of the substantive changes associated with participation. Firms not entering into a VA may not only be considered to lack legitimacy, they might also send a negative signal, and encourage critics to review their performance Firms, then, may join a VA as a way to hide their poor performance.

Late joiners may perceive that the risks associated with symbolic participation are small. If a program clearly states that no penalties will be associated with free riders, firms face no threat of punishment for symbolic cooperation. Joining after the announced success of a program, a firm may not fear damaging the reputation of the program or being singled out. For example, in the case of the Climate Challenge Program, the DOE announced in October 1996 that the electric utilities participating in the Program had committed to reduce, avoid or sequester more than 44 million metric tons of carbon equivalent (MMTCE) by the year 2000. This represented approximately half (45%) of the total cuts that the U.S. pledged at the world environmental summit under FCCC in 1992 (DOE/FE0355, 1996). It is therefore possible that companies joining a program after such a point might have believed the program was already successful and that their lack of contribution would not endanger the program's perceived effectiveness. In addition, media attention to a VA may decline over time to focus on other issues (Hoffman, 1999). Later joiners may therefore be under less scrutiny than early joiners.

In summary, because early and late joiners face different incentives and pressures, we expect that they will adopt different cooperative behaviors within VAs. Specifically in relation to the Climate Change Program, we hypothesize as follows:

Hypothesis 4. Late joiners were more likely to cooperate symbolically while early joiners were more likely to cooperate substantively within the Climate Change Program.

EMPIRICAL ANALYSIS

To test our hypotheses, we collected data from different sources. From the DOE, we used the Climate Challenge "participation accords" and "letters of commitment" to identify participating firms.[8] We also used data on utilities' characteristics and environmental performance from the U.S. Federal Energy Regulatory Commission (FERC) Form Number 1 (U.S. DOE, FERC Form 1, from the U.S. Energy Information Administration (Forms EIA-860, EIA-861 and EIA-906), and from the U.S. Environmental Protection Agency Clean Air Market Program's website. After merging these databases, we retained 133 investor-owned electric utilities representing 61% of the total U.S. electricity production by utilities from 1995-2000 and 75% of the CO_2 emissions emitted by the electric sector during that period. Out of these 133 firms, 82 participated in the Climate Challenge Program. Our sample includes 46% of the total 124 signed agreements with the DOE.[9]

Estimated Model and Dependent Variables

Our goal was to examine the motivations that explain utilities' participation in the Program and to assess their performance outcomes. The decision to participate in the Climate Challenge Program and the performance results were likely to be influenced by the same factors (Anton, Deltas, & Khanna, 2004;

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[8] Utilities with more than 50,000 customers develop individual participation accords while those with fewer than 50,000 customers submit letters of commitment. http://www.climatevision.gov/climate_challenge/cc_accords.htm

Khanna & Damon, 1999). To compare emissions outcomes between participants and non-participants of the Climate Challenge Program, thus, to isolate the impact of participation in a VA on environmental performance, we needed to correct for a potential endogeneity problem (Hartman, 1988; Heckman, 1978; 1979; Maddala, 1983). We therefore used a two-stage estimation model that determines simultaneously the outcome of program participation (here CO_2 emission rate) and the determinants of a firm's participation decision to address this issue (Khanna & Damon, 1999; King & Lenox, 2000; Rivera, 2002; Welch et al., 2000).

The other empirical challenge that we faced and that differed from previous studies was that, in the first-stage equation, we wanted to predict not only the probability of participation in the VA, but also to differentiate between early and late joiners. Because we wanted to understand differences among various types of participants, we modified the traditional first-stage equation to predict the likelihood that a firm would be a non-participant, a late joiner, or an early joiner. In the second stage, we used the predicted values of these various types of participants to test how voluntary cooperative strategies contributed to pollution reduction.

In the ***first stage regression***, we predict participation in the VA using two models. First a binary logit model predicts participation in the Climate Challenge Program and second a multinomial logit model predicts the types of participant representing three groups: (1) non participant, (2) late joiner and (3) early joiner. Both models are estimated by maximum likelihood (Greene, 2003).

Participation. This binary variable represents the decision of a firm to participate in the Climate Challenge Program. It takes a value equal to 1 the year of enrollment and the following years, and 0 otherwise. The Climate Challenge participation agreements were used to identify participants and non-

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[9] An agreement can represent several firms. Non-investor owned utilities are not included in our analysis as they are not part of

participants and the year of enrollment in the Program. These were accessed through the DOE's website. We use this measure as a dependent variable in the binary logit model for the first stage regression (Model 1a). The binary logit model provides an estimation of the likelihood that a given electric utility would participate in the Climate Challenge Program. This model allows us to analyze the aggregate effectiveness of the Program in the second stage regression.

The participation model in the binary logit model is specified as follows (first stage):

$$\Pr ob\,(\text{Participation}_{i,t} = 1) = F(Z_{i,t-1}'\beta) \qquad \text{(Model 1a)}$$

where ***Participation*** is the binary dependent variable of this first stage, $Z_{i,t-1}$ is the set of exogenous independent variables used as instruments, and F is the cumulative logistic distribution ($F(x) = e^x/(1+e^x) = 1/(1+e^{-x})$).

Type of Participant. This categorical variable represents the type of participant within the Climate Challenge Program. Early participants were those that enrolled in the Program during the official ceremony organized in March 1995 by the DOE, and late participants were those that enrolled in the Program at a later date (end of 1995 to end of 1998). The official ceremony of March 1995 was a high visibility event involving high level officials such as Al Gore. It marked the conclusion of more than a year of active negotiations between the industry and the DOE concerning the general "rules" of the Climate Challenge Memorandum of Understanding as well as the specific items included in each signed agreement. Utilities that signed the agreement after the official ceremony did not participate in the initial setting and configuration of the program. They did not show interest only after the Program was up running. There is therefore a significant difference between early joiners who participated in initial negotiations and late joiners who joined after the program was established and publicized outside of the

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the Federal Energy Regulatory Commission (FERC) Form 1 database.

industry. We created a categorical variable and coded non-participants as 1, late joiners as 2, and early joiners as 3. [10] This measure is used as a dependent variable in the multinomial logit model for the first stage regression (Model 2a). Our sample includes 82 participating firms with 61 early joiners and 21 late joiners. The number of non-participating firms included in the sample is 51. The multinomial logit model provides an estimation of the likelihood that a given electric utility would participate in the Climate Challenge Program as a late joiner or will participate as an early joiner. This model allows us to compare the effectiveness of different types of participants. Multinomial logit handles non-independence of these groups by estimating the models for all outcomes simultaneously, using one group as a baseline.

The participation model in the multinomial logit model is specified as follows (first stage):

$$\Pr ob\,(\text{Types of Participant}_{i,t} = j) = \frac{e^{Z_{i,t-1}'\beta^{(j)}}}{\sum_{j=1}^{J} e^{Z_{i,t-1}'\beta^{(j)}}} \quad \text{(Model 2a)}$$

where ***Types of Participant*** is the categorical dependent variable of this first stage and takes a value of 1 to 3 (i.e. $j = 1, \ldots, 3$), depending the firms' group and $Z_{i,t-1}$ is the set of exogenous independent variables used as instruments.

In the ***second stage regression***, we use the predicted values of participation and the types of participant to test whether they explained reductions in emissions. We used the changes in rates of CO_2 emissions (CO_2/Generation) from one year to another to assess the changes in the level of emissions.

Changes in CO_2 rates. We assess the outcome of the Climate Challenge Program in terms of changes over time from 1996 through 2000. The variable changes in CO_2 emissions rates reflects the changes in the rates between two consecutives years. We computed the differences in CO_2 emissions' rate between

[10] Of the 124 agreements signed with the DOE, seven agreements were signed at the end of 1995, one agreement in 1996, eight in 1997 and two agreements in 1998. An agreement can represent several firms because they can be signed at the holding level.

two consecutive years across the whole period of the program. The U.S. Environmental Protection Agency reports under the Clean Air Market Program the amount of CO_2 emissions emitted by each utility. We divide this by the amount of net generation reported on Form EIA-906.

$$\text{Second Stage Dependent variable: Change in CO2 rate}_{\text{i}} = \left(\frac{\text{CO2 emissions}_{\text{i,t}}}{\text{Generation}_{\text{i,t}}}\right) - \left(\frac{\text{CO2 emissions}_{\text{i,t-1}}}{\text{Generation}_{\text{i,t-1}}}\right)$$

This variable is normally distributed; we therefore use pooled regression (Model 1c) and random-effect general least squares (GLS) panel regression (Model 2c).

The formulations using this variable are the following (second stage):

$$\text{Changes in CO2}_{\text{i}} = \delta \text{ Participation}_i + X_i'\gamma + \varepsilon_i \qquad \text{(Model 1c)}$$

$$\text{Changes in CO2}_{\text{i}} = \alpha \text{ Late joiners} + \eta \text{ Early joiners} + X_i'\gamma + \varepsilon_i \qquad \text{(Model 2c)}$$

where the variable changes in CO_2 emissions' rate is the dependent variable that we use to measure the outcome of the Climate Challenge Program. $Participation_i$ is the predicted probability of participation in the Climate Challenge Program obtained in the first stage using binary logit, and X_i is a set of control variables that could also explain reduction in the change of CO_2 emissions rate. The predicted probabilities for each group defined in the type of participant from multinomial logit are *late joiners* and *early joiners*. The category of *non-participant* is the baseline. The probability of participation is lagged 1 year because participation in the Program is associated with activities that need time to be undertaken, before they affects the emissions of the firm.

Independent and Control Variables in the First stage

The Climate Challenge Program started in 1995 and ended in 2000 but firms could only enroll until 1999. In the first stage, we examine the motivations that explain the utilities' participation in the Climate Challenge Program using the independent variables with 1 year lagged to avoid reverse causality.

Therefore, the independent variables used in the first stage are data from 1994 until 1998. As detailed in the previous section, we use several measures as proxy for political pressure. The first one represents the regulatory expenses of the utility. The second one is a measure emanating from political/legislative actors by the voting record of each state's congressional delegation. The third one represents a proxy of the resources of the states allocated to the environment as measured by the environmental agency employment to the total number of the state's employees.

Regulatory expenses. Following Welch et al. (2000), we include the annual amount of regulatory expenses paid by the firm as a proxy of regulatory agency pressure. The data came from the FERC Form Number 1, and report particulars of regulatory commission expenses incurred relating to prepare cases that are submitted to a regulatory body, or cases to which such a body was party. It includes, for example, fees paid to the Federal Energy Regulatory Commission or the costs of dockets.

League of Conservation Voters (LCV). We measure the pressure emanating from political/legislative actors by the voting record of each state's congressional delegation (members of the US Senate and US House of Representatives) in which the firm operates. Several researchers have used the scores of the League of Conservation Voters (LCV) as a measure of the elected representatives' preferences of a state (Hamilton, 1997; Hedge & Scicchitano, 1994; Kassinis & Vafeas, 2002, 2006; Lubell, Schneider, Scholz, & Mete, 2002; Ringquist & Emmert, 1999; Viscusi & Hamilton, 1999). Each year, the LCV selects environmental issues to constitute an "environmental agenda" with a panel comprising the main U.S. environmental groups. The organization then creates an index by counting the number of times each representative or senator in Congress votes favorably on the environmental agenda (e.g., on the global warning gag rule, tropical forest conservation, global climate change). The index ranges from 0 to 100, with 100 representing a record of voting for the environmental agenda in all cases. The variable is the average of the environmental scores of the U.S. House of Representatives and U.S. senators of the states where each utility operated (Kahn, 2002), weighted by the percentage of generation of each firm in each state for multi-state utilities.

State environmental employees. Following Kassinis and Vafeas (2006), we measure a state's long-term commitment to the environment through its investment in people as a ratio of the state's environmental agency employment to the total number of the state's employees. It captures the state's commitment to environmental protection and its institutional capacity to support its commitment. We collected the data on states' environmental agency employees from the Environmental Council of the States (ECOS), a national, nonprofit, nonpartisan association of states and territorial environmental commissioners, and obtained the total number of state employees from the U.S. Census Bureau.

Trade association membership. We measure the links between the trade association and the utilities using membership of the Edison Electric Institute (EEI). Created in 1933, EEI is the association of US shareholder-owned electric companies. Its members serve 71 percent of end use customers in the U.S., and generate almost 60 percent of the electricity produced by U.S. electric generators. The Edison Electric Institute works closely with all its members, representing their interests and advocating equitable policies in legislative and regulatory arenas. We created an indicator that reflects whether a utility was a member of the trade association taking the value 1, and 0 otherwise.

Environmental effort. Following Welch et al. (2000), we include a measure of a firm's environmental expenses as the ratio of the environmental expenses divided by total operations expenses. Data were obtained from the FERC Form Number 1. Under the category of environmental expenses, utilities report the expenses and costs incurred due to the operation of environmental protection facilities. This contains, for example, the costs of air and water pollution control facilities, noise abatement equipment, the preparation of environmental reports, etc.

In the first stage, we also control for additional variables that may affect the probability of a firm being an early or late joiner. These include the level of pollution in the state, a proxy for the environmental preference in the state, the productive efficiency of the firm, whether the firm is a big player in its states of operations, and the size of the firm as measured by its number of subsidiaries.

State pollution: Firms located in states with higher levels of pollution might be subjected to greater scrutiny by and pressure from environmental NGOs to undertake some action to reduce CO_2 emissions and to participate in the Program. Following King and Lenox (2000) and Kassinis & Vafeas (2002), we base the measure of pollution using the state's toxic emissions (the total amount of on- and off-site toxic release) for all sectors. We collected this information from the EPA's Toxics Release Inventory (TRI) database. The amount of total emissions is divided by the state's land area. We construct a firm-level measure weighting this ratio by the percent of electricity generated by the utility in each state and year.

Sierra Club. As have previous studies (e.g. Helland, 1998; Kassinis & Vafeas, 2002; Riddel, 2003) (Maxwell, Lyon, Hacket, 2000), we measure the environmental preferences of the population of the state in which a firm operates based on membership figures for one of the major environmental non-governmental organizations, the Sierra Club. The measure itself is the number of dues-paying Sierra Club members per 1,000 state residents.

Productive efficiency. The ability to produce electricity efficiently has an important impact on a utility's profitability and on the availability of slack resources as electric utilities are highly capital intensive (Delmas & Tokat, 2005). Therefore, productive efficiency can be an alternative way to control for the availability of slack resources. We estimate productive efficiency using Data Envelopment Analysis (DEA) (Banker, Charnes, & Cooper, 1984; Charnes, Cooper, & Rhodes, 1978). The DEA technique uses linear programming to convert multiple input and output measures into a single measure of relative efficiency for each observation. Our construction of the measure of productive efficiency is derived from the work of Delmas and Tokat (2005). Data came from the FERC Form Number 1 (U.S. DOE, FERC Form 1, 1994-1998). The productive efficiency of a firm in a specific year is computed by comparing it with all other firms in the same year, using a program written by Coelli (Coelli, 1996). We use the following items as *inputs*: labor cost; plant value; production expenses; transmission expenses; distribution expenses; sales, administrative and general expenses; and electricity purchased from other sources in megawatt hours (MWh) (Majumdar & Marcus, 2001). We consider the following *outputs*: quantities of low-voltage sales (residential and commercial); high-voltage sales (industrial, interchanges out, and wheeling delivered); and electricity for resale to other utilities in MWh (Roberts, 1986; Thompson, 1997).

Big player. Visibility affects the level of social pressure that a firm is subjected to (Pfeffer & Salancik, 1978). Research has noted that bigger and more visible firms are more likely to be the target of activism (Meznar & Nigh, 1995) and to participate in collective action (King and Lenox, 2000). To provide a proxy for visibility we follow Delmas and Tokat (2005), and note whether a firm was among the top four sellers in a state in any of the residential, commercial or industrial markets. For each year and state, we identify which firms were among the four big players in their states using the retail sales reported on Form EIA-861 for the period 1994-1998, assigning the value 1 when the firm was a big player and 0 otherwise.

Number of subsidiaries. The size of a company has been used as one of the main predictors of participation in political activity (Hillman et al., 2004). Size is often a proxy for the availability of resources within a firm but also of the ability of a firm to impact the results of collective action. As a proxy for the size of a utility, we include the number of subsidiaries that belong to a firm as taken from the FERC Form Number 1.

Year effects. We include dummy variables for the years 1996 to 1999 in the first-stage model. We omitted the 1995 dummy to avoid overdetermination.

Independent and Control Variables in the Second stage

In the second stage, in addition to the predicted probability of participation in the Climate Challenge Program, we include variables that could also explain changes in the CO_2 emissions rate during the 1996-2000 timeframe. This includes the variable of environmental effort from the first stage.

Change in the percentage of fossil fuel used. The type of technology a firm uses for generating electricity might explain its emissions rate. Firms that generate electricity from fossil fuels, especially coal, emit more CO_2 than those that use renewable resources. To account for these differences, and following Welch et al (2000), we utilize the change in the percentage of generation from fossil fuel using data from Form EIA-906.

Change in the number of plants. Changes in the emissions rate might be explained because firms change their size by changing the number of plants that are under their operation. We compute the change in the number of plants under the ownership of a firm at t minus the number of plants owned by the firm at t-1 using data from Form EIA -906.

Year of installation of the generating units. The age of generating units could have an impact on CO_2 emissions rate as it is associated with technology and the capacity to be clean. We compute the average of the years of the installation of all the generating units that belong to a utility. Form EIA-860 reports the year of installation at the facility level. We aggregate this information at the firm level based on the percentage of ownership reported in the same database.

Merger Process with Gas or Electricity Utilities. We also control for the effects of merger activity that occurred during the course of the Climate Challenge Program. From 1995 to 2000, 36 mergers or acquisitions were completed between investor-owned electric utilities or between investor-owned electric utilities and independent power producers (U.S. DOE, 2000). We measure whether an electric utility was merging with other electric power producers or with gas producers. During the merger process, there can be changes in the structure of a firm. For example, firms could decide to downsize the labor force, adopt similar technologies in the merged facilities, or retire some of their facilities. During this adjustment period, it is possible a firm will pay less attention to environmental performance, and pollute more. If the utility or its holding company went through a merger process, then the indicator is 1 the year before until the year after the merger is completed (i.e. if the merger took place in year 1998, the indicator would be 1 for the years 1997 through 2000).

Information disclosure. The level of environmental information that firms are required to disclose in each state might affect their corresponding emissions. Some states require electricity suppliers to provide information regarding fuel sources and emissions associated with electricity generation. In our study, if the firm generated in a state that required a full or partial environmental disclosure, the information disclosure variable takes the value 1 and 0 otherwise. We use information from the Database of States Incentives for Renewable Energy (DSIRE).[11] For multi-state utilities, this variable is weighted based on the percentage of production within each state by the utility. Information disclosure was not required in the period previous to the creation of the Climate Challenge Program.

Renewable Portfolio Standard: This variable captures the effect of operating in a state with an established renewable portfolio standard (RPS). These standards mandate that utilities generate a specified proportion of their energy from renewable sources. We first create a variable that takes the value 1 if the state had an RPS in place and 0 if not, using the Database of State Incentives for Renewable Energy (DSIRE). For multi-state utilities, this variable is weighted based on the percentage of electricity produced within each state by the utility. Renewable portfolio standards did not exist in the period previous to the creation of the Climate Challenge Program.

Year effects: We incorporate dummy variables for the years 1997 to 2000 in the second stage model.

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[11] Interstate Renewable Energy Council (IREC). http://www.dsireusa.org/.

RESULTS

Table 1 displays the descriptive statistics for the first and the second stage regression.

First stage: Participation model

Table 2 presents the results for the participation decision model using the binary logit and multinomial logit specification. As discussed earlier, this methodology allows us to compare the effectiveness of the participation and the different types of participants. The first column (model 1a) contains the results using the binary logit analysis predicting the probability of participation in the VA. The second column (model 2a1) shows the results of the multinomial logit predicting the probability of being a late joiner (as compared with being a non-participant). The third column (model 2a2) displays the results of the multinomial logit predicting the probability of being an early joiner as compared with being a non-participant. The fourth column (model 2a3) includes the results of the multinomial logit predicting the probability of being an early joiner as compared with being a late joiner. Models 1 and 2 correctly classify 75.06% and 78.80% of the observations, respectively.

The multinomial logit model makes the assumption that categories are independent. This is called the independence of irrelevant alternatives assumption (IIA). We use a formal Hausman, McFadden and Small Hsiao test, which confirmed the independence of our categories (Small & Hsiao, 1985).[12]

In the first model (model 1a), the variables regulatory expenses and League of Conservation Voters are positive and significant at the 5 and 1 percent level, respectively. Firms that paid a higher amount of regulatory expenses were more likely to enroll in the Program. Firms that had a higher level of pressure from elected legislatures were also more likely to enroll in the Program. Looking at the same variables in the multinomial logit models (models 2a1, 2a2 and 2a3), we find that early joiners differed from late joiners and non-participants. The variables regulatory expenses and League of Conservation Voters are both significant for early joiners as compared with non-participants and with late joiners. However, these two variables do not significantly differentiate late joiners from non-participants. We therefore find evidence that firms that incurred high regulatory expenses and a greater pressure from elected legislatures were more likely to be early joiners in the Program. This confirms hypothesis 1 concerning the role of political pressure in predicting early participation in the VA. The variable representing the number of state environmental employees divided by the total number of employees- did not significantly impact the probability of a utility's participation in the Climate Challenge Program. This could be explained by the fact that this variable may not represent the type of regulations or programs that impact an electric utility, and may relate more, for example, to the maintenance of parks and connected activities.

The variable representing trade association membership is a significant predictor of participation at the 5 percent level. It is important to note that this variable is significant for early joiners as compared with non-participants and late joiners. We therefore find evidence that firms that belonged to the trade association were more likely to enroll in the Program and to join it early. This confirms hypothesis 2 concerning participation in the trade association to predict early participation in the VA

With respect to the effect of existing resources, the variable environmental effort is positive and significant at the 1 percent level to predict participation and to differentiate early joiners from late joiners and early joiners from non-participants. This indicates that early joiners undertook more environmental effort than late joiners and non-participants. This variable also differentiates late joiners from non-participants with a negative and significant sign at the 1 percent level. This means that late joiners have undertaken even less

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[12] Results available upon request from the authors.

environmental efforts than non-participants. This confirms hypothesis 3 on the role of environmental efforts in distinguishing between early participant and late participants in the Program.

Turning to the control variables, we find that size matters in explaining participation and differentiating among early and late joiners. The variable number of subsidiaries exhibits a positive and significant sign at the 1 percent level in all models. The bigger firms, measured using the number of subsidiaries owned by a firm, were more likely to join the Program. The variable big player shows a positive and significant sign at the 1 percent level in models 2a2 and 2a3. Big player firms were more likely to enroll in the Program earlier. The variable representing the productive efficiency of the firm is also significant and positive. This shows that the more efficient the firm, the more likely it was to join the Program. However, we note that early joiners and late joiners did not exhibit significant differences in levels of efficiency.

In both analyses, our findings do not support the claim that the environmental preferences of the population measured by the number of Sierra's membership per 1,000 residents affected the behavior of utilities in regard to the Program. This result differs from previous studies showing the effect of such a variable on environmental voluntary activities (Maxwell, Lyon, Hacket, 2000). This could be explained by the fact that the Climate Challenge Program is mostly an effort to pre-empt regulation and less to appease environmental NGOs which may in general have looked at this particular environmental practice with suspicion. In addition, the level of pollution in the state in which the electric utility produced did not have a significant effect on the decision to enroll in the Program.

Second stage: Outcome of Climate Challenge Program model

Table 3 presents the regression results for the outcome of the Climate Challenge Program with changes in CO_2 emissions rates as the dependent variable (second stage). Models 1b and 1c display the regression results when the probability of participation from the first stage is introduced into the equation. Model 1b is the pooled regression while model 1c presents the random-effects general least square (GLS) panel model. Models 2b and 2c contain the results for the multinomial probabilities predicting late and early joiners. Model 2b is the pooled regression while model 2c includes the random-effects GLS regression. The Lagrangian Multiplier (Breusch & Pagan, 1980) suggested the use of panel rather than pooled estimation. The Hausman test (Hausman, 1978) showed that a random-effects model is more appropriate than a fixed-effects model.[13]

In the first models (1b and 1c), the probability of participation is not significant. This means that participants in the Climate Challenge Program were not more likely than non-participants to reduce their CO_2 emissions. In the second models (2b and 2c), the probability of participation for early joiners is negative and significant at the 5 percent level. This shows that, among participants, only early entrants reduced their emissions significantly more than non-participating firms. If a utility with an average CO_2 emissions rate equal to 0.67 tons per MWh in 1995 (the U.S. average of CO_2 emissions rate in the electric industry in that year) decided to participate early in the Climate Challenge Program, it would exhibit a CO_2 emissions' rate of 0.418 tons per MWh in 2000 (the other variables being held constant). This means a relative decrease of 7.5 percent per year for early joiners as compared to a relative reduction of 2.5 percent per year for all participants (early and late joiners together). This confirms hypothesis 4, which states that early joiners were more likely to undertake substantive cooperation than late joiners.

Turning to the control variables, the variable representing change in percentage of generation from fossil fuel and change in the number of plants owned by the firm are positive and significant at the 1 percent level in all models. Firms that increased the percentage of their generation from fossil fuel increased their emissions rate. Firms that increased the number of plants they owned also increased their emissions rate. The variable year of installation is negative and significant at the 10 percent level, indicating that older

[13] Results available from the authors upon request.

plants were more likely to increase their emissions rate over time. The variables representing mergers with electric and gas utilities are not significant. Firms undertaking mergers did not seem to be paying less attention to environmental performance than other firms. Likewise, the variables representing disclosure and renewable standard portfolio policies in the states where a firm operated are not significant. This could be explained because these programs were started toward the end of our study period and more time may be needed to show some effect on performance. The dummies for years are statistically significant at the 10 percent level, except for the dummy associated with the year 1997, implying an incremental change in CO_2 rate in the years 1998, 1999 and 2000 compared with the reference year 1996.

DISCUSSION AND CONCLUSION

We have identified key factors that explain firms' cooperative behavior within VAs. We analyzed three types of cooperative behavior: non-cooperation, symbolic cooperation, and substantive cooperation. Non-cooperation represented the behavior of firms that did not participate in the VA. Substantive cooperation included participation in the VA associated with improvements in environmental performance. Symbolic cooperation signified firms that participated in the VA but did not improve their environmental performance significantly more than non-participants. Our results show that early joiners and late joiners to the Climate Challenge program adopted different types of cooperative behavior. Symbolic cooperation was more likely with later entrants while substantive cooperation resulting in changes in emissions was more likely with early entrants.

We found that these differences in cooperative behavior were explained by the different institutional pressures experienced by early and late entrants and by their previous levels of investments in environmental improvements. Early entrants were subjected to a higher level of political pressure at the state level, and more dependent on local and federal regulatory agencies. They were also better connected to the trade association. When considering investments in environmental improvements, late joiners were also significantly different from early joiners and non-participants. In particular, they had undertaken less environmental effort than early joiners and non-participants prior to the creation of the Program.

We also assessed the overall effectiveness of the Program and found no significant difference between participants and non-participants in the reduction of their emissions. Even if early entrants reduced their emissions significantly more than non-participants, when late joiners are included in the analysis, the Program overall does not seem to have been effective. Free riding behavior, might not be problematic for the viability of a voluntary program if it is limited to a small number of participants and if the result of free riding is compensated for by the good behavior of other participants. However, because free riding behavior can detract from the overall effectiveness of a program, it is important to assess and adjust for the possible impact of free riders on the overall effectiveness of a program. The problem of free riding certainly exists within other collective cooperative political strategies, but here we actually measured its extent. An important question remains: why would early joiners tolerate free riding? As Lenox suggests, it is possible that some members are willing to tolerate free riding rather than quit because their continued participation is necessary to maintain the institution (2006). As we show, early joiners have more at stake than late joiners. They are under more political pressure and are also more visible. Defection of substantive contributors to the program, would attract attention and conceivably even lead to the collapse of the agreement.

Our research advances theory in several ways. We started by pointing out that the corporate political strategy literature was limited in its ability to explain differing collective action behavior because it treated cooperation as static and dichotomous. Helping to respond to the call by several scholars to study the issue of timing in corporate political strategies in more detail (Bonardi, Hillman, & Keim, 2005), we were able to tease out the institutional pressures that explain different types of cooperation over time. Our findings show that it is very important to analyze various modes of cooperation, and to understand their temporal variation. In particular, we highlighted some of the dynamics at stake within VAs that may encourage free riding and endanger the fate of such programs. We were also able to demonstrate how the social context in which a firm operates impacts its level of engagement in collective corporate strategy. Early joiners and late joiners of the Climate Change Program operated in very different institutional fields. Early joiners were more connected than late joiners to the industry and more dependent on regulators. The analysis of VAs proved to be particularly interesting as a Corporate Political Strategy because these arrangements include both cooperation between firms and the government and also cooperation among firms. We show the importance of analyzing pre-existing relationships among these actors to predict the level of cooperation within VAs.

Our study also makes contributions to the institutional theory literature. This literature argues that early joiners are mostly interested in the technical efficiency of a practice while followers are subjected to more institutional pressures. In this stream of research, early joiners seem to function out of their institutional context. As Westphal, Gulati and Shortell noted, earlier adopters are "motivated by the opportunity for efficiency gains and free from the 'iron cage' of isomorphic pressures" (1997:374). In our study, we challenge these assumptions. We find that early joiners respond to institutional pressures and to political pressures at the state level, as well as to peer pressure exerted by their trade association. This is consistent with the findings of Bansal, who identified the presence of institutional pressures to explain the early adoption of environmental management practices (Bansal, 2005). Regarding late joiners, the institutional literature has shown that these respond primarily to normative pressures. In our study, however, we find that late joiners could adopt a strategic approach to their participation in the Program. In brief, they were seeking the benefits of participation achieved by the early joiners (such as benefits to their reputation and potentially forestalled regulation) without incurring the costs associated with substantive participation. The notion of free riding has not been explicitly included in previous institutional analyses, beyond the possible understanding of late joiners as free riders on the legitimacy established by early joiners.

We advance the institutional literature also by describing key pressures and incentives that early joiners face, and by linking them to performance. The institutional literature has sought mostly to explain convergence toward similar behavior or isomorphism. In our study, we link institutional pressures and incentives to divergence of behavior over time. Furthermore, while previous studies have shown a positive relationship between the number and the quality of initial adopters and subsequent adoptions, we show that this might not always occur. For example, Rosenkopf and Abrahamson suggest that initial adopters with strong reputations could intensify pressure on other organizations to imitate adoption (Rosenkopf & Abrahamson, 1999). Our results show that even if non-adopters decide to join the program to be associated with "high quality" early joiners --here firms that have undertaken efforts to reduce their emissions-- this does not mean they will commit to the same type of actions within a program. Therefore, the quality of early adopters does not guaranty the quality of the participation of later adopters. We have to look at other factors to explain the types of cooperative behavior. We find that institutional pressures and previous investments are the most important predictors of the type of cooperative behavior.

The electric utility sector constituted an opportune field to analyze the issue of the effectiveness of collective political strategies within the context of the natural environment for several reasons. Because the electric utility sector is highly regulated and also because electric utilities are among the leading polluters in the U.S., this is a sector where non-market strategies may be more prominent than in other sectors. However, collective political strategies in the context of the environment are starting to be at the forefront for many other industries facing increasing environmental regulatory oversight. This study can therefore illuminate collective corporate strategies such as VAs that are emerging in other sectors. Our model identifies conditions that trigger different types of behavior within VAs. We chose to study the Climate Challenge Program because it is representative of most of the VAs currently implemented, the majority without sanctioning mechanisms. Our findings also point to the limits of VAs lacking sanctions to promote cooperative behavior, and are particularly relevant for policymakers. The U.S. Environmental Protection Agency has typically encouraged a group of very well known and successful organizations to take the lead in participating in voluntary programs, hoping that these firms would set an example. Our findings suggest that this strategy might not always be effective because followers may only collaborate symbolically and jeopardize the overall effectiveness of the program. We suggest that policymakers who wish to design effective environmental agreements need to adjust the design of VAs for factors that trigger substantive or symbolic cooperation.

Our study has several limitations. First, we studied the factors that could reduce the effectiveness of a VA in terms of its ability to get its members to cooperate substantively. However, we did not assess whether the Climate Challenge Program specifically was successful at changing political outcomes. This is beyond our study and would necessitate identifying, whether changes in the political landscape, independent of the Climate Change Program, reduced the level of threat that more stringent regulation would be put into place. Second, our study did not take into consideration the other strategic choices that firms could or did pursue outside their participation in the VA. Such choices could include lobbying, for example (de Figueiredo & Tiller, 2001). Further research is needed to look at the interaction of various strategies and how they impact the likelihood that a firm will undertake substantive or symbolic cooperation within a VA. Third, we focused on cooperative strategies in the U.S., showing that variations in political pressure exerted by regulators at the state level are important predictors of cooperative strategies. In other contexts, scholars have shown that national regulatory environments impact corporate political activity (Hillman & Wan, 2005; Murtha & Lenway, 1994). For example, Delmas and Terlaak have shown that participation in voluntary programs differs across nations (Delmas & Terlaak, 2002). It would be interesting to analyze the effect of differing national regulatory settings on the willingness of firms to cooperate within VAs. This is particularly important in the case of climate change as the major transboundary issue of our time where the potential of VAs could be significant – either negatively or positively.

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TABLE 1

DESCRIPTIVE STATISTICS OF VARIABLES USED IN FIRST & SECOND STAGE REGRESSION [a]

First stage Model	Mean	Sd.	1	2	3	4	5	6	7	8	9	10	11
1. Participation [b]	0.60	0.49	1.00										
2. Regulatory expenses	2.65	3.21	0.10*	1.00									
3. League of Conservation Voters	46.09	22.31	0.08*	0.03	1.00								
4. State's environmental employees	3.88	1.44	-0.01	-0.13*	-0.27*	1.00							
5. Sierra Club	1.89	3.29	-0.03	0.08*	0.21*	0.02	1.00						
6. State's pollution	0.48	0.37	0.09*	-0.09*	-0.14*	0.21*	-0.11*	1.00					
7. Trade association's membership	0.80	0.40	0.15*	0.12*	-0.04	-0.01	-0.04	0.02	1.00				
8. Productive efficiency	0.88	0.15	0.16*	0.01	-0.24*	0.11*	-0.12*	0.13*	0.12*	1.00			
9. Environmental effort	3.83	3.53	0.07	-0.05	-0.10*	0.04	-0.07	0.16*	-0.01	0.02	1.00		
10. Visibility / *Big player*	0.83	0.38	0.08*	0.25*	-0.05	0.26*	0.12*	0.12*	0.15*	0.07	-0.03	1.00	
11. Number of subsidiaries	1.66	2.37	0.38*	0.12*	0.10*	0.16*	0.07	0.10*	0.21*	0.13*	-0.07	0.08*	1.00

Second Stage Model	Mean	Sd.	1	2	3	4	5	6	7	8	9
1. Change in CO_2 emissions rate	0.07	0.31	1.00								
2. Change in % of generation from fossil fuel	-0.61	11.66	0.22*	1.00							
3. Change in the number of plants	0.50	3.75	0.29*	0.28*	1.00						
4. Environmental effort	3.68	3.15	-0.06	0.01	-0.04	1.00					
5. Year of installations (average)	1957.76	11.38	-0.10*	0.05	-0.13*	-0.03	1.00				
6. Merger process with electric util.	0.16	0.37	0.01	-0.08 *	0.04	0.02	-0.01	1.00			
7. Merger process with gas utility	0.04	0.21	0.06	-0.09*	0.04	-0.06	-0.07	0.01	1.00		
8. Information disclosure	0.08	0.26	0.11*	-0.17*	0.22*	-0.04	-0.13*	0.07	0.01	1.00	
9. Renewables Portfolio Standard	0.07	0.25	0.05	-0.15*	0.09*	-0.10*	-0.14*	0.14*	0.03	0.25*	1.00

[a] N=633. Correlations with an absolute value greater than 0.08 are significant at 5% level.

[b] 82 participating firms are included with 61 early joiners and 21 late joiners. The number of non-participating firms included in the sample is 51.

TABLE 2
LOGIT ESTIMATES OF PARTICIPATION IN CLIMATE CHALLENGE PROGRAM [A]

Model	Binary Logit	Multinomial Logit		
Dependent variable	Participants (Model 1a)	Late joiners (Model 2a1)	Early Joiners (Model 2a2)	Early Joiners (Model 2a3)
Reference group	Non-participants	Non-participants	Non-participants	Late Joiners
Regulatory expenses	0.078 (0.033)*	-0.020 (0.050)	0.085 (0.036)*	0.105 (0.049)*
League of Conservation Voters	0.017 (0.005)**	0.002 (0.006)	0.023 (0.006)**	0.020 (0.006)**
State's environmental employees	0.029 (0.081)	0.025 (0.102)	-0.024 (0.095)	-0.049 (0.110)
Sierra Club	0.008 (0.026)	0.022 (0.030)	-0.004 (0.034)	-0.026 (0.035)
State's pollution	0.140 (0.326)	-0.574 (0.450)	0.092 (0.366)	0.666 (0.457)
Trade association's membership	0.521 (0.250)*	0.023 (0.310)	0.952 (0.303)**	0.929 (0.354)**
Productive efficiency	2.513 (0.725)**	1.881 (0.940)*	3.492 (0.856)**	1.611 (1.028)
Environmental effort	0.091 (0.028)**	-0.174 (0.054)**	0.148 (0.033)**	0.323 (0.055)**
Visibility / *Big player*	0.499 (0.308)	-0.088 (0.392)	1.216 (0.377)**	1.304 (0.442)**
Number of subsidiaries	0.645 (0.078)**	0.446 (0.106)**	0.864 (0.098)**	0.418 (0.075)**
Year 1996	0.217 (0.297)	0.050 (0.395)	0.256 (0.340)	0.206 (0.409)
Year 1997	0.633 (0.298)*	0.048 (0.390)	0.195 (0.339)	0.147 (0.406)
Year 1998	0.508 (0.298)+	-0.135 (0.395)	0.018 (0.339)	0.153 (0.412)
Year 1999	0.569 (0.317)+	-0.004 (0.408)	0.051 (0.364)	0.055 (0.429)
Constant	-5.246 (0.849)**	-2.143 (1.072)*	-7.518 (1.044)**	-5.375 (1.232)**
Observations	633	633	633	633
% correctly classified	75.06%	78.80%		

[a] Number of participating firms: 82 including 61 early joiners and 21 late joiners. Number of non-participating firms: 51.

Standard errors are in parentheses.

+ Significant at 10%;* significant at 5%; ** significant at 1%.

TABLE 3
REGRESSION ESTIMATES OF CHANGES IN CO_2 EMISSIONS' RATE 1996-2000[A]

Dependent variable: Changes in CO_2 rates (CO_2 rate $_t$ - CO_2 rate $_{t-1}$)	Pooled (Model 1b)	Random GSL (Model 1c)	Pooled (Model 2b)	Random GSL (Model 2c)
Probability of Participation	-0.091 (0.079)	-0.086 (0.085)		
Probability of Participation (late joiners)			0.043 (0.105)	0.056 (0.111)
Probability of Participation (early joiners)			-0.255 (0.114)*	-0.252 (0.121)*
Change in percentage of generation from fossil fuel	0.005 (0.002)**	0.005 (0.002)**	0.005 (0.002)**	0.005 (0.002)**
Change in the number of operating plants	0.033 (0.006)**	0.033 (0.006)**	0.033 (0.006)**	0.033 (0.006)**
Environmental Effort	0.005 (0.062)	0.010 (0.065)	-0.013 (0.062)	-0.008 (0.065)
Year of installations (average)	-0.003 (0.002)+	-0.004 (0.002)+	-0.004 (0.002)*	-0.004 (0.002)+
Merger process with electric utility	-0.053 (0.055)	-0.063 (0.055)	-0.055 (0.054)	-0.064 (0.055)
Merger process with gas utility	0.030 (0.097)	0.026 (0.099)	0.044 (0.097)	0.039 (0.099)
Information disclosure	0.036 (0.082)	0.025 (0.084)	0.006 (0.083)	-0.002 (0.085)
Renewable standard portfolio	-0.066 (0.086)	-0.059 (0.087)	-0.074 (0.086)	-0.067 (0.087)
Year1997	0.062 (0.060)	0.061 (0.059)	0.062 (0.060)	0.061 (0.059)
Year 1998	0.107 (0.063)+	0.108 (0.062)+	0.102 (0.062)+	0.104 (0.061)+
Year 1999	0.136 (0.063)*	0.139 (0.062)*	0.130 (0.063)*	0.133 (0.062)*
Year 2000	0.164 (0.069)*	0.171 (0.068)*	0.160 (0.068)*	0.167 (0.067)*
Constant	6.872 (3.512)+	7.081 (3.734)+	7.068 (3.504)*	7.243 (3.724)+
Observations	633	633	633	633
R-squared (adjusted model b / overall model c)	0.13	0.14	0.15	0.21
$\chi^2_{(Breusch-Pagan)}$		3.13+ [0.0767]		4.04* [0.0445]
$\chi^2_{(Hausman)}$		6.65 [0.9191]		8.84 [0.8414]

[a] The estimates values are unstandardized coefficients. Standard errors are in parentheses. The corresponding p-values for Breusch and Pagan and Hausman tests are in bracket. + Significant at 10%;* significant at 5%; ** significant at 1%.

WHAT DRIVES PARTICIPATION IN STATE VOLUNTARY CLEANUP PROGRAMS? EVIDENCE FROM OREGON

Allen Blackman
(corresponding author)
Resources for the Future
1616 P Street, N.W.
Washington, DC 20009
(202) 328-5073
blackman@rff.org

Thomas P. Lyon
University of Michigan
Ross School of Business
tplyon@bus.umich.edu

Kris Wernstedt
Virginia Tech.
Urban Affairs and Planning
krisw@vt.edu

Sarah Darley
Resources for the Future
darley@rff.org

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WHAT DRIVES PARTICIPATION IN STATE VOLUNTARY CLEANUP PROGRAMS? EVIDENCE FROM OREGON

Abstract

Over a quarter of a century after the passage of federal Superfund legislation, hundreds of thousands of properties contaminated with hazardous substances have yet to be remediated. To reduce this backlog, all but a handful of states have created Voluntary Cleanup Programs (VCPs) that offer liability relief, subsidies, and other incentives for responsible parties to voluntarily clean up contaminated properties. Yet we know little about what drives participation in these programs, in part because the requisite data are scarce. We analyze VCP participation in Oregon, one of a small number of states that maintains a data base of known contaminated sites. In contrast to previous VCP research, we conclude that Oregon's program does not mainly attract sites with little or no contamination seeking a regulatory "clean bill of health." Furthermore, we find that regulatory pressure—in particular, Oregon's practice of compiling a public list of sites with confirmed contamination—drives VCP participation. Together, these findings imply that Oregon has been able to spur voluntary remediation by disclosing information on contamination, a relatively inexpensive and hence efficient approach. Our results comport with key themes in the literature on voluntary environmental programs: the threat of mandatory regulation spurs participation in such programs, and disclosure of environmental performance information is an efficient policy tool for promoting abatement and remediation.

Key words: environment, hazardous waste, brownfields, contaminated property, duration analysis, Oregon

JEL codes: Q53, Q58, C41

1. INTRODUCTION

Over a quarter of a century after the passage of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund), hundreds of thousands of properties contaminated with hazardous substances have yet to be remediated (Simons 1998; Heberle and Wernstedt 2006). Part of the reason for this backlog is CERCLA itself which─by making liability for cleanup retroactive, strict, joint, and several─created incentives for property managers and developers to shun contaminated properties for fear of being saddled with the cost of cleanup. State "mini-superfund" laws with similar liability features may have compounded the problem. In addition, federal and state regulators typically only have resources to oversee cleanup of a relatively small number of severely contaminated sites (GAO 1997; Dana 2005).

To address these concerns, since the late 1980s, all but a handful of states have created programs that offer a basket of incentives for responsible parties and others to voluntarily remediate contaminated sites.[1] These incentives typically include relief from liability for future cleanup and/or third-party lawsuits; variable (versus uniform) cleanup standards that link the level of required cleanup to the future use of the site; flexible enforcement of environmental regulations; expedited permitting; and financial support for remediation through mechanisms such as grants, loans, subsidies, and tax incentives (EPA 2005). By 2004, roughly 20,000 contaminated sites had participated in, or were participating in, state voluntary cleanup programs (VCPs) (U.S. Environmental Protection Agency 2005).

Despite the prominent role that state VCPs now play in contaminated site policy, we know relatively little about the factors that drive participation in these programs─information that is needed to enhance their efficiency and effectiveness. This gap in the empirical literature is partly due to the difficulty of collecting the necessary information. Econometric analysis of participation requires data on contaminated sites that are not participating in the VCP—a control group—as well as those that are—a treatment group. But data on nonparticipating sites are scarce because contaminated properties may be "mothballed" to avoid detection and because state regulatory agencies lack the resources to identify them.

To our knowledge, only one econometric analysis of VCP participation has appeared. Alberini (2007) examines VCP participation in Colorado which, like most states, does not maintain a database of contaminated properties that are not participating in clean up programs. To construct a sample of nonparticipating sites, Alberini uses the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), a national EPA registry of sites in need of investigation or cleanup. CERCLIS focuses principally on sites with relatively severe (confirmed or suspected) contamination that are candidates for the federal Superfund program. She finds that

[1] Federal legislation has also attempted to address these problems. The Small Business Liability Relief and Brownfields Revitalization Act of 2002 provided firmer statutory footing for expanded liability protection and authorized up to $200 million annually for site assessment and remediation and up to $50 million annually in assistance to state and tribal response programs.

Colorado's VCP mainly attracts sites with minimal contamination and high development potential not listed in CERCLIS. She concludes that

> ... these findings cast doubt on whether the VCP is truly attaining its original cleanup and environmental remediation goals and hints at the possibility that participation might be driven exclusively by the desire to rid the parcel of any stigma associated with the current or previous use of land (or to prevent such an effect with future buyers).

The present paper analyses VCP participation in Oregon, one of a small number of states that maintains a data base of contaminated sites, including those with minimal contamination. We use these data to construct a control sample.[2] In contrast to Alberini's findings for Colorado, we conclude that Oregon's VCP does attract sites with significant contamination. Furthermore, we find that regulatory pressure—in particular, Oregon's practice of formally compiling a public list of sites with confirmed contamination—drives VCP participation. Together, these findings imply that Oregon has been able to spur voluntary remediation by publicly disclosing information on contamination, a relatively inexpensive and hence efficient approach. Our results comport with key themes in the literature on voluntary environmental programs: the threat of mandatory regulation spurs participation in such programs, and public disclosure of environmental performance information is an efficient policy tool for promoting abatement and remediation.

The remainder of the paper is organized as follows. The second section reviews the literature on the factors that drive participation in voluntary environmental regulatory programs, and VCPs in particular. The third section provides background on Oregon's VCP. The fourth section discusses our data and variables. The fifth section presents our econometric model and the sixth section discusses our results. The final section offers conclusions.

2. LITERATURE

A considerable literature has developed to explain participation in different types of voluntary environmental initiatives including public programs administered by regulatory agencies, agreements negotiated between regulators and polluters, and unilateral private-sector commitments.[3] This section reviews the literature on participation in public programs, and VCPs in particular. It also briefly discusses a second relevant literature: that on public disclosure initiatives.

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[2] We sought to identify a state that both operates a VCP with a sufficiently large number of sites and that maintains a database of nonparticipating sites. Towards that end, we contacted regulatory authorities in 16 states (CA, CO, CT, IL, IN, KS, MA, MI, MO, NC, NC, NJ, OR, PA, TX, and WA) that have VCP programs with more than 100 participating sites according to EPA (2005). Of these states, four (CT, NC, OR, and MO) maintain data on nonparticipating sites.

[3] For reviews of this literature, see Lyon and Maxwell (2002), Alberini and Segerson (2002), and Khanna (2001).

2.1. Public programs

Empirical research on voluntary environmental public programs suggests that pressures applied by regulators, markets, and civil society drive participation. Variation in transactions costs associated with joining these programs also helps to explain why some actors participate and other do not.

2.1.1. Regulators

A leading hypothesis in the literature on voluntary environmental regulation is that private parties participate in order to preempt more stringent mandatory regulation, or to soften enforcement of existing regulation (Segerson and Miceli 1998; Maxwell, Lyon and Hackett 2000). Research on this "background threat" hypothesis as it relates to voluntary programs (as distinct from other types of voluntary regulation) has mostly focused on whether firms under pressure from regulatory authorities were more likely to join the U.S. Environmental Protection Agency's 33/50 program.[4] Khanna and Damon (1999), Videras and Alberini (2000), Sam and Innes (2006), and Vidovic and Khanna (2007) all find that firms named as potentially responsible parties at a higher-than-average number of Superfund sites were more likely to participate. Similarly, Videras and Alberini (2000) and Sam and Innes (2006) find that firms that were out of compliance with the Resource, Conservation and Recovery Act or Clean Air Act were more likely to join. The evidence about the impact of regulatory pressure on 33/50 participation is not one-sided, however. For example, Arora and Cason (1996) and Gamper-Rabindran (2006) find that firms that violated Clean Air Act requirements were not more likely to participate. As for research on other public voluntary programs, Videras and Alberini (2000) show that firms named as potentially responsible parties at a higher-than-average number of Superfund sites were more likely to participate in EPA's Waste Wi$e and Green Lights programs. Finally, Blackman et al. (2007) find that Mexican firms inspected and fined by the federal environmental regulatory agency were more likely to join the Clean Industry Program, a prominent national voluntary regulatory program.

Closely related to the hypothesis that regulatory pressure drives firms into voluntary programs is the notion that firms participate in order to obtain preferential treatment from regulators. Cothran (1993), for example, cites several case studies in which firms were able to obtain permits and regulatory variances in record time by undertaking voluntary environmental investments and maintaining good compliance records. Similarly, anecdotal evidence about Project XL, EPA's flagship voluntary program during the 1990s, suggests that firms obtained significant production cost advantages from participation, chiefly through relief from certain environmental regulations (Marcus, Geffen, and Sexton 2002). Decker (2003) provides econometric evidence that firms obtain permits for new facilities more quickly if they have engaged in voluntary abatement.

[4] Launched in 1991, the 33/50 program required participants to pledge to cut their emissions of 17 high-priority toxic chemicals by 33 percent by 1992 and by 50 percent by 1995.

2.1.2. Markets and civil society

Pressure brought to bear by consumers may also motivate participation in public voluntary programs. Theory suggests that firms may voluntarily improve their environmental performance to attract "green" consumers (Arora and Gangopadhayay 1995). Some empirical evidence suggests that this logic applies to participation in voluntary programs. For example, Arora and Cason (1996) and Vidovic and Khanna (2007) show that firms with a higher ratio of advertising expenditures to sales were more likely to participate in EPA's 33/50 program, and Videras and Alberini (2000) show that firms selling directly to final consumers were more likely to participate in the Waste Wi$e and Green Lights programs.

Pressures generated by communities and nongovernmental organizations may also create incentives for firms to join voluntary programs. Such pressures are the focus of the literature on so-called informal regulation, which mostly consists of cross-sectional, plant-level econometric analyses of environmental performance in developing countries (see World Bank 1999 for a review). For example, Blackman and Bannister (1998) find that in the early 1990s, pressures applied by industry and neighborhood organizations spurred participation in a voluntary clean fuels initiative targeting small Mexican brick kilns.

2.1.3. Transactions costs

The transactions costs associated with joining voluntary regulatory programs, including nonpecuniary learning costs, inevitably vary across firms. For example, transactions costs are likely to be lower for firms with a dedicated environmental management staff and experience dealing with regulatory agencies. Such variation in transactions costs may help to explain participation. For example, Blackman and Mazurek (2001) find that in a sample of 11 firms, transactions costs associated with participating in EPA's Project XL averaged over $450,000 per firm, varied considerably across firms, and appear to have deterred some firms from participating.

2.2. Drivers of remediation

As noted in the introduction, to our knowledge, Alberini (2007) is the only published econometric analysis of participation in a VCP. However, a number of articles using other methods have examined a closely related topic: property managers' and developers' incentives to remediate contaminated properties, whether or not this is done via a VCP. Alberini et al. (2005) and Wernstedt, Meyer, and Alberini (2006) present results of conjoint choice experiments designed to identify the type of policies that create incentives for real estate developers to remediate contaminated properties. Alberini et al. (2005) find that European developers can be attracted to contaminated sites by offering subsidies, liability relief, and less stringent regulation. Wernstedt, Meyer, and Alberini (2006) find that U.S. developers place a relatively high value on liability relief—from both cleanup costs and claims by third parties—and a relatively low value on reimbursement of environmental assessment costs. They also find considerable heterogeneity in the value developers place on these incentives, depending on their experience with contaminated sites.

Research has also examined the impact of specific drivers of remediation including financial incentives, community support, and the level of contamination. Sherman (2003) analyzes various cleanup subsidies including property tax abatements, site assessment grants, development grants, and low-interest loans, and concludes that of these, property tax abatements are the most attractive to developers. However, he notes that financial incentives typically are not able to change developers' decisions about whether or not to remediate a contaminated property. Lange and McNeil (2004) present an analysis of survey data from 100 EPA brownfields grant recipients in the public sector and conclude that community support, consistency with local plans, and cost minimization, are the most important determinants of redevelopment success. Schoenbaum (2002) examines a sample of contaminated and uncontaminated properties in inner city Baltimore and fails to find a systematic relationship between contamination and the probability that a property was developed, suggesting that other factors such as access to transportation and crime rates play a more important role in developers' decision-making. However, McGrath (2000) finds that sites in Chicago that may have been contaminated were less likely to be redeveloped.

2.3. Public disclosure

In addition to the literature on voluntary environmental public programs (including state voluntary cleanup programs), the literature on public disclosure is also relevant. Public disclosure initiatives collect and disseminate data about private parties' environmental performance in order to both inform the public about threats to their health and the environment, and to strengthen private incentives for pollution control and remediation (Teitenberg 1998). Often characterized as the "third wave" of environmental regulation (after command-and-control and market based approaches), public disclosure has grown increasingly popular over the past 20 years, in part because it is viewed as a relatively inexpensive environmental management tool (Kerret and Gray 2007; Dasgupta, Wheeler and Wang 2007).

A principal concern of the economics literature on public disclosure has been testing its efficacy in improving environmental quality. Although evidence about the U.S. Toxic Release Inventory (TRI), arguably the best-known public disclosure program, is mixed (Bui 2005; Greenstone 2003; Koehler and Spengler 2007), studies of other programs have generated compelling evidence that public disclosure can drive emissions reductions. These programs include: so-called performance evaluations and ratings initiatives in Indonesia and India that not only disseminate raw emissions data, but also use it to rate the performance of participating plants (García et al. 2007; Powers et al. 2008); 1996 amendments to the U.S. Safe Drinking Water Act mandating that community drinking water systems publicly report regulatory violations (Bennear and Olmstead 2007); rules requiring U.S. electric utilities to publicly report the extent of their reliance on fossil fuels (Delmas, Montes-Sancho, and Shimshack 2007); and a policy of publicizing the identity of plants that are noncompliant in British Colombia (Foulon, Lanoie, and Laplante 2002).

A second focus of the literature on public disclosure has been understanding how it drives emissions reductions. Research on this topic suggests that public disclosure leverages many of the same pressures discussed in the literature on public voluntary programs including those generated by regulators, markets, and civil society (Bennear and Olmstead 2007; Dasgupta et al. 2006). In addition, some studies suggest that environmental performance has an impact partly by simply improving plant managers' information about their own emissions and abatement options (Blackman et al. 2004; Dasgupta, Wheeler, and Wang 2007).

3. OREGON'S CLEANUP PROGRAMS

This section discusses the data that Oregon collects on contaminated properties and its mandatory and voluntary clean up programs

3.1 The Environmental Cleanup Site Information database

Oregon's Department of Environmental Quality (DEQ) maintains an Environmental Cleanup Site Information (ECSI) data base, which in July 2006 contained information on 4,223 contaminated, potentially contaminated, and formerly contaminated sites.[5] The sites in the database came to the attention of DEQ in a variety of ways including corroborated citizen complaints and referrals from other regulatory programs such as DEQ's hazardous waste program and the federal CERCLIS.[6] The criterion for inclusion in ECSI is simply that a site is known to be, or suspected to be, contaminated. ECSI contains a variety of data about sites including their location, former and present uses, ownership, and any remedial actions that have been performed. ECSI also contains information on all DEQ actions and decisions regarding each site.

DEQ maintains two lists that are subsets of ECSI: the Confirmed Release List, and the Inventory of Hazardous Substance Sites. The Confirmed Release List consists of sites where contamination has been confirmed (by qualified observation, operator admission, or laboratory data), has been deemed "significant" by virtue of its quantity or hazard, has not been regulated under another program, and has not been adequately cleaned up or officially deemed to require no further action. Managers of sites on the Confirmed Release List are subjected to enhanced pressures from both regulatory and nonregulatory actors. They can be required to participate in DEQ's mandatory clean up program and may have difficulty transacting their property. Hence, "listing" is a serious regulatory action. Prior to listing, DEQ notifies site managers of their intent to do so, and gives them an opportunity to comment and provide additional information. In addition, DEQ provides a public comment period prior to delisting a site that has completed requisite clean up. The Inventory of Hazardous Substance Sites is a subset of the Confirmed

[5] Including 377 "candidate" or "historical" sites that are not considered fully fledged entries. ECSI is not comprehensive; it does not include a significant number of sites about which DEQ has not information.
[6] ECSI excludes sites with petroleum releases from underground storage tanks.

Release List. It comprises sites on which contamination is considered a threat to human health or the environment and must be cleaned up.

3.2. Oregon's mandatory and voluntary cleanup programs

Oregon has three clean up programs for contaminated sites: the Site Response Program, the Voluntary Cleanup Program (VCP), and the Independent Cleanup Pathway (ICP). The Site Response Program is DEQ's mandatory program. DEQ classifies all sites as "high," "medium," or "low" priority for further regulatory action. The Site Response Program is reserved for high-priority sites (although not all such sites are required to participate). For sites in this program, DEQ provides oversight throughout the investigation and cleanup and selects the remedial action. Of the 4,223 sites in ECSI, 10% are participating in, or have participated in, the Site Response Program.

The VCP and ICP are DEQ's voluntary cleanup programs. Both the VCP and ICP are targeted at medium- and low-priority sites. However, high priority sites are allowed to participate in the VCP but not the ICP. The ICP, and to a lesser extent the VCP, entail lower levels of DEQ oversight than the mandatory Site Response Program. Of the 4,223 sites in ECSI, 27% have participated in, or are participating in, the VCP and 7% have participated in, or are participating in, the ICP.

The mechanics of participation in the VCP are as follows. Site managers submit an "intent to participate" form and deposit $5,000 in an account that DEQ may draw upon to cover administrative expenses. Next, DEQ reviews written documentation on the site, visits the site, and works with the site manager to develop a cleanup plan. DEQ holds a public comment period and then decides whether or not to approve, disapprove, or modify the cleanup plan. If the plan is approved, the site manager implements it. When implementation is complete, DEQ invites public comment again and, barring serious objections, issues either a "no further action" (NFA) determination that provides assurance that DEQ will not require further remediation, or a conditional NFA that provides this assurance contingent upon the site manager undertaking certain actions, such as land use control.

DEQ promotional materials list a set of benefits and risks of participating in the VCP (DEQ undated a). The benefits include DEQ guidance and oversight, possible exemptions from permits for on-site work, and DEQ permission to redevelop part of the site while cleanup is ongoing on other parts. Among risks are that all sites joining the program are added to ECSI, and that sites that fall behind in their implementation of cleanup plans can be forced to join the mandatory Site Response Program.

The ICP entails less DEQ oversight than the VCP. Essentially, site managers who pass an initial screening are allowed to complete an investigation and cleanup independently and then request final approval from DEQ. That said, ICP participants can access DEQ oversight if they want it and are willing to pay for it. According to ICP promotional materials, among the risks of participation are that DEQ may not approve of independently planned and implemented cleanups. Also, DEQ does not provide permit waivers to ICP participants (DEQ undated b).

DEQ recruits participants in the VCP and ICP by sending invitation letters to the managers of ECSI sites where DEQ has determined that further action is needed. The vast majority of such letters simply describe the programs. The remainder, which are sent to high-priority sites only, essentially give site managers an ultimatum: either join the VCP, or be forced to participate in the mandatory Site Response Program. Of the 1,318 sites in the ECSI database that are participating in, or that have participated in the VCP or ICP, 1,142 (87%) joined after being included in the ECSI database and receiving an invitation letter. The remaining sites were unknown to DEQ before they submitted an application to join.

4. ANALYTICAL FRAMEWORK, DATA AND VARIABLES

This section describes the analytical framework, data, and variables we use to analyze participation in the VCP and ICP.

4.1. Analytical framework

We assume that a site manager will join the VCP or ICP if the net benefits (benefits minus costs) of doing so are positive. The benefits include: (i) the expected savings in transaction costs and cleanup costs that arise from avoiding the mandatory Site Response Program, which entails less discretion choosing how and how much to remediate, less regulatory flexibility (e.g., expedited and waived permits), and a higher level of DEQ oversight; (ii) the avoided future liability costs from obtaining an NFA; (iii) the expected appreciation in property value from remediation and obtaining an NFA over and above the savings in cleanup and liability costs; and (iv) the expected reduction in costs imposed by neighbors, community groups, environmental non-governmental organizations, and other stakeholders concerned about contamination. The costs of participation include: (i) pecuniary transactions costs such as DEQ administrative fees; (ii) pecuniary and nonpecuniary transactions costs involved in learning about the VCP and ICP and negotiating the DEQ bureaucracy; (iii) costs of any actual cleanup; and (iv) for sites that are unknown to DEQ, the cost of informing DEQ about potential contamination, including costs associated with being added to ECSI.

We expect these benefits and costs of participation to vary across sites, so that net benefits of participation are positive for some sites and negative for others. We do not directly observe benefits and costs. Using the ECSI along with data from block group-level census data, however, we can observe site characteristics that proxy for these costs. We use these proxies as explanatory variables in our regression analysis. In Section 4.2 below we discuss the relationship between these proxies and the net benefits of participation.

4.2. Regression samples

We cannot run a single regression to explain participation in VCP and ICP because the subsample of non-participating sites is different for each program: as noted above, high priority sites are eligible to participate in the VCP, but not in the ICP. Therefore, we constructed two samples of ECSI sites, one to explain participation in the VCP, and one to explain participation in the ICP.

The first several steps of the data base assembly were the same for each of the two samples. First, we used geographic information system software to associate each ECSI site with a census block group and merged the site-level ECSI data with block-group level census data. Of the 4,223 sites in ECSI, 458 had to be dropped either because locational information (latitude and longitude) was missing in the ECSI data, or because block group data was missing in the census data. Next, we dropped 340 sites that were ineligible to join the VCP or ICP because they were participating in the mandatory Site Response Program (319 sites), or were listed on the federal National Priorities List (11 sites). We also dropped 120 ECSI sites that received an "ultimatum" letter from DEQ warning them that if they did not join the VCP, they would be forced to join the mandatory Site Response Program. We dropped these sites because their participation in the VCP was not fully voluntary. In addition, we dropped four sites that DEQ declared "orphans" because a responsible party could not be identified. Finally, we dropped 1,506 sites for which ECSI did not contain enough information to determine the prior industrial or other use of the site. The result was a data set containing 1,805 sites.

To create the sample used to analyze the VCP—which we will call the "VCP sample"—we dropped an additional 125 sites for which the VCP join data was inconsistent (because join date preceded the date the site was entered into ECSI), leaving a total of 1,680 sites, 613 (36%) of which participated in the VCP.

To create the sample used to analyze the ICP program—which we will call the "ICP sample"—starting with the data set of 1,805 sites, we dropped 124 additional sites DEQ deemed to be high priority for further action because such sites are not eligible to participate in the ICP. In addition, we dropped 39 sites for which the ICP join date was inconsistent (again because join date preceded the date the site was entered into ECSI), leaving a total of 1,642 sites, 155 (9%) of which participated in the ICP.

4.3. Variables

Table 1 lists the variables used in the econometric analysis and for each sample, presents means for the entire sample and for the subsamples of participants and nonparticipants. We use four types of variables to explain participation in the VCP and ICP: (i) dummy variables that have to do with DEQ regulatory activity; (ii) continuous variables that capture the characteristics of the neighborhood in which the site is located; (iii) variables that interact the regulatory activity and neighborhood characteristics variables; and (iv) dummy variables that control for the type of industrial or commercial activity found on each site. We are not able to include explanatory variables derived from the information in ECSI that ranks the severity of contamination ("high," "medium," "low") because this information is missing or unreliable for the majority of the sample.

4.3.1. Regulatory activity variables

Among the regulatory activity variables, *CRL* is a dummy variable that indicates whether DEQ placed the site on the Confirmed Release List. As Table 1 shows, DEQ "listed" roughly a quarter of the sites in the VCP and ICP samples. We expect *CRL* to be positively correlated with participation because, as discussed above, listed sites are subjected to enhanced pressures to clean up from regulators and other actors such as mortgage lenders. For example, listed sites face a higher probability of being forced into the mandatory Site Response Program and being denied bank credit. Thus, all other things equal, we expect the net benefits of participation to be higher for such sites. Table 1 provides a preliminary indication of a positive correlation between listing and participation in the VCP. In the VCP sample, the percentage of sites that were listed was much higher among VCP participants (42%) than nonparticipants (16%). This seeming positive correlation between *VCP* and *CRL* does not prove that listing causes participation, however, because it may simply reflect an underlying correlation between *CRL* and another site characteristic. For example, it could reflect the fact that sites used for manufacturing (versus retail) tend to participate, and also tend to be listed. Alternatively, or in addition, it could reflect the effect of *VCP* on *CRL*, that is, it could be that sites that participate are subsequently listed. As discussed below, to control for site characteristics and potential endogeneity in *CRL* and other regulatory variables, we use a duration model that explicitly accounts for the timing of participation, listing, and other regulatory activities.

CERCLIS is a dummy variables that indicates whether the federal government includes the site in CERCLIS, which, as discussed above, is a database used by the U.S. Environmental Protection Agency (EPA) to track activities conducted under its CERCLA authority. We expect that *CERCLIS* is positively correlated with participation in the VCP and ICP because inclusion in this federal list, like inclusion in ECSI, presumably enhances regulatory and non-regulatory pressures to cleanup and thereby increases the net benefit of participation.

PERMIT is a dummy variable that indicates DEQ has issued a permit to the site manager, whether for air emissions, liquid effluents, or hazardous waste. About a sixth of the sites in our two regression samples received permits from DEQ. We expect *PERMIT* to be positively correlated with participation for two reasons. First, all other things equal, DEQ likely has more comprehensive and more accurate information about potential contamination on permitted sites than on nonpermited sites. As a result, one of the main costs to site managers of participation—revealing information about potential contamination to DEQ—is lower for permitted sites. Second, by virtue of their ongoing contacts with DEQ, permitted sites likely have more accurate and more comprehensive information about the VCP and ICP than do nonpermitted sites (Wistar 2006). As a result, their costs of participation are lower.

Finally, we include dummies that indicate which of the three DEQ regional offices (east, west, and northwest) are responsible for administering the site: W_REGION, and NW_REGION (the east region is the reference category). The west and northwest regions each have approximately 37% of the sites in our samples, while the east region has roughly 26%. These dummies aim to control for differences in program administration across the three regions that affect the net benefits of participation. We have no strong expectations about the signs of these dummies.

4.2.2. Community characteristics variables

We include two variables that measure potentially relevant characteristics of the communities in which the site is located. *HOUSEVAL*, the median housing value in the relevant census block group, aims to capture the market value of the site.[7] To the extent *HOUSEVAL* is a good proxy for market value, we expect it to be positively correlated with participation for two reasons. First, site managers and developers may have stronger financial incentives to remediate more valuable properties. Also, contamination on particularly valuable sites may attract more attention from regulators, neighbors, and others.

TR_TIME is the median travel time to work in minutes in the relevant census block. It is included to control for locational factors that might influence a site manager's decision to participate including the market value of the site and proximity to companies that provide remediation services. We expect this variable to be negatively correlated with participation (as is distance to central business district in Alberini 2007) because sites located farther from business districts may be less valuable and may attract less attention from regulators, neighbors and others.

4.2.3. Interaction terms

We include two interaction terms: *CRL_HOUSEVAL*, which is *CRL* interacted with *HOUSEVAL*, and *CRL_TR_TIME*, which is *CRL* interacted with *TR_TIME*. The aim of including these terms is to try to shed light on how listing affects the probability of participation.

4.2.4. Prior use variables

Finally, we include 14 dummy variables, *SIC1–SIC 14*, that indicate the two-digit SIC code most closely associated with the site's prior commercial or industrial use. These variables are intended to control for a variety of site characteristics including size, complexity, and the nature of the contamination. In our regression samples, the categories with the greatest proportion of sites are SIC8 (transportation, communications, electricity, gas and sanitary) with roughly 18%; SIC 12 (services including dry cleaning and auto

[7] We also collected data on commercial property values compiled at the county level for tax assessment purposes. However, we were unable to use these data in our regression analysis because most Oregon countries do not collect the data needed to locate the properties in the appropriate census block group or to control for property size.

repair) with roughly 17%; SIC10 (retail trade) with 11%, and SIC4 (manufacture of wood products) with roughly 10%. Although ECSI contains more direct information on site characteristics, including the size and current operational status, these data are too incomplete to be used in our analysis.

5. ECONOMTRIC MODEL

We use a duration model to analyze participation in the VCP and ICP. Such models are used to explain intertemporal phenomena, such as the length of time that patients with a life-threatening disease survive, and the length of time industrial facilities operate before adopting a new technology.[8] Duration models estimate a hazard rate, h, which may be interpreted as the conditional probability that a phenomenon occurs at time t given that it has not already occurred and given the characteristics of the unit of analysis (patient, plant) at time t. The hazard rate is defined as

$$h(t, \mathbf{X_t}, \beta) = f(t, \mathbf{X_t}, \beta)/(1- F(t, \mathbf{X_t}, \beta)) \qquad (1)$$

where $F(t, \mathbf{X_t}, \beta)$ is a cumulative distribution function that gives the probability that the phenomenon (death, adoption of a technology) has occurred prior to time t, $f(t, \mathbf{X_t}, \beta)$ is its density function, $\mathbf{X_t}$ is a vector of explanatory variables related to the characteristics of the unit of analysis (which may change over time), and β is a vector of parameters to be estimated. In our study, the hazard rate is the conditional probability that a site in our data set joins the VCP or ICP program at time t, given that it has not already joined and given the characteristics of the site at time t.

In duration models, the hazard rate is typically broken down into two components. The first is a baseline hazard, $h_0(t)$, that is a function solely of time (not of any explanatory variables) and that is assumed to be constant across all plants. The baseline hazard captures any effects not captured by explanatory variables (such as the diffusion of knowledge about the VCP and ICP or changes in macroeconomic conditions). The second component of the hazard rate is a function of the explanatory variables. Combining these two components, the hazard rate h(t) is written

$$h(t) = h_0(t)\exp(\mathbf{X_t}'\beta). \qquad (2)$$

The vector of parameters, β, is estimated using maximum likelihood.

A duration framework is appropriate for analyzing participation in the program for two reasons. First, two of the regulatory activity variables—*CRL* and *CERCLIS*—may be simultaneously determined along with VCP and ICP; that is, they are potentially endogenous. In theory, participation could result in a site being added to the Confirmed Release List or to CERCLIS. A duration model controls for this problem because it explicitly accounts for the intertemporal relationship of these explanatory variables and

[8] For an introduction, see Keifer (1998).

participation: once a site joins the VCP or ICP, it drops out of the likelihood function, so the model only takes into consideration cases where listing precedes participation.[9]

A second reason for using a duration model is that it avoids the problem of "right censoring" that would arise in a simple cross-sectional dichotomous choice model because some of the plants that were not participating in July 2006, when our ECSI data were collected, could join subsequently. A duration model circumvents this problem by estimating the conditional probability of participation in each period.

We use a Cox (1975) proportional hazard model. There are two broad approaches to specifying duration models. One is to make parametric assumptions about the time-dependence of the probability density function, $f(t, \mathbf{X_t}, \beta)$. Common assumptions include exponential, Weibull, and log-logistic distributions. Each assumption implies a different shape for the baseline hazard function, $h_0(t)$.[10] A second general approach is to use a Cox (1975) proportional hazard model which does not require a parametric assumption about the density function. This feature accounts for the broad popularity of the Cox model among economists, and it is the reason we choose it. We use days as our temporal unit of analysis.

6. RESULTS

Table 2 presents regression results for the Cox proportional hazard model. Model 1 and Model 2 focus on participation in the VCP and Model 3 focuses on participation in the ICP. Because the hazard function given by equation (2) is nonlinear, the estimated coefficients do not have a simple interpretation (technically, they are the effect on the log hazard rate of a unit change in the explanatory variable at time t). Exponentiated coefficients, however, can be interpreted as the hazard ratio—that is, the ratio of the hazard rate given an increase in an explanatory variable at time t (a unit increase in a continuous variable or a change from 0 to 1 of a dichotomous dummy variable) relative to the baseline hazard rate at time t. A hazard ratio greater than 1 indicates that an increase in the explanatory variable increases the hazard rate relative to the baseline. For example, a hazard ratio of 2 means that an increase in the explanatory variable doubles the hazard rate relative to the baseline.

6.1. Voluntary Cleanup Program

Of the regulatory variables in Model 1, *CRL*, *PERMIT*, and *NW_REGION* are significant at the 5% level. As expected, both *CRL* and *PERMIT* are positively correlated with participation. The hazard ratios for these variables indicate that all other things equal, a site that has been placed on the Confirmed Release List is 28% more likely to join the VCP than a site that has not been listed and a site that has been permitted is 30% more

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[9] We are not able to account for the timing of *PERMIT* because the requisite data in ECSI are incomplete.
[10] For example, an exponential probability density function generates a flat hazard function, $h_0(t)$. The implication is that the probability of joining the VCP and ICP (apart from the influences of regulatory activity and site characteristics) stays the same over time. A log-logistic probability density function, on the other hand, generates a hazard function that rises and then falls.

likely to join the VCP than a site that has not been permitted. The regression results also indicate that the DEQ administrative region where the site is located affects the probability of participation: sites administered by the northwest DEQ region are 34% more likely to join than sites in the east region (the reference group). Evidently, listing a site in CERCLIS has no impact on the probability of participation.

Of the community characteristic variables, *TR_TIME* is significant at the 10% level. However, the magnitude of the effect is quite small. Surprisingly, *HOUSEVAL* is not significant. Of the prior use variables, all are significant at the 5% or 10% level. The largest effects are for *SIC4* and *SIC13*.

Model 2 interacts CRL with HOUSEVAL and TR_TIME in order to try to better identify the effect of CRL. Here, CRL is no longer significant, but results for the remaining variables in Model 1 are qualitatively identical. The interaction term CRL_HOUSEVAL is significant at the 5% level, but CRL_TR_TIME is not significant. These results suggest that listing has a significant impact when the market value of the site is relatively high. Alternatively, they suggest that the market value of the site has an impact when the site is listed.

6.2. Independent Cleanup Pathway

Of the regulatory variables in Model 2, only *W_REGION* and N*W_REGION*, the two dummies that indicate which DEQ region administers the site are significant, both at the 1% level. The hazard ratios indicate that sites in the west region are 3.24 times more likely to participate in the ICP than sites in the east region, and sites in the northwest region are 2.57 times more likely to participate. Neither of the two community characteristics variables are significant. Finally, four of the prior use dummy variables are significant, all at the 5% level. The largest effects are for *SIC7* and *SIC9*.

6.3. Discussion

Several of the results from the empirical analysis are particularly noteworthy. First, both of Oregon's voluntary cleanup programs are attracting sites with significant contamination. This is evident from the simple summary statistics in Table 1 which indicate that 42% of the 613 sites in our sample that participated in the Oregon VCP, and 25% of the 155 sites that participated in the ICP were included by DEQ on the Confirmed Release List. Recall that two of the conditions for inclusion on this list are that contamination on the site has been confirmed and deemed significant by virtue of its quantity or hazard. This finding contrasts sharply with the situation in Colorado where, according to Alberini (2007) the state voluntary cleanup program almost exclusively attracts sites with minimal contamination and high development potential.

Second, Models 1 and 2 imply that sites with relatively high market values that DEQ includes on the Confirmed Release List are more likely to join the VCP, all other things equal. The result for *CRL* in Model 1 indicates that for the average site, inclusion in the Confirmed Release List increases the probability of participation by 28%, all other things equal. The results for *CRL* and *CRL_HOUSEVAL* in Model 2 suggests that inclusion on the Confirmed Release List mainly affect the probability of participation for sites with relatively high market values. Two complementary explanations for these finding are possible. One is that listing enhances regulatory and nonregulatory pressures for remediation, and these pressures are strongest in areas where property values are relatively high. For example, community groups in high-property value areas may place more pressure to remediate on listed sites than do community groups in areas with low-property values. In addition, managers of high-value listed sites may have stronger financial incentives to remediate than managers of low-value listed sites. For example, listing may not affect the managers' decisions to transact their site when the market value is low; in such cases, managers may have no intention of selling or developing their site. However, for valuable sites, listing may derail plans to sell or develop the site, and may create incentives to join the VCP to obtain an NFA letter.

These two findings—that the Oregon VCP is attracting sites with significant contamination and that listed sites are more likely to join—are potentially important from a policy perspective. Together, they imply that the DEQ has been able to spur voluntary remediation of some contaminated sites by adding them to the Confirmed Release List.

A third finding is that listing does not drive participation in the ICP. The reason may be that the ICP, by virtue of the criteria and rules for participation, selects for sites where contamination is less severe and where remediation is relatively straightforward. Presumably, regulatory and non-regulatory pressures for remediating such sites are relatively low. If DEQ faces resources constraints that force it to focus on the most heavily contaminated sites, then managers of lightly contaminated sites know that their chances of being drafted into the mandatory Site Response Program are relatively minimal. Moreover, even if this does happen, the costs of mandatory cleanup are probably relatively low. Also, sites of the type that participate in the ICP probably face relatively little pressure from non-regulatory actors.

A final noteworthy result is that sites with DEQ permits are more likely to participate in the VCP. We hypothesized that sites that are permitted are more likely to join partly because they face lower costs of doing so since DEQ is more likely to already know about potential contamination on permitted sites and managers of such sites are more likely to already be familiar with DEQ and its VCP. Without follow on research, we cannot be sure that this explanation is valid. However, it also hints at the potential importance of informational issues in explaining VCP participation.

7. CONCLUSION

We have presented an econometric analysis of participation in a state voluntary cleanup program. We have overcome the problem of assembling a control group of nonparticipating sites by focusing on a VCP in a state that maintains a registry of known contaminated sites. The regressors in our econometric analysis are site characteristics that aim to capture the benefits and costs of participation, including the expected savings that arise from avoiding the mandatory Site Response Program, and the cost of revealing to

DEQ that a site is contaminated. We have used a duration model to account for the intertemporal relationship between our explanatory variables and participation, and to avoid right censoring.

Our results suggest that Oregon's voluntary cleanup programs are attracting sites with significant contamination, and that, all other things equal, sites that state regulators have formally added to a public list of sites with confirmed significant contamination are more likely to subsequently join one of the state's main voluntary programs. Together, these findings imply that state regulators can spur voluntary remediation of contaminated sites by collecting, verifying, and publicly disclosing information on contamination. This is a mechanism for encouraging VCP participation that, to our knowledge, has not yet received any attention in literature. Compared to some other policy tools frequently used to encourage participation in VCPs, it would appear to be relatively inexpensive. Our findings comport with a growing body of evidence that suggests public disclosure of environmental performance information is an efficient policy tool for promoting abatement and remediation.

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Table 1. Variables in econometric analysis: definition and sample means

Variable	Description	VCP Sample			ICP Sample		
		All n=1,680	**Parts. n=613**	**Nonparts. n=1,067**	**All n=1,642**	**Parts. n=155**	**Nonparts. n=1,487**
DEPENDENT							
VCP	Participant in Voluntary Cleanup Program?*	0.365	1	0	0.398	0.477	0.389
ICP	Participant in Independent Cleanup Pathway?*	0.107	0.109	0.105	0.094	1	0
INDEPENDENT							
Regulatory activity							
CRL	On Confirmed Release List?*	0.255	0.423	0.159	0.242	0.245	0.242
CERCLIS	In CERCLIS?*	0.168	0.119	0.197	0.155	0.084	0.162
PERMIT	Has DEQ permit?*	0.168	0.194	0.150	0.151	0.110	0.155
E_REGION	In DEQ eastern region?*	0.263	0.321	0.229	0.257	0.181	0.265
W_REGION	In DEQ western region?*	0.371	0.238	0.448	0.378	0.361	0.380
NW_REGION	In DEQ northwestern region?*	0.366	0.440	0.323	0.365	0.458	0.355
Neighborhood characteristics							
HOUSEVAL	Median house value in census block group ($)	142,237.1	145,068.4	140,610.5	142,564.6	158,785.8	140,873.7
TR_TIME	Med. travel time to work in census block group (min.)	12890.9	13,120.9	12,758.8	13042.9	14,051.8	12,937.7
Prior use							
SIC1	SIC div. A: ag., forestry, farming*	0.044	0.024	0.056	0.045	0.032	0.046
SIC2	SIC div. B: mining*	0.060	0.021	0.082	0.055	0.026	0.058
SIC3	SIC div. C: construction*	0.004	0.002	0.005	0.004	0.006	0.004
SIC4	SIC div. D, maj. grp. 24: mfg. wood products except furniture*	0.102	0.124	0.089	0.098	0.103	0.097
SIC5	SIC div. D, maj. grp. 28: mfg chemicals	0.027	0.016	0.034	0.027	0.026	0 .027
SIC6	SIC div. D, maj. grps. 33&34: primary metal except machinery and transportation*	0.039	0.046	0.035	0.034	0.032	0.034
SIC7	SIC div. D, other maj. grps: mfg. all other products*	0.076	0.078	0.074	0.072	0.077	0.071
SIC8	SIC div. E: transport, comm. electric, gas, and sanitary*	0.176	0.206	0.159	0.186	0.155	0.189
SIC9	SIC div. F: wholesale trade (includes bulk oil & salvage)*	0.100	0.124	0.086	0.094	0.110	0.093
SIC10	SIC div. G: retail trade*	0.107	0.093	0.115	0.110	0.097	0.111
SIC11	SIC div. H: finance, insurance, and real estate*	0	0	0	0	0	0
SIC12	SIC div. I: services (includes dry cleaning, auto repair)*	0.174	0.171	0.175	0.173	0.265	0.163
SIC13	SIC div. J: public administration (includes military)*	0.043	0.051	0.039	0.046	0.045	0.046
SIC14	Not classifiable*	0.049	0.044	0.052	0.056	0.026	0.059

*Dichotomous dummy variables (0/1)

Table 2. Duration regression results

Variable	Model 1 Dep. var. = VCP	Model 2 Dep. var. = VCP	Model 3 Dep. var. = ICP
Regulatory activity			
CRL	1.280** (0.125)	1.021 (0.212)	0.743 (0.167)
CERCLIS	1.024 (0.149)	1.026 (0.150)	1.455 (0.425)
PERMIT	1.303** (0.139)	1.310** (0.139)	0.956 (0.259)
W_REGION	1.122 (0.131)	1.126 (0.132)	3.240*** (0.815)
NW_REGION	1.342** (0.165)	1.327** (0.165)	2.577*** (0.737)
Neighborhood characteristics			
HOUSEVAL	1.000 (0.00000069)	1.000 (0.0000074)	1.000 (0.0000011)
TR_TIME	1.000* (0.000004)	1.000** (0.0000048)	1.000 (0.0000083)
Interaction terms			
CRL_HOUSEVAL	n/a	1.000** (0.0000012)	n/a
CRL_TR_TIME	n/a	1.000 (0.0000075)	n/a
Prior use			
SIC2	0.482* (0.191)	0.481* (0.191)	0.626 (0.449)
SIC4	3.379*** (1.040)	3.411*** (1.043)	2.545* (1.296)
SIC5	2.440** (0.965)	2.467** (0.974)	2.777 (1.750)
SIC6	2.537*** (0.892)	2.470** (0.869)	2.449 (1.663)
SIC7	2.577*** (0.804)	2.545*** (0.791)	3.022** (1.674)
SIC8	2.468*** (0.723)	2.477*** (0.723)	1.911 (0.973)
SIC9	2.010** (0.603)	2.018** (0.603)	3.191** (1.634)
SIC10	2.094** (0.647)	2.087** (0.642)	2.362 (1.239)
SIC12	2.016** (0.591)	2.001** (0.584)	2.879** (1.432)
SIC13	2.615*** (0.892)	2.598*** (0.887)	1.472 (0.855)
SIC14	2.156** (0.719)	2.194** (0.726)	1.130 (0.716)
Number of observations	1,680	1,680	1,642
Log pseudolikelihood	-3687.138	-3685.5098	-771.856

(standard errors in parentheses)
* significant at 10% level
** significant at 5% level
*** significant at 1% level

Should You Turn Yourself In? The Consequences of Environmental Self-Policing

Sarah L. Stafford

Abstract

Facilities that self-police under the Environmental Protection Agency's Audit Policy are eligible for reduced penalties on disclosed violations. This paper investigates whether self-policing has additional consequences; in particular, whether self-policing reduces future enforcement activity. Using data on U.S. hazardous waste enforcement and disclosures, I find that facilities that self-police are rewarded with a lower probability of inspection in the future, although facilities with good compliance records receive a smaller benefit than facilities with poor records. Additionally, facilities that are inspected frequently are more likely to disclose than facilities that face a low probability of inspection. The results suggest that facilities may be able to strategically disclose in order to decrease future enforcement. © 2007 by the Association for Public Policy Analysis and Management

INTRODUCTION

In 1995, the U.S. Environmental Protection Agency (EPA) issued the Audit Policy, a policy designed to encourage greater compliance with environmental regulations by providing incentives for regulated facilities to conduct environmental audits and voluntarily disclose any violations that they discover.[1] Under the Audit Policy, facilities that self-police—that is, voluntarily disclose a violation to regulators—are eligible for significant penalty reductions. EPA's Web site for environmental auditing also notes that when facilities self-police, it can render "formal EPA investigations and enforcement actions unnecessary."[2] This statement implies that, as well as rewarding self-policers with reduced penalties, EPA's Audit Policy may provide additional incentives in the form of reduced future enforcement.

Although the Audit Policy has been in effect for about a decade, there has been relatively little analysis of its implementation or effect on regulated entities. EPA provides anecdotal evidence of the Audit Policy's use, as well as statistics on self-disclosures made under the policy, but its only formal evaluation is a 1999 voluntary survey of a small number of companies that disclosed environmental violations under the policy.[3] While the respondents to the survey generally indicated a favor-

[1] EPA issued "Incentives for Self-Policing: Discovery, Disclosure, Correction, and Prevention of Violations," more commonly referred to as the Audit Policy, on December 22, 1995 (60 *Federal Register* 66705).
[2] See http://www.epa.gov/compliance/incentives/index.html, last accessed September 6, 2006.
[3] See U.S. EPA (1999).

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able experience with the policy, there was no analysis of the factors that induced facilities to self-police. In a non-EPA study, Pfaff and Sanchirico (2004) examine all cases filed in the Audit Policy Docket from 1994 to 1999 and compare the profile of voluntarily disclosed violations to the profile of violations detected by regulators in terms of the statutes violated, types of violations, and average fines. They find that the typical disclosed violation is relatively minor: In particular, reporting and recordkeeping violations constitute over 90 percent of disclosed violations. While there is no formal analysis of the factors that drive facilities to self-police, the authors provide a number of potential explanations for their finding that self-disclosed violations are very different in nature from detected violations, including the structure of the Audit Policy's incentives and the cost of auditing.[4] Pfaff and Sanchirico also speculate that facilities could be using the disclosure of minor violations as "red herrings" to discourage future inspections or distract regulators from other problems.

Although EPA implies that self-policing may have future consequences and Pfaff and Sanchirico suggest that facilities might be strategically disclosing violations to affect future enforcement, to date no study has examined whether facilities that self-police actually do receive differential treatment in the future. It is important to understand what the future consequences of self-policing are, to be able to fully evaluate EPA's Audit Policy. This paper uses data on self-disclosures and enforcement activity at regulated hazardous waste facilities to examine whether disclosures do affect future enforcement activity. In addition, the analysis provides insight into other factors that motivate self-policing. A more complete understanding of the factors that drive facilities to self-police will also help to assess the effectiveness of the current policy and potentially can be used to fine-tune the program to increase its effectiveness. While the results of the analysis are obviously most relevant for EPA's Audit Policy, they will also provide important lessons on the use of self-policing as a regulatory tool in other policy arenas.

The remainder of this paper is organized in sections that describe EPA's self-policing policy in more detail; provide a theoretical framework for considering the self-policing decision; outline the empirical approach for the analysis and describe the data; present the results of the analysis; discuss the implications of the analysis for EPA's Audit Policy and, more generally, for self-policing as a regulatory tool; and offer concluding remarks.

EPA'S SELF-POLICING POLICY

Starting in the 1980's, EPA began encouraging facilities to voluntarily undertake environmental audits. In 1986, EPA issued an Environmental Auditing Policy Statement which recommended the use of environmental auditing and encouraged states and local governments to develop environmental auditing initiatives. In December of 1995, EPA issued "Incentives for Self-Policing: Discovery, Disclosure, Correction and Prevention of Violations," which both revised the 1986 policy statement and provided incentives for facilities to voluntarily disclose and correct violations of environmental regulations. The provision of explicit incentives for self-policing extended the revised policy well beyond environmental auditing. However, because it evolved from EPA's initial policy on environmental auditing, the revised

[4] As discussed in more detail in the Theoretical Framework section of this article, because EPA does not forgive the portion of the penalty that is based on economic benefit, self-policing benefits are greatest for those violations where the economic benefit is a relatively small portion of the overall fine.

policy is commonly referred to as the Audit Policy. In fact, facilities do not have to conduct environmental audits to benefit from the incentives contained in this policy. Any facility that voluntarily identifies, discloses, and corrects violations of environmental regulations is eligible for a reduction in the penalties associated with those violations. Additionally, as long as no actual harm has occurred, EPA will not recommend criminal prosecution for facilities "acting in good faith to identify, disclose, and correct violations."[5]

To be eligible for a complete waiver of punitive penalties, the self-disclosure must meet all of the following nine conditions:

1. Systematic discovery: Discovery must either take place during an environmental audit or during a self-evaluation that is part of a due diligence program.
2. Voluntary discovery: The process through which the violation is discovered cannot be required by federal, state, or local authorities and cannot be required by statute, regulation, permit, or consent agreement.[6]
3. Prompt disclosure: Violations must be disclosed within 21 days of discovery.
4. Independent discovery and disclosure: The disclosure cannot be made after an inspection or investigation has been announced or notice of a suit has been given.
5. Correction and remediation: Any harm from the violation must be remediated and the violation must be corrected within 60 days of the date of discovery, unless technological issues are a factor.
6. No recurrence: The facility must identify why the violation occurred and take steps to ensure that it won't recur.
7. No repeat violations: The same or a closely related violation can't have occurred within the past three years at the facility or within the past five years at other facilities owned by the same parent organization.
8. Not excluded: No serious harm or imminent endangerment to human health and the environment can have occurred as a result of the violation, and the violation cannot have been a violation of an order, consent agreement, or plea agreement.
9. Cooperation: The facility must cooperate with EPA, including providing all requested documents.

If the disclosure meets conditions two through nine but does not meet the first condition for systematic discovery, it is eligible for only 75 percent mitigation of the punitive penalties rather than complete mitigation.

It is important to note that the Audit Policy does not apply to the portion of the penalty that is based on the economic benefit gained from noncompliance. For example, if a facility neglects to sample a particular wastestream for several months and discovers this violation through an environmental audit, assuming the violation meets all of the conditions above, the facility would receive a complete reduction in the punitive portion of the penalty but would continue to owe a penalty equal to the savings it received from not having conducted those samples. This requirement is necessary to ensure that regulated entities have no incentive to deliberately violate and then self-police. In the example above, there would be no benefit to deliberately

[5] 60 FR 16876.
[6] The initial disclosure period was 10 days, but the time frame was increased to 21 days in 2000 (65 FR 19618, April 11, 2000).

not sampling and then self-policing, because the regulated entity has to pay the cost of sampling after disclosure.

During the development of the Audit Policy, EPA repeatedly sought comments from the regulated community. One commenter on an early version of the policy suggested that EPA should commit to taking audits into account when assessing enforcement actions. In response, EPA stated that agreeing to forgo inspections or reduce enforcement responses is "fraught with legal and policy obstacles."[7] However, EPA also noted that, because effective audit programs should improve compliance, facilities that audit should have improved environmental performance, which is likely to be considered in setting inspection priorities. Such language is consistent with EPA's current statements that self-policing can make formal inspections less necessary.

THEORETICAL FRAMEWORK

A number of theoretical papers have examined the concept of voluntary self-policing in a static model.[8] For example, Kaplow and Shavell (1994) model a probabilistic enforcement regime and show that if regulated facilities that self-police face a reduced fine equal to the certainty equivalent of the sanction they would receive if they did not disclose, but instead took their chances that the violation would be discovered, self-policing will not affect deterrence. Facilities for which the reduced fine is less than the cost of compliance will violate and self-police, while facilities for whom the reduced fine is greater than the cost of compliance will comply. Additionally, such a regime will result in a welfare improvement because enforcement effort is reduced, as self-policers need not be inspected. Innes (1999) extends this model by considering the potential benefits of remediation under a self-policing policy. As in the Kaplow and Shavell model, facilities will self-police and remediate as long as the total cost of self-policing (any fines plus the cost of remediation) is less than or equal to the expected cost of detection. With self-policing, remediation will increase because self-policers remediate with certainty, while non-disclosers only remediate when caught. However, Innes also shows that self-policing may result in a reduction in the initial level of care taken to prevent environmental harm.[9] In a separate paper, Innes (2001) shows that if violators can engage in avoidance activities, self-policing can increase efficiency by reducing such activities and, in turn, allowing the government to achieve the same level of deterrence with a reduced enforcement effort.[10]

Mishra, Newman, and Stinson (1997) also construct a model of self-policing. Unlike the Kaplow and Shavell model and the Innes models, which are all general models of regulatory enforcement, this model is designed to capture specific aspects of EPA's Audit Policy. Thus, the focus is on a facility's incentive to conduct

[7] See the "Final Policy Statement," July 9, 1986, 51 FR 25004, Section I.

[8] The term self-policing is used in this paper to denote a situation in which a facility voluntarily notifies authorities that it has violated a regulation. Other authors such as Kaplow and Shavell (1994) have termed this same activity "self-reporting." However, the term self-reporting has also been used to describe situations where facilities are required by law to report information to regulators (such as the self-reported emissions data required for the Toxics Release Inventory).

[9] For example, if environmental damages increase over time, it may be optimal to induce additional self-policing (and thus early remediation) by setting the cost of self-policing below the expected cost of detection. However, lowering the cost of self-policing decreases the level of deterrence and thus can result in a decrease in the initial level of care.

[10] Because avoidance activities are reduced, the cost of increasing penalty levels is reduced and the government can substitute higher penalties for lower enforcement effort.

a compliance audit as well as its decision to self-police. In this model, welfare improvements result from increased remediation and decreased enforcement effort, but because violations are probabilistic and do not depend on the facility's actions, there is no change in the level of deterrence. Friesen (2006) also assumes that violations are probabilistic and that facilities can learn of their compliance status only through costly compliance audits. Assuming that facilities must remediate any disclosed violations, Friesen shows that facilities will only audit if they intend to remediate the violation, although not all facilities will disclose their remediated violations. Friesen also shows that the regulators will not inspect a facility that has disclosed a violation.

In all of the environmental self-policing models, a facility's decision to self-police depends on the cost of disclosure relative to the likelihood of detection and the cost of detection.[11] Obviously, the models vary significantly in the factors that affect the cost of disclosure (for example, whether a compliance audit or remediation is required), the likelihood of detection (whether facilities face different probabilities of detection or whether audits increase the likelihood of detection), and the cost of detection (whether remediation costs increase over time). However, none of the existing self-policing models allow regulated facilities and regulators to repeatedly interact or allow for optimal actions to take future consequences into account.[12] In a repeated setting, regulators could use decreased future enforcement as an added inducement for self-policing. Thus, when deciding whether or not to self-police, facilities would compare the cost of disclosure to the likelihood of detection, the cost of detection, and any future changes in enforcement. Because EPA's Web site implies that self-policing can affect future enforcement activity, I develop a dynamic model of self-policing to provide a theoretical framework for this empirical analysis.

Although there are no self-policing models that incorporate a dynamic enforcement regime, a number of papers have considered dynamic enforcement of regulations more generally. Two of the most influential models are Harrington's (1988) targeted enforcement model and Scholz's (1984) cooperative regulatory enforcement model. Harrington's targeted enforcement model uses changes in future inspection activity to motivate current compliance and shows that such a regime can maintain a higher level of compliance than can be obtained through more traditional, non-targeted enforcement.[13] Scholz's model of cooperative regulatory enforcement also uses future consequences to encourage compliance and shows that such a strategy can be more beneficial than a strict deterrence approach. However, in Scholz's model, regulators use differences in sanctions (that is, harsh sanctions versus a more cooperative approach) rather than differences in inspections as both a punishment and a reward. Given Harrington's focus on changes in the probability of enforcement, it was chosen as the starting point for the dynamic self-policing model.

In Harrington's targeted enforcement model, regulators classify all regulated facilities into one of two groups: G_1 is the "good" group and G_2 is the targeted or

[11] In addition to the models discussed above, there several other papers that address environmental self-policing, including Heyes (1996), Innes (2000), Kesan (2000), and Pfaff and Sanchirico (2000).
[12] Friesen's (2006) self-policing model is sequential but it is not dynamic. Livernois and McKenna (1999) and Hentschel and Randall (2000) present dynamic models of mandatory self-reporting, as opposed to voluntary self-policing.
[13] While Harrington was not the first to introduce targeted or state-dependent enforcement (see, for example, Landsberger and Meilijson (1982)), he was the first to develop a model of targeted enforcement in an environmental context.

"bad" group. Inspection probabilities vary across the groups with the inspection probability for G_1 less than the inspection probability for G_2.[14] Facilities found in violation of regulations are always moved into the target group while facilities found to be in compliance can transition to the non-target group with some positive probability. Each period, facilities choose whether or not to comply. The regulator then inspects the facility with a probability based on the facility's group, and facilities are moved from one group to the other if warranted. Facilities that are not inspected stay in their group for the next period. This targeted enforcement regime can lead to higher levels of compliance than would occur under a regime where all facilities face the same probability of inspection.[15] Additionally, anecdotal and empirical evidence suggests that the targeted enforcement model is consistent with current EPA enforcement practices.[16]

Using Harrington's model as a starting point, I develop a model of self-policing in a targeted enforcement regime (hereafter referred to as the SEPTER model). The remainder of this section provides an overview of the model, focusing on its predictions for facility and regulator behavior. A companion paper, Stafford (2006), presents the SEPTER model in more detail. As in Harrington, facilities start in one of two groups, based on past compliance behavior. Inspection probabilities vary across the groups with the inspection probability for G_1 (π) less than the inspection probability for G_2 (ρ). Facilities found in violation of regulations are always moved into the target group, while facilities found to be in compliance can transition to the non-target group with some positive probability. Additionally, in the SEPTER model, facilities that self-police can be rewarded with some positive probability of transitioning to the non-target group.

There are two possible types of noncompliance, deliberate and inadvertent.[17] By including both deliberate and inadvertent compliance, the SEPTER model captures the fact that self-policing is not possible for all violations.[18] Facilities are required to abate pollution at a cost of c per period. If a facility does not abate and is inspected, the deliberate violation will be discovered and the facility will be fined Z. Facilities are also subject to probabilistic spills that occur with probability p and will inadvertently render the facility noncompliant. To discover whether a spill has occurred, facilities must conduct an audit at a cost of a. Returning to compliance costs k, but once remediated the spill cannot be detected by regulators. If the spill occurs and a facility does not remediate but is inspected, it is assessed a fine F which includes the cost of remediation as well as a punitive fine. Alternatively, if the facility discovers the occurrence, remediates, and discloses it to regulators, the facility receives a fine R. Since R does not include the cost of remediation, $R + k$ must be less than F. To be consistent with EPA's Audit Policy, facilities must make the disclosure decision prior to an inspection occurring. Finally, note that facilities cannot disclose deliberate violations to receive a reduced fine.

[14] Fines for discovered violations also vary across the two groups.
[15] There have been a number of extensions to Harrington's basic model (see, for example, Harford and Harrington (1991) and Friesen (2003)). However, none of them have incorporated self-policing.
[16] For example, the introduction to EPA's Fiscal Year 2002 Enforcement and Compliance Assurance Report states that EPA uses "data analysis and other relevant information to marshal and leverage resources to target significant noncompliance," (U.S. EPA 2003, page 3). Helland (1998) examines enforcement of the Clean Water Act using data on the pulp and paper industry and finds that regulator behavior is generally consistent with a targeted enforcement model.
[17] Harrington (1988) assumes only deliberate compliance.
[18] As noted in the second section of this article, some violations are expressly excluded from the Audit Policy.

Each period, regulators receive one of four possible signals about the facility's compliance status:

i. Compliance: The facility is inspected and there is no detected violation;
ii. Violation: The facility is inspected and a violation (deliberate or inadvertent) is detected;
iii. Disclosure: The facility discloses an inadvertent violation and there is no deliberate violation (either because the facility abated or because there is no inspection); or
iv. No information: The facility does not disclose and there is no inspection.

As shown in the transition matrix presented in Table 1, with no new information, the facility's group does not change. Facilities in G_2 that are found in compliance will move to G_1 with probability g. Facilities found to be in violation will be in G_2 next period, regardless of their starting point. Finally, facilities that disclose but have not been found to be in violation through an inspection will stay in G_1 if they begin in G_1 and will move to G_1 with probability q if they begin in G_2. Assuming that inspection probabilities and fines are constant, as long as future payoffs are discounted by δ where $0 \leq \delta < 1$, the optimal facility policy is a stationary policy that will be independent of the initial state of the system.

With respect to deliberate violations, the facility has two possible choices, to abate or to pollute. With respect to the probabilistic violations, the facility must make three decisions: (1) whether to audit; (2) whether to remediate a violation if one is discovered; and (3) whether to disclose a violation. If a facility decides not to audit, it has no more decisions to make. If it does audit, it can choose to remediate but conceal the violation, remediate and disclose the violation, or not remediate and not disclose. This is consistent with EPA's Audit Policy, as remediation is required as a part of disclosure. However, auditing without remediating or disclosing is dominated by not auditing, as the facility saves the cost of auditing with no change in the probability of detection. Thus there are three viable actions with respect to probabilistic violations: No Audit, Audit-Remediate-Conceal, or Audit-Remediate-Disclose. Combining these actions with the actions for deliberate violations yields six possible strategy combinations:

1. Abate/No Audit
2. Pollute/No Audit
3. Abate/Conceal
4. Pollute/Conceal
5. Abate/Disclose
6. Pollute/Disclose

Table 1. Transition matrix for each target group.

Regulator's Information	Starting in G_1		Starting in G_2	
for Period t	Stay in G_1	Move to G_2	Move to G_1	Stay in G_2
Compliance	1	0	g	1-g
Violation	0	1	0	1
Disclosure	1	0	q	1-q
No information	1	0	0	1

Given these strategies, one can write down the expected cost of each strategy based on whether the facility is in G_1 or G_2. The facility then has 36 possible policies denoted by f_{ij} where i describes the strategy taken in G_1 and j describes the strategy taken in G_2. To evaluate the expected cost of each policy, one solves the system of equations formed by taking (1) the expected cost of strategy i using G_1 as a starting point, and (2) the expected cost of strategy j using G_2 as a starting point. Some of the expected cost functions are very straightforward. For example, a facility that chooses a policy of abatement and disclosure in both groups (f_{55}) is always in full compliance and has an expected present value cost of

$$\frac{c + a + p(k + R)}{1 - \delta}.$$

However, other policies have much more complicated expected costs, as the regulated facility will move in and out of the two groups based on inspections and disclosures.

Given the regulator's targeting plan and the facility's costs, the goal of the facility is to choose the policy that minimizes the present value of expected costs. Which policy will ultimately be most profitable depends on the relative costs of abatement and auditing, as shown in Table 2.[19] As long as audit costs are low, facilities will always audit. However, whether they will abate or disclose depends on abatement costs and fines for disclosed violations. As long as abatement costs are low, facilities will always abate, but whether they will audit and disclose depends on the relative costs of auditing and the fines for disclosed violations. When both audit and abatement costs are low, facilities will always audit and abate, but will not disclose because facilities do not care about the probability of inspection. When neither audit nor abatement costs are low, the optimal strategy is more difficult to determine and depends not only on the relative costs of auditing and abatement, but also on the rates at which facilities are moved between the two groups and the fines imposed for disclosed violations.

Regulators can affect a facility's optimal strategy by manipulating the self-policing policy parameters (that is, the setting of R and q), as well as other enforcement param-

Table 2. Optimal facility policies as a function of audit and abatement costs.

	Abatement Costs		
Audit Costs	Low: $\pi Z > c$	Moderate: $\rho Z > c > \pi Z$	High: $c > \rho Z$
Low: $\pi pF > a + pk$	f_{33}	f_{43}, f_{45}	f_{43}, f_{44}, f_{45}, f_{46}
Moderate: $\rho pF > a + pk > \pi pF$	f_{13}, f_{15}	f_{13}, f_{15}, f_{23}, f_{25}	f_{13}, f_{14}, f_{15}, f_{16}, f_{23}, f_{24}, f_{25}, f_{26}
High: $a + pk > \rho pF$	f_{11}, f_{13}, f_{15}	f_{11}, f_{13}, f_{15}, f_{21}, f_{23}, f_{25}	f_{11}, f_{12}, f_{13}, f_{15}, f_{16}, f_{21}, f_{22}, f_{23}, f_{25}, f_{26}

1 = Abate/No Audit, 2 = Pollute/No Audit, 3 = Abate/Conceal, 4 = Pollute/Conceal, 5 = Abate/Disclose, 6 = Pollute/Disclose.

[19] Because auditing without remediation is never optimal, in the following discussion, the cost of remediation is subsumed in the cost of auditing.

eters such as the inspection rate and the fines for violations. For example, decreasing the fine for disclosed violations (R) or increasing the probability that a facility that discloses in the target group will be moved to the non-target group (q) will increase both audits and disclosures at facilities in the target group, although such changes will not affect auditing or disclosure in the non-target group.[20] However, such actions are likely to result in decreased abatement overall, as disclosure will become a more cost effective method of decreasing future enforcement relative to abatement. This effect is consistent with Pfaff and Sanchirico's (2004) proposition that facilities might use the disclosure of minor violations as "red herrings" to discourage inspections or distract regulators from other problems. In fact, as discussed in more detail in Stafford (2006), any changes to the self-policing or enforcement policy parameters will involve tradeoffs between increased auditing and disclosures and increased abatement.

Given the tradeoffs between auditing, disclosures, and abatement, it is not possible to explicitly solve for the optimal self-policing policy without specifying both the joint distribution of abatement and audit costs as well as the relative benefit from auditing (that is, remediation of probabilistic violations), disclosure, and abatement. Such data do not currently exist and would be very difficult to obtain. However, we can determine empirically whether the SEPTER model provides an appropriate description of regulator and facility behavior. There is already some existing anecdotal and empirical evidence suggesting that EPA uses targeted enforcement, so we should find that compliance histories affect inspection probability even if SEPTER is not an appropriate model of EPA's self-policing policy. Additionally, all self-policing models imply that facilities with a high probability of enforcement are more likely to disclose than facilities with a low probability of enforcement, ceteris paribus. However, only the SEPTER model implies that disclosures in the recent past should decrease the probability of future inspections and that the effect of disclosures on future inspections should depend on the facility's compliance history (that is, whether or not they are in a target group).

EMPIRICAL APPROACH

Because federal environmental regulations are media-specific, there are separate programs that regulate air, water, toxic materials, and hazardous waste. Although facilities may be regulated under more than one program, each program conducts its own enforcement actions. It is very difficult, therefore, to consider overall enforcement activity. Thus, to analyze enforcement and disclosure behavior, this analysis focuses only on facilities subject to hazardous waste regulations, more formally known as Subtitle C of the Resource Conservation and Recovery Act (RCRA). The analysis includes approximately 631,000 regulated hazardous waste facilities that were identified using EPA's RCRAInfo database.[21] The RCRAInfo database includes data regarding each facility's location, size, regulatory status, compliance history, enforcement history, and whether the facility is regulated by another media program. However, it does not include comprehensive disclosure information.[22] Therefore EPA's

[20] If R is greater than 0, facilities in the non-target group will never disclose, so decreasing R or increasing q will have no effect on their optimal strategies.
[21] The RCRAInfo database is available online through EPA's Envirofacts data warehouse (http://www.epa.gov/enviro/). The data for this study was extracted from files on the FTP server in May 2004. All facilities with a valid Generator Status that were not classified as "Non-Notifiers" were included in the analysis.
[22] While there is some data on disclosures in RCRAInfo, disclosure information is not a required data element. Additionally, a comparison of the disclosure data in RCRAInfo to other EPA sources of disclosure information suggests that the data provided in RCRAInfo are quite incomplete.

Office of Enforcement and Compliance Assistance provided a list of all facilities that voluntarily self-disclosed in 2001.[23] Cross-referencing the 1,158 facilities with disclosures with the facilities regulated under RCRA resulted in 325 matches.

The analysis examines the effect a disclosure in 2001 has on the probability that a facility is inspected in 2002. Because whether or not a facility is inspected is a binary variable, the appropriate regression for this analysis is a probit. However, according to the SEPTER model, whether a facility discloses will depend in part on expected enforcement activity; that is, whether or not the facility is in the target group. Thus, I use a bivariate probit regression similar to that used in Morgenstern and Al-Jurf (1999) to control for the fact that disclosures should be endogenous.[24] More specifically, let $INSP_i^* = X_i\beta_1 + DISC_i\beta_2 + \varepsilon_i$ represent the benefit to the regulator of inspecting facility i, where X_i is a vector of explanatory variables, $DISC_i$ indicates whether the facility disclosed a violation in the previous year, and ε_i is a random error term. Although $INSP_i^*$ is not observable, $INSP_i$ is observable and takes the following form:

$$INSP_i = \begin{cases} 1\text{ (inspected)} & \text{if } INSP_i^* > 0 \\ 0\text{ (not inspected)} & \text{if } INSP_i^* \leq 0 \end{cases}.$$

Let $DISC_i^* = Z_i\delta + \eta_i$ represent the benefit to facility i of disclosing a violation where Z_i is a vector of explanatory variables and η_i is a random error term. Since the benefit of disclosure depends in part on the probability that a facility will be inspected, Z_i includes X_i. Although $DISC_i^*$ is not observable, $DISC$ is observable and takes the following form:

$$DISC_i = \begin{cases} 1\text{ (disclosure)} & \text{if } DISC_i^* > 0 \\ 0\text{ (no disclosure)} & \text{if } DISC_i^* \leq 0 \end{cases}.$$

The error terms ε_i and η_i are assumed to have a bivariate normal distribution and I apply the Huber-White sandwich variance estimator to correct for possible heteroskedasticity.

This model can be estimated using maximum likelihood, although the effect of disclosures on the inspection decision is only identified subject to either an exclusion or a covariance restriction. For an exclusion restriction to be valid, the variable excluded from X_i should be theoretically, as well as statistically, related to the facility's benefit from disclosure, but unrelated to the regulator's benefit from inspection. This analysis excludes the variable *State Audit Immunity* from the Inspection equation to identify the model. *State Audit Immunity* is a dummy variable indicating whether or not the state in which the facility is located has a law providing immunity from civil penalties to facilities that self-disclose. State immunity laws decrease the cost of disclosure for a facility because they limit the penalty that can be assessed for disclosed violations. However, this immunity does not apply to violations that are discovered during the course of a regulator's inspection, and there-

[23] Data were obtained through a Freedom of Information Act request. After removing duplicate entries from the list of facilities supplied by EPA, there were 431 disclosures representing at least 1,158 facilities.

[24] This method is also discussed in Chapter 15 of Wooldridge (2002). A secondary concern is that disclosures are a very rare event, occurring at only 325 of 630,832 hazardous waste facilities (approximately 0.05 percent) in 2001. King and Zeng (2001) present a rare event logit model that can be used in such situations. However, there is no analogous rare event correction for use in a bivariate probit model, and because a Rivers-Vuong test rejects the exogeneity of the disclosure variable, controlling for the endogeneity of disclosures is more critical than correcting for a rare event. Moreover, there is only one qualitative difference in the results of a rare event logit regression of disclosures compared to a standard probit regression of disclosures (that is, one explanatory variable loses significance).

fore should not affect the incentives of a regulator to inspect a facility. Thus, in theory, *State Audit Immunity* should affect the disclosure decision but not the inspection decision. Moreover, *State Audit Immunity* does not have a significant effect if it is included in a standard probit regression of the Inspection equation that excludes the disclosure variables, so it is not statistically related to the likelihood of an inspection. However, as discussed in more detail in the Results section, it does have a significant effect on the likelihood that a facility discloses.

Table 3 lists the explanatory variables used in this analysis, along with their means, standard deviations, and expected effects in the Inspection and Disclosure equations. In the SEPTER model, a facility's group is the only factor that affects the likelihood of an inspection. In practice, however, other factors are likely to affect the probability of an inspection—such as the potential for environmental damage at the facility (and thus the benefit to a regulator from deterring a violation), the cost of compliance, and the regulator's resource constraints. Therefore, the reduced-form Inspection equation includes variables that proxy for a facility's group, as well as variables that capture these other additional factors. The reduced-form Disclosure equation includes the explanatory variables from the Inspection equation (other than the disclosure variables), as well as *State Audit Immunity*, to identify the model. While the primary role of the Disclosure equation is to control for the endogeneity of the disclosure variables used in the Inspection equation, the results should also provide insight into the factors that affect disclosure. However, it is important to remember that disclosures cannot occur if a facility does not have a violation, and because the analysis does not directly model the violation process, the interpretability of the Disclosure results will be limited.[25]

All of the facility-level variables are extracted from EPA's RCRAInfo database, with the exception of *Disclosure in 2001*. The first six variables indicate the type of regulated facility. *Large Quantity Generators* are facilities that generate over 1,000 kilograms of hazardous waste a month, while *Small Quantity Generators* generate between 100 and 1,000 kilograms a month, and *Conditionally Exempt Generators* generate less than 100 kilograms a month.[26] Because the quantity of hazardous waste generated by a facility should be highly correlated with the potential for environmental damages at a site, in the Inspection equation, I expect the coefficients on these variables to be positive. Additionally, the more waste on site, the higher the probability of a spill or violation, and thus I expect positive coefficients in the Disclosure equation as well. Similarly, because facilities that treat, store, or dispose hazardous waste (*Treatment, Storage, or Disposal Facility*) have a higher potential for environmental releases than facilities that only generate waste but do not manage it on site, I expect a positive coefficient in the Inspection equation. Because such facilities are also subject to additional regulations, I anticipate that they are more likely to be in violation and thus more likely to disclose as well.

Transporters are facilities that transport hazardous waste. Given that the paperwork requirements for waste transport are quite extensive and paperwork violations

[25] A detection controlled estimation (DCE) model like that used in Helland (1998) would allow for the estimation of the violation equation in addition to the Inspection and Disclosure equations. However, the DCE model does not allow for correlated errors, and the results of our bivariate probit model indicate that, at a minimum, the errors in the Inspection and Disclosure equations are correlated. Moreover, the DCE is not designed to control for endogenous explanatory variables.

[26] The omitted category is non-generators; that is, facilities that do not generate hazardous waste themselves. Non-generators could include transporters, transfer facilities, and some types of hazardous waste management facilities. While a facility may only fall into one of the three possible generator categories, a regulated facility can concurrently be a generator, a treatment facility, and a transporter.

Table 3. Variable means and expected effects.

Explanatory Variable	Mean	Standard Deviation	Expected Effect: Inspection Equation	Expected Effect: Disclosure Equation
Large quantity generator	0.06	0.23	+	+
Small quantity generator	0.29	0.45	+	+
Conditionally exempt generator	0.25	0.43	+	+
Treatment, storage, or disposal facility	0.002	0.04	+	+
Transporter	0.03	0.17	?	+
Other permit	0.02	0.15	+	+
Inspected in 2001	0.03	0.17	–	–
Five-year inspection history	0.15	0.51	+	+
Ignored	0.89	0.31	–	–
Violated in 2001	0.01	0.11	+	+
Newly caught in 2001	0.008	0.09	+	+
Five-year violation history	0.20	1.48	?	?
Good compliance record	0.95	0.21	–	–
Disclosure in 2001	0.0005	0.02	–	NA
Disclosure in 2001 × Good comp. record	0.0003	0.02	+	NA
State self-policing policy	0.39	0.49	–	+
State audit privilege	0.40	0.49	–	+
State audit immunity	0.36	0.48	NA	+
State inspections	0.04	0.03	+	+
State inspection intensity	1.36	0.22	–	–
State violations	0.04	0.03	–	+
State regulated facilities	0.25	0.16	?	?
Region 1	0.06	0.16	?	?
Region 2	0.14	0.34	?	?
Region 3	0.10	0.29	?	?
Region 4	0.13	0.34	?	?
Region 5	0.25	0.43	?	?
Region 6	0.09	0.29	?	?
Region 7	0.05	0.23	?	?
Region 8	0.03	0.16	?	?
Region 9	0.11	0.31	?	?

are one of the more common types of disclosures, I expect a positive coefficient on this variable in the Disclosure equation. However, it is not clear whether transporters should be more, or less, likely to be inspected than other types of facilities. First, it is not obvious whether transporter facilities pose more or less of a risk than other types of facilities and second, transporters are also subject to Department of Transportation inspections, which may act as a substitute for EPA inspections. The last variable that captures the nature of the regulated facility is *Other Permit,* which indicates whether the facility is permitted under an environmental program other than the hazardous waste program. This indicates that the facility is complex and has significant environmental exposure, so I expect a positive coefficient in the Inspection equation. Because disclosures may occur for violations of other environmental programs, I also expect a positive coefficient in the Disclosure equation.

The next set of variables captures the enforcement and compliance history of the facility over the previous five years, that is, from 1997 to 2001. *Inspected in 2001* indicates whether the facility was inspected in 2001. Obviously EPA cannot inspect every facility each year, as only 3 percent of the universe was inspected in 2001.

Therefore, I expect a negative coefficient on this variable in the Inspection equation. Because facilities that face a lower probability of inspection are less likely to disclose, I also expect a negative coefficient in the Disclosure equation. *Five Year Inspection History* is a count of the number of years between 1997 and 2001 that the facility was inspected. If this variable is high, it suggests that the facility is in the target group, and thus I expect a positive coefficient in the Inspection equation and a positive coefficient in the Disclosure equation. The variable *Ignored* is equal to 1 if the facility was not inspected at all over the past five years. If a facility is ignored, as almost 90 percent of this universe is, the facility is likely to be in the non-target group, and thus I expect a negative coefficient in both equations.

Violated in 2001 indicates whether a violation was detected at the facility in 2001. If a facility discloses a violation in 2001, but no other violation is detected by regulators, this variable is equal to 0. *Newly Caught in 2001* is equal to 1 if a violation was detected in 2001, but no violations were detected between 1997 and 2000. While only one percent of facilities have a detected violation in 2001, note that only 3 percent of facilities were inspected, so that violations are detected at approximately one-third of all inspected facilities. Additionally, note that most of the facilities that violated in 2001 were also newly caught. I expect positive coefficients on both of these variables in the Inspection equation, as a violation in 2001 should move a facility into (or keep a facility in) the target group. Because facilities in the target group are more likely to disclose, I also expect a positive coefficient in the Disclosure equation. *Five Year Violation History* is a count of the number of detected violations at the facility between 1997 and 2001. If there are only two groups, a target group and a non-target group, this variable should have no effect in the Inspection equation. However, if there are several target groups or if it takes more than one violation to move into the target group, I would expect a positive coefficient in both equations. Finally, *Good Compliance Record* is equal to 1 if the facility had no detected violations from 1997 to 2001. This variable is also a proxy for membership in the non-target group, and I expect negative coefficients in both equations.

The explanatory variable *Disclosure in 2001* indicates whether the facility disclosed any violations (not just hazardous waste violations) in 2001. In the SEPTER model, a disclosure will decrease the likelihood of an inspection for facilities in the target group, but will not change the likelihood of inspection for facilities in the non-target group. However if, in practice, there is a continuum of inspection probabilities rather than just two groups, one would expect disclosures to be rewarded for all facilities and thus, I expect a negative coefficient on *Disclosure in 2001*. Although I could not directly include state dummies in the analysis as there are so few facilities that disclose in any given state, I do include a number of variables in the analysis to control for state differences in enforcement programs, as well as dummies for the different EPA regions. Other research has shown that states with self-policing policies (*State Self-Policing Policy*) or audit privilege (*State Audit Privilege*) may use such policies as substitutes for more traditional enforcement, so I expect a negative sign on these two variables in the Inspection equation.[27] Along with *State Audit Immu-*

[27] In theory, one benefit of such policies is that enforcement resources can be reduced with no effect on deterrence, and thus I would expect them to have a negative effect on the likelihood of inspection. See, for example, Kaplow and Shavell (1994) and Innes (1999). Additionally, Stafford (2005) finds that state audit privilege and self-disclosure policies do appear to decrease the likelihood of inspections. Data on state audit legislation and self-policing policies is provided by the National Conference of State Legislatures at http://www.ncsl.org/programs/esnr/audits.htm.

nity, these policies are designed to encourage the use of audits and disclosures, and thus I expect a positive sign on all three variables in the Disclosure equation.

State Inspections measures the total number of inspections conducted in the state in 2001, normalized by the total number of regulated facilities in the state, and *State Inspection Intensity* is equal to the number of inspections divided by the number of unique facilities inspected.[28] The higher the number of state inspections, the more likely it is that any one facility will be inspected. The higher the inspection intensity, the more likely it is that a state conducts multiple inspections as a single facility, and thus the lower the probability of inspection at any given facility. Since the higher the probability of an inspection, the higher the benefit from disclosure, I expect consistent signs across the Inspection and Disclosure equations. *State Violations* measures the total number of violations detected in the state in 2001, normalized by the total number of regulated facilities in the state. Because regulators often follow up past violations with inspections to confirm that the violation has been corrected, I expect a negative coefficient on this variable in the Inspection equation. However, if there are numerous state violations, more facilities may be in the target group and thus have higher incentives to disclose. Finally, *State Regulated Facilities* measures the number of regulated facilities in the state. This variable is included to control for possible size effects. States with larger workloads are likely to be larger and more industrialized than other states. However, the effect of this variable on Inspections is not obvious. On one hand, states with larger workloads may have relatively well established environmental programs. On the other hand, such states could face a resource constraint. Similarly, the effect on disclosures is not obvious. Finally, I include dummies for nine of EPA's ten regions to control for regional differences in enforcement policies, although I have no prior expectations as to the effect of these dummies on the likelihood of inspections or disclosures.

RESULTS

The primary objective of this analysis is to determine whether voluntary disclosures under EPA's self-policing policy are rewarded with a decrease in future enforcement. The results of the bivariate probit regression, presented in Table 4, demonstrate that disclosures do affect the probability of future inspections. The coefficient on *Disclosure in 2001* is negative and significant, indicating that regulators do reward disclosures by decreasing future enforcement. To get a rough estimate of the size of the disclosure effect, I calculated the change in the probability (in percentage points) that a "representative facility" would be inspected in 2002 if it discloses in 2001. This representative facility is given the mean values for all continuous explanatory variables and the median values for discrete explanatory variables. As shown in Table 5, the representative facility has an initial inspection probability of 1.87 percent. If this facility discloses a violation, it will be rewarded with a 1.83 percentage point decrease in the likelihood of inspection. Thus, after disclosure, the probability of inspection would be 0.04 percent. If a facility's characteristics are not the same as those of the representative facility, both the initial inspection probability and the size of the effect of a disclosure will change. However, on average, a disclosure in 2001 reduces the probability of inspection in 2002 by four-fifths.[29] It is

[28] The state inspection, enforcement, and workload variables were aggregated from EPA's RCRAInfo database.

[29] For each facility, I estimated the probability of inspection given the facility's characteristics and no disclosure as well as the probability of inspection given the facility's characteristics and a disclosure. I then calculated the average decrease in the probability of inspection as a percentage of the initial probability of inspection.

Table 4. Bivariate probit results for all RCRA-regulated facilities.

	Inspection Equation		Disclosure Equation	
Explanatory Variable	Coefficient	Standard Error	Coefficient	Standard Error
Large quantity generator	0.73**	0.01	0.64**	0.05
Small quantity generator	0.21**	0.01	0.19**	0.05
Conditionally exempt generator	0.12**	0.01	0.03	0.06
Treatment, storage, or disposal facility	0.63**	0.06	–0.30**	0.12
Transporter	0.22**	0.02	–0.11	0.09
Other permit	0.21**	0.02	0.33**	0.06
Inspected in 2001	0.07**	0.02	0.09	0.08
Five-year inspection history	0.39**	0.01	0.12**	0.03
Ignored	0.04**	0.02	–0.18**	0.06
Violated in 2001	0.12**	0.04	0.04	0.10
Newly caught in 2001	0.18**	0.04	0.02	0.13
Five-year violation history	0.01**	0.002	–0.0003	0.004
Good compliance record	–0.17**	0.02	–0.03	0.07
Disclosure in 2001	–1.28**	0.28		
State self-policing policy	–0.06**	0.01	0.10**	0.05
State audit privilege	–0.08**	0.01	–0.04	0.07
State audit immunity			0.18**	0.06
State inspections	7.07**	0.18	0.51	0.95
State inspection intensity	–0.28**	0.02	–0.18**	0.08
State violations	1.67**	0.16	1.63**	0.82
State regulated facilities	–0.58**	0.04	–0.74**	0.21
Region 1	0.07**	0.02	–0.28**	0.11
Region 2	0.02	0.03	0.13	0.13
Region 3	–0.07**	0.02	–0.07	0.09
Region 4	–0.33**	0.02	–0.24**	0.09
Region 5	–0.05**	0.02	–0.30**	0.10
Region 6	–0.21**	0.02	–0.03	0.09
Region 7	–0.22**	0.02	0.01	0.10
Region 8	–0.33**	0.03	–0.21*	0.12
Region 9	–0.36**	0.03	–0.37**	0.13
Constant	–1.86**	0.04	–3.04**	0.17
Correlation coefficient (ρ)	0.45**	0.09		

**Statistically significant at 5%, *Statistically significant at 10%.

also interesting to note that, for the representative facility the reward for a disclosure is of similar magnitude as the punishment the facility would receive for a violation (an increase of 2.39 percentage points if the facility is newly caught or an increase of 1.02 percentage points if the facility has violated previously). Thus, disclosures can significantly mitigate the consequences of a bad inspection (that is, one where violations are discovered).

The SEPTER model implies that a disclosure will decrease the likelihood of an inspection for facilities in the target group, but will not change the likelihood of inspection for facilities in the non-target group. To determine whether the reward to disclosure differs for facilities with good and bad compliance records, I ran the bivariate probit regression on two separate subgroups: those facilities with no detected violations from 1997 to 2001 and those facilities with at least one detected

Table 5. Factors that affect the probability of inspection and disclosure.

	Inspection	Disclosure
Probability for Representative Facility:	1.87%	0.02%
Change in probability if the facility:		
Is a large quantity generator	+7.03%	+0.15%
Is a small quantity generator	+1.19%	+0.02%
Is a conditionally exempt generator	+0.62%	+0.002%
Is a treatment, storage, or disposal facility	+5.50%	–0.01%
Is a transporter	+1.29%	–0.01%
Has another permit	+1.21%	+0.04%
Was inspected in 2001	+0.34%	+0.01%
Increase five-year inspection history by one standard deviation	+1.11%	+0.004%
Has not been ignored	–0.16%	+0.02%
Violated in 2001*	+1.02%	+0.01%
Was newly caught in 2001*	+2.39%	+0.01%
Increase five-year violation history by one standard deviation	+0.04%	–0.000%
Does not have good compliance record	+0.91%	+0.002%
Disclosed in 2001	–1.83%	—
State has self-policing policy	–0.28%	+0.01%
State has audit privilege	–0.35%	–0.003%
State has audit immunity	—	+0.02%
Increase state inspections by one standard deviation	+1.20%	+0.001%
Increase state inspection intensity by one standard deviation	–0.27%	–0.003%
Increase state violations by one standard deviation	+0.23%	+0.003%
Increase state regulated facilities by one standard deviation	–0.39%	–0.006%

Statistically significant changes (at 10%) indicated in bold.
*Since this change cannot occur in isolation, all other variable changes that must have occurred are also taken into account. For example, facilities that are newly caught must also have been inspected in 2001 and have violated in 2001. The change in probability reported in the table is the cumulative effect of all of the variable changes, not the marginal effect. However, the statistical significance indication refers to the marginal effect only.

violation during that period.[30] Table 6 presents the estimated effect of a disclosure on the probability of inspection for these two subgroups.[31] Because facilities with good compliance records represent approximately 95 percent of the total population of RCRA-regulated facilities, it is not surprising that the results for facilities with good compliance records are quite similar to the results for all facilities. However, for facilities with poor compliance records—that is, facilities with at least one violation from 1997 to 2001—the probability of inspection is significantly higher at the representative facility, as is the probability of a disclosure. As implied by the SEPTER model, the reward for disclosure is also much larger for facilities with poor compliance records. In fact, although the representative "poor" facility is almost 10 times more likely to be inspected than the representative "good" facility in the absence of a disclosure, the estimated probability of inspection is approximately the same for a good facility that has disclosed and a poor facility that has

[30] Because *Disclosed in 2001* is an endogenous variable, it is not possible to simply interact *Disclosed in 2001* with the *Good Compliance Record* variable.
[31] Complete results of the bivariate probit regression for these two subgroups are available from the author upon request.

disclosed. Thus, the assumption that regulators reward disclosures by moving facilities out of the target group is consistent with evidence. However, although facilities with good compliance records that disclose get a smaller benefit from disclosure than facilities with poor records, even facilities with good records receive a positive reward from disclosure. While the SEPTER model implies that facilities in the non-target group should not be rewarded by disclosure, this is due to the assumption that there are only two groups of facilities. If, instead, there is a continuum of inspection probabilities rather than just two groups, one would expect disclosures to be rewarded for all facilities.

Although the focus of this analysis is on self-policing and disclosures, it should be noted that the other coefficients in the Inspection equation are generally consistent with the expectations discussed in the Empirical Approach section above, and provide additional evidence of a targeted enforcement regime. However, there are a couple of interesting results that warrant discussion. First, given that EPA cannot inspect every facility each year, I expected the coefficient on *Inspected in 2001* to be negative, although it is actually positive and significant. This suggests that in addition to compliance history and the other factors measured in this analysis, there are unobserved or omitted characteristics that the enforcement agency is targeting, such as specific activities or substances at the facility that make the facility more likely to be inspected. Second, the coefficient on *Ignored* is also positive and significant, the opposite of our expectation. Thus, facilities are not ignored by regulators forever; rather, there is a higher probability of being inspected, *ceteris paribus*, if the facility has been ignored in the past. This suggests that inspections in a given year may not be random; that is, regulators may have some underlying schedule that they use to determine where to employ enforcement resources and that time since last inspection may be an important determinant of a facility's likelihood of inspection. If this is true, models that assume probabilistic inspection such as the model presented in the Theoretical Framework section above are missing an important feature of the enforcement system.

Next consider the Disclosure equation. As discussed previously, in interpreting these results, one must remember this is a reduced form model and does not consider the underlying violation process. However, the findings do provide useful insights into the factors that affect disclosures under EPA's Audit Policy. According to the SEPTER model, facilities in the target group should be more likely to disclose than facilities that are not in the target group. Assuming that the variable *Ignored* provides a rough proxy for membership in the non-target group, the results show that non-target facilities are significantly less likely to disclose than facilities that are not ignored.

Table 6. Estimated effect of disclosure on inspection.

	All Facilities	Facilities with Good Compliance	Facilities with Poor Compliance
Number of observations	630,862	601,702	29,160
Prob. of inspection at representative facility	1.87%	1.57%	15.33%
Prob. of disclosure at representative facility	0.02%	0.01%	0.22%
Change in prob. of inspection if representative facility disclosed in 2001	–1.83%	–1.45%	–15.25%

The positive and significant coefficient on *Five Year Inspection History* is also consistent with expectations that facilities that face a higher probability of inspection are more likely to disclose. Also as expected, *Large Quantity Generators, Small Quantity Generators*, and facilities that are subject to regulation under other media programs (that is, Other Permit) are more likely to disclose. However, the negative and significant coefficient on *Treatment, Storage, and Disposal* facility is not consistent with the expectation that such facilities are subject to more regulation and thus more likely to violate and to disclose. It could be that because treatment, storage, and disposal facilities are both highly regulated and heavily inspected, these facilities are less likely to discover inadvertent violations; that is, the types of violations for which the Audit Policy is most appropriate. The other findings from the Disclosure equation that are particularly interesting are the results for S*tate Self-Policing Policy*, *State Audit Privilege*, and *State Audit Immunity*. These programs were all adopted specifically to increase audits and disclosures. While the results show that state self-policing policies and audit immunity legislation are effective at increasing disclosures, the insignificant coefficient on *State Audit Privilege* suggests that such legislation does not increase disclosures. The most likely explanation for this result is that privilege alone does not provide direct incentives to facilities to disclose, although it does decrease the potential risks from auditing.[32]

Finally, as shown in Table 5, a large quantity generator is over three times more likely to be inspected than the representative facility and seven times more likely to disclose. Therefore, as a robustness check, Table 7 presents the results of the bivariate probit analysis when only large quantity generators are included in the regression—approximately 35,000 facilities. There are a few qualitative differences between the results for large quantity generators and the results for all facilities. First, in the Inspection equation, the coefficients on *Inspected in 2001* and *Ignored* have significant but opposite signs in the two regressions. In fact, the negative coefficients in the large quantity generator regression are consistent with the ex ante predictions that facilities inspected in 2001 and ignored facilities would be less likely to be inspected in 2002. Second, a number of coefficients that were significant in the regression for all regulated facilities are no longer significant in the regression for large quantity generators (and in some cases, the sign of the coefficient changes). However, despite the qualitative differences between the two regressions, the primary results are the same and generally support the SEPTER model. In particular, regulators do reward large quantity generators that disclose with lower probabilities of inspection in the future.

IMPLICATIONS FOR EPA'S AUDIT POLICY AND SELF-POLICING IN GENERAL

Given the empirical evidence presented above, the SEPTER model appears to provide a reasonable description of self-policing under EPA's Audit Policy. It is important to note that in the SEPTER model, facilities may increase the level of auditing and abatement without making disclosures, so that one cannot evaluate the effectiveness of a self-policing policy by looking at disclosures alone. Another key feature of the SEPTER model is that facilities may make tradeoffs between self-policing and other forms of regulatory compliance. For example, facilities may strategically disclose violations in order to decrease future enforcement and then take advantage of the "enforcement

[32] However, privilege may indirectly decrease the cost of disclosure, as it protects information gathered during the course of an environmental audit from being used in judicial or administrative proceedings. Without privilege, facilities might be reluctant to disclose, as that would indicate the presence of environmental audit records that could be subpoenaed.

Table 7. Bivariate probit results for large quantity generators only.

		Inspection Equation		Disclosure Equation	
Explanatory Variable	Mean	Coefficient	Std. Error	Coefficient	Std. Error
Treatment, storage, or disposal facility	0.03	0.86**	0.06	–0.32**	0.13
Transporter	0.04	0.09**	0.04	–0.06	0.12
Other permit	0.12	0.27**	0.03	0.39**	0.07
Inspected in 2001	0.15	–0.16**	0.04	0.05	0.11
Five-year inspection history	0.72	0.33**	0.01	0.10**	0.03
Ignored	0.64	–0.09**	0.03	–0.37**	0.11
Violated in 2001	0.08	0.11**	0.05	0.07	0.12
Newly caught in 2001	0.04	0.04	0.06	–0.21	0.18
Five-year violation history	0.36	0.01**	0.003	–0.003	0.005
Good compliance record	0.76	–0.13**	0.03	0.01	0.09
Disclosure in 2001	0.004	–1.21*	0.69		
State self-policing policy	0.36	–0.08**	0.03	0.13	0.10
State audit privilege	0.40	–0.06*	0.03	–0.005	0.13
State audit immunity	0.29			0.14	0.12
State inspections	0.04	6.03**	0.59	–0.77	1.52
State inspection intensity	1.37	0.03	0.05	0.24	0.17
State violations	0.04	–0.75	0.49	1.30	1.66
State regulated facilities	0.30	–0.65**	0.12	0.31	0.39
Region 1	0.04	–0.24**	0.07	–0.28	0.20
Region 2	0.19	–0.22**	0.08	–0.33	0.23
Region 3	0.08	–0.08	0.06	–0.22	0.16
Region 4	0.09	–0.17**	0.07	–0.34**	0.16
Region 5	0.29	–0.21**	0.06	–0.70**	0.20
Region 6	0.09	–0.42**	0.07	–0.13	0.17
Region 7	0.03	–0.16**	0.08	–0.10	0.20
Region 8	0.01	0.05	0.10	–0.33	0.25
Region 9	0.16	–0.34**	0.07	–0.42*	0.24
Constant		–1.14**	0.10	–2.75**	0.31
Correlation coefficient (ρ)		0.42	0.27		

**Statistically significant at 5%; *statistically significant at 10%.

holiday" to commit more significant violations of environmental regulations. The results of this empirical analysis show that the decrease in future enforcement is quite dramatic and thus, the possibility for using disclosures as "red herrings" is very real.

In light of the low level of participation of hazardous waste facilities in EPA's self-policing policy, one might ask whether the potential for strategic disclosure really poses a significant concern. As shown in Table 3, only 5 of every 10,000 RCRA-regulated facilities disclosed a violation in 2001, compared to 1 in 100 facilities that had a violation detected by regulators. While self-policing is slightly more common in the entire regulated community—in 2001, approximately 1 of every 1,000 regulated facilities disclosed a violation—it is still not a frequent annual occurrence.[33] Given current

[33] According to EPA's Envirofacts database, in July of 2002, there were approximately 1.1 million unique facilities regulated by EPA (http://www.epa.gov/enviro/html/frs_demo/presentations/frs_factsheet_July2002.pdf). In 2001, 1,158 facilities voluntarily disclosed a violation to EPA.

participation levels, unless the consequences from self-disclosure persist for a very long time, the percentage of facilities on "enforcement holidays" will be insignificant relative to the large percentage of facilities that are already "ignored" by regulators.

It is clear that EPA would like to significantly increase the number of facilities participating in the self-policing program.[34] One obvious way to increase participation is to make sure that the regulated community is fully aware of the benefits to self-policing, particularly the reduction in future enforcement. However, this could significantly increase the number of strategic disclosures. Unfortunately, there is no easy solution to the problem of strategic disclosure either for EPA's Audit Policy or for self-policing in general. Because self-policing can increase the level of auditing and remediation, as well as allow regulators to shift enforcement resources from self-policers to other facilities, it can have a significant positive impact on environmental performance. However, if reduced penalties alone are not enough to induce auditing and disclosure, decreased future enforcement may be necessary to motivate self-policing. Thus, regulators need to carefully weigh the benefits of increased self-policing against the potential that facilities may strategically disclose.

Both the empirical results and the SEPTER model also demonstrate that facilities that are currently targeted by regulators are much more likely to self-police than facilities that are not targeted. One reason for this is that the cost of self-policing for facilities with a relatively low probability of inspection is high compared to the expected cost of detection. Additionally, non-target facilities might be concerned that a disclosure would draw the regulators' attention and might increase the likelihood of future enforcement. The fact that non-target facilities are unlikely to self-disclose can explain, at least in part, the current low level of participation with EPA's Audit Policy. Of the more than 600,000 regulated hazardous waste facilities, approximately 90 percent appear to be in the non-target group. Non-target facilities have the lowest level of contact with regulators and thus are more likely to inadvertently violate regulations than facilities that have learned about the appropriate way to comply through their encounters with regulators. To increase the participation of these facilities in the Audit Policy, EPA might want to draw attention to the fact that disclosures will not result in increased future enforcement, even for facilities with low ex ante probability of inspection and, to the contrary, usually results in a significant decrease in future enforcement. More generally, since non-target facilities are less likely to participate in self-policing, regulators that are developing or modifying self-policing policies might want to focus outreach efforts on such facilities or consider methods for increasing the incentives for these facilities.

CONCLUSION

This paper presents an empirical analysis of the effect of Audit Policy disclosures on future enforcement efforts. The most important finding is that facilities that self-disclose under EPA's Audit Policy are rewarded with a significantly lower probability of inspection in the near future. While there is some evidence that the reward for disclosure is smaller for facilities with relatively good compliance records, there is no evidence that disclosures increase future enforcement efforts for these facilities. This lends support to Pfaff and Sanchirico's (2004) concern that facilities could use the disclosure of minor violations under the Audit Policy as "red herrings" to discourage future inspections.

[34] See Goal 5.2 in the Fiscal Year 2005 Performance and Accountability Report, U.S. EPA, 2005, page 5–11.

The analysis also provides insight into the factors that motivate self-policing. Facilities that have not been inspected over the past five years are less likely to disclose, while facilities that are inspected frequently are more likely to disclose, in part because they have more to gain from decreasing future enforcement efforts. Large and small quantity generators are more likely to disclose, as are facilities that are regulated under more than one media program. However, hazardous waste treatment, storage, and disposal facilities are less likely to disclose, perhaps because these facilities are less likely to discover inadvertent violations; that is, the types of violations for which the Audit Policy is most appropriate. Finally, facilities in states with environmental audit immunity or self-policing policies are more likely to disclose, as such policies provide additional incentives for disclosure.

The results of the analysis generally support the theoretical model of self-policing in a targeted enforcement regime that is summarized in this paper. This model suggests that some facilities will increase their level of auditing and abatement without making disclosures, implying that one should not evaluate the effectiveness of a self-policing policy by looking at disclosures alone. Additionally, the model indicates that some facilities may strategically disclose violations in order to decrease future enforcement and then take advantage of the "enforcement holiday." Thus, regulators need to carefully weigh the benefits of increased self-policing against the potential that facilities may strategically disclose. Finally, both the empirical results and the theoretical model suggest that facilities that are not on regulators' target list are the least likely to self-police, even though such facilities might benefit significantly from self-policing. Thus, regulators may want to focus their outreach efforts on such facilities or consider methods for increasing the incentives for these facilities.

This paper provides the first evidence on the consequences of self-policing. However, there are a number of complementary analyses that would further expand our understanding of how the Audit Policy is being implemented and how it affects overall environmental performance. First, this analysis only considers hazardous waste enforcement. It would be interesting to see whether disclosures have similar effects on enforcement for other environmental media or in non-environmental self-policing programs. Second, this analysis only considers the effect of disclosures on the immediate future. A panel analysis would provide information on the persistence of the rewards to self-disclosure. Finally, a more focused analysis of a facility's decision to disclose that also models the likelihood that a facility has something to disclose would provide a much deeper understanding of the factors that motivate self-policing.

SARAH L. STAFFORD is Associate Professor of Economics at The College of William & Mary, Williamsburg, VA.

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Green Production through Competitive Testing

Erica L. Plambeck and Terry A. Taylor

Graduate School of Business, Stanford University, Stanford, CA 94305

Graduate School of Business, Columbia University, New York, NY 10027

Abstract

Electronics waste is severely damaging to the environment and human health, especially in developing countries. New regulations in the European Union, California and China prohibit the sale of electronics containing certain hazardous substances. However, because testing for these substances is expensive and destructive of the product, regulators cannot test all or even a significant fraction of the electronics sold. Electronics manufacturers have an incentive to test competitors' products, reveal violations to the regulator, and thus gain market share when the competitors' products are blocked from the market. We find that in many cases, regulators should not test products directly, but instead should rely on electronics manufacturers to do all the testing. Relying on competitive testing is most effective in markets dominated by a few firms and, conversely, is least effective in highly competitive markets composed of many small firms. Unfortunately, in the long run, reliance on competitive testing causes entry and expanded production by manufacturers with low quality, weak brands and consequently low compliance. The phenomenon of competitive testing has the potential to play out in any competitive market governed by product-based environmental, health or safety standards, and our insights apply more broadly to these settings.

Subject Classifications: Cournot oligopoly; environmental regulation; industry self-regulation

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1 Introduction

Electronics contain heavy metals and other potentially toxic substances, and constitute a fast-growing portion of the waste stream. The United States alone scraps approximately 400 million units per year (Daly 2006), and electronics account for 40% of the lead in U.S. landfills, which threatens groundwater (Eilperin 2005). Used electronics are exported to developing countries and illegally burned to extract valuable metals; the resulting air and water pollution is severely damaging to human health (Basu 2006).

The sage of operations management, W. E. Deming, famously said "build quality in," which implies that to solve the environmental problems with e-waste, hazardous substances should be eliminated from *production*. Espousing this principle, the European Union (EU), China, and California are moving to prohibit the sale of electronics containing six restricted hazardous substances.[1] However, because testing for these restricted substances is complex, expensive and destructive of the product, regulators cannot test all or even a significant fraction of the electronics sold. Instead, regulators may choose to rely upon electronics manufacturers to test their competitors' products. In the United Kingdom, regulators will inspect products in response to "notification of concern from external parties" (EU RoHS 2006). The California department of toxic substances promises to follow up on any violation reported via its website www.dtsc.ca.gov/database/CalEPA_Complaint/index.cfm. When a regulator finds that an electronics manufacturer's product violates the Restrictions on Hazardous Substances (RoHS), the regulator will prevent the sale of that product. For example, Dutch authorities halted the sale of PlayStation consoles because a peripheral cable contained cadmium, which caused Sony to miss $110 million in revenue (Shah and Sullivan 2002). Industry analysts believe that Dutch authorities tested the PlayStation cable for cadmium in response to a tip from one of Sony's competitors (Hess 2006). Electronics manufacturers have an incentive to test competitors' products, reveal violations to the regulator, and thus gain market share when the competitors' products are blocked from the market.

This paper examines whether a regulator should test products directly, or instead rely solely upon manufacturers to test their competitors' products. Further, we examine the impact of competitive testing on the structure, output, profitability and environmental impacts of the electronics industry.

[1] Lead, mercury, cadmium, hexavalent chromium, and two types of brominated flame retardants.

Electronics manufacturers know better than any regulator which components and materials are likely to harbor which restricted substances, and also have a better understanding of the cost of compliance. A relevant economics literature examines pollution prevention when the regulatory agency lacks information about the costs, benefits and/or means of environmental improvement and has incentive problems. For example, Lewis (1996) and references therein show how manufacturers' private information about the cost of reducing emissions may prevent or complicate the implementation of emissions-permit-markets or taxes on emissions. Boyer et al. (2000) point out that the regulator has no incentive to exert monitoring effort when firms are perfectly compliant; this distorts monitoring and investment in environmental improvement from the socially optimal levels. The contribution of this paper is examine the engagement of manufacturers in the testing process, which helps to overcome these problems of asymmetric information.

Recently, other researchers have examined alternative forms of industry self-regulation of environmental impacts. Motivated by the "Responsible Care" program initiated by chemicals manufacturers, Maxwell et al. (2000) model Cournot oligopolists that voluntarily reduce pollution, in order to head off government regulation that would be more stringent and costly. In the tuna industry, nuclear power industry, and others, stakeholders have difficulty discerning the environmental impacts of individual firms and may therefore sanction the entire industry. King et al. (2002) examine strategies (sharing of best practices, standardized reporting, elite clubs, etc.) to cope with this reputational commons problem. Reinhardt (2000) argues that firms with relative advantage in environmental improvement should press for standards and regulation through industry associations, as in the example of the American Forest and Paper Association's Sustainable Forestry Initiative.

The next section introduces our model and concludes by providing a road map for the rest of the paper.

2 Model Formulation

Consider N manufacturers with vertically-differentiated quality. Consumers perceive that manufacturer n's product has quality $u_n > 0$, and are heterogenous in their valuation for quality. Specifically, the market contains a unit mass of consumers with quality valuation parameter v uniformly distributed on $[0, \overline{v}]$. A consumer with quality valuation v who purchases product n at price

p_n has utility

$$u_n v - p_n.$$

Each consumer may purchase one product or nothing, and in the latter case has zero utility. The valuation parameter v may represent differences in income as in Shaked and Sutton (1982) or in taste as in Motta (1993). We index the firms according to their quality:

$$u_1 \leq u_2 \leq ... \leq u_N. \tag{1}$$

Each manufacturer n chooses his production quantity Q_n and his compliance effort e_n to eliminate hazardous substances. Manufacturer n's production cost is $\theta [c(e_n)Q_n + F(e_n)]$ and all units produced are compliant with RoHS with probability e_n. The fixed cost of compliance $\theta F(e_n)$ arises from product and process development (R&D), component supplier qualification and selection, investment in lead-free soldering equipment, inventory tracking and monitoring systems (IT), and legal and consulting fees. The per-unit production cost $\theta c(e_n)$ reflects the cost of substituting alternative materials for the hazardous substances in various components, yield problems with the new materials, and component inspection. Because a product contains hundreds of subcomponents, and the material in each must be RoHS-compliant in order for the entire product to be RoHS-compliant, manufacturer n cannot guarantee perfect compliance: $e_n \leq \overline{e} < 1$. We assume $c(0) > 0$, $F(0) = 0$, and both $c(e_n)$ and $F(e_n)$ are increasing and strictly convex with $\lim_{e_n \uparrow \overline{e}} [c(e_n) + F(e_n)] = \infty$ for some $\overline{e} \in (0, 1)$. Throughout the paper, we adopt the convention that "increasing (decreasing)" means "weakly increasing (decreasing)."

The regulator knows the cost functions $c(\cdot)$ and $F(\cdot)$ but has uncertainty about the magnitude of compliance costs, represented by the random variable θ. The regulator knows only the distribution of θ, which has support $[\underline{\theta}, \overline{\theta}]$ where $0 < \underline{\theta} \leq \overline{\theta} < \infty$. In contrast, the firms perfectly understand the cost of compliance. That is, the firms know $c(\cdot)$, $F(\cdot)$, and the realization of θ.

Given the compliance efforts of all N manufacturers, the expected environmental damage is

$$\Sigma_{n=1}^{N} x(1 - e_n)Q_n$$

where x is a positive constant. If the regulator did not impose RoHS, the manufacturers would choose not to incur the extra costs to eliminate hazardous substances, and so environmental damage would be $\Sigma_{n=1}^{N} xQ_n$. The restricted hazardous substances have various environmental impacts that are not fully understood, and assigning a single monetary value to these impacts is very difficult.

One may interpret x as the regulator's expected environmental cost per unit of noncompliant production, or as the regulator's best estimate of society's willingness to pay to eliminate the hazardous substances.

Each manufacturer n also chooses his expenditure t_{nm} in testing the product of his competitor-manufacturer m for hazardous substances, for $n, m \in \mathcal{N} \equiv \{1, .., N\}$ and $m \neq n$. If he finds hazardous substances in the competitor's product, he reports the violation to the regulator. In addition, the regulator (she) spends t_{Rm} in testing the product of manufacturer m for hazardous substances, for $m \in \mathcal{N}$. If the units produced by manufacturer n are noncompliant (recall that this event occurs with probability $1-e_n$), then testing by the other manufacturers and regulator lead to the detection of the hazardous substances with probability $d\left(\alpha t_{Rn} + \Sigma_{m\in\mathcal{N}\backslash n} t_{mn}\right)$. The probability of detection is strictly increasing and strictly concave with $d(0) = 0$ and $\lim_{t\uparrow\infty} d(t) = \overline{d} \in (0, 1)$. The regulator is less effective than the manufacturers in testing, which is represented by $\alpha \in (0, 1]$.

If hazardous substances are detected in the units produced by manufacturer n, then the regulator will prevent manufacturer n from selling any units in the market. Thus, with probability

$$s\left(e_n, \alpha t_{Rn} + \Sigma_{m\in\mathcal{N}\backslash n} t_{mn}\right) \equiv 1 - d\left(\alpha t_{Rn} + \Sigma_{m\in\mathcal{N}\backslash n} t_{mn}\right)(1 - e_n)$$

manufacturer n successfully brings his full production quantity Q_n to market; with probability $d\left(\alpha t_{Rn} + \Sigma_{m\in\mathcal{N}\backslash n} t_{mn}\right)(1 - e_n)$ manufacturer n is prohibited from doing so. That is, the sales quantity for manufacturer $n \in \mathcal{N}$ is the random variable

$$\widetilde{Q}_n = \begin{cases} Q_n & \text{with probability } s\left(e_n, \alpha t_{Rn} + \Sigma_{m\in\mathcal{N}\backslash n} t_{mn}\right) \\ 0 & \text{with probability } 1 - s\left(e_n, \alpha t_{Rn} + \Sigma_{m\in\mathcal{N}\backslash n} t_{mn}\right). \end{cases} \tag{2}$$

For a given vector of the manufacturers' compliance and testing efforts, we assume that $\widetilde{Q}_n$ and $\widetilde{Q}_m$ for $m \neq n$ are independent.

Under the standard condition $\Sigma_{n=1}^{N} Q_n < 1$, which is necessary to invert the demand functions under Cournot competition with vertically differentiated products (Motta 1993), the market equilibrium price per unit for manufacturer n's product is

$$p_n = \overline{v}(u_n(1 - \Sigma_{m=n}^{N} \widetilde{Q}_m) - \Sigma_{m=1}^{n-1} u_m \widetilde{Q}_m); \tag{3}$$

we refer the reader to (Motta 1993) for the derivation of (3). Then, manufacturer n's expected profit under cost multiplier θ is

$$\pi_n = \overline{v}\left[u_n\left(1 - \Sigma_{m=n+1}^{N} s\left(e_m, \alpha t_{Rm} + \Sigma_{j\in\mathcal{N}\backslash m} t_{jm}\right) Q_m - Q_n\right) - \Sigma_{m=1}^{n-1} u_m\ s\left(e_m, \alpha t_{Rm} + \Sigma_{j\in\mathcal{N}\backslash m} t_{jm}\right) Q_m\right]$$

$$\times\, s\left(e_n, \alpha t_{Rm} + \Sigma_{m\in\mathcal{N}\backslash n} t_{mn}\right) Q_n - \theta[c(e_n)Q_n + F(e_n)] - \Sigma_{m\in\mathcal{N}\backslash n} t_{nm}. \tag{4}$$

If manufacturer n anticipates testing by the regulator of t_{Rk} for $k \in \mathcal{N}$ and production quantity, compliance effort, and testing by the other manufacturers of (Q_m, e_m, t_{mj}) for $m \in \mathcal{N}\backslash n$ and $j \in \mathcal{N}\backslash m$, then manufacturer n chooses his own production, compliance effort and testing (Q_n, e_n, t_{nm}) for $m \in \mathcal{N}\backslash n$ to maximize (4).

Initially, in §3 and §4, we focus on compliance effort e_n and testing t_n decisions; Q_n is fixed at strictly positive level, and this may be interpreted as manufacturer n's capacity. In these sections, when the firms are symmetric (i.e., $u_n = u$ and $Q_n = Q$ for $n = 1, .., N$) we impose the conditions that the detection function is sufficiently concave, the cost functions are increasingly convex, and the marginal cost of an infinitesimally small compliance effort is not too large

$$d''(t) < -\max\left(\frac{d'(t)^2}{d(t)}, \frac{\overline{v}u(N-1)d'(t)^2}{(1-\overline{d})\underline{\theta}[c''(0)Q + F''(0)]}, \underline{d}\right) \text{ for some } \underline{d} > 0 \tag{5}$$

$$c'''(e)Q + F'''(e) \geq 0, \tag{6}$$

$$\overline{\theta}[c'(0)Q + F'(0)] < \overline{v}u(1 - NQ)Q/2. \tag{7}$$

These conditions ensure the existence of a unique symmetric equilibrium (see §3). Similar conditions ensure the existence of an equilibrium in the case with asymmetric firms; our formal results do not require these conditions.

The remainder of the paper is organized as follows. In §3 and §4, we focus on the short-run equilibrium in compliance and testing. In §3, we show that for moderate values of the environmental cost parameter x, the regulator should impose RoHS but rely on the manufacturers to do the testing. Thereafter, we focus on competitive testing ($t_{Rn} = 0$ for $n = 1, .., N$). In §4, we examine analytically the short-run equilibrium in compliance effort and testing. In §5, we present a numerical study of the long-run equilibrium in entry, production quantity, compliance effort and testing. We draw conclusions in §6. All proofs are in the appendix, with the exception that the proof of Proposition 2 is in Plambeck and Taylor (2007).

3 The Role of the Regulator

As noted above, in this section, we take each manufacturer's quantity $Q_n > 0$ as given, and examine the short-run equilibrium in compliance and testing. This is appropriate when the manufacturer's quantity is essentially determined by long-term investments in capacity, and so is fixed over the time horizon in which the firms make compliance and testing decisions. This section focuses on the question of whether the regulator should impose RoHS and whether she should directly test manufacturers. We address this question after first establishing some properties of the equilibrium in compliance and testing. Finally, we describe the impact of RoHS and regulator testing on the firms' expected profits.

In this section, we assume that the regulator can publicly commit to a level of testing expenditure before the manufacturers decide upon their own testing and compliance efforts. We say that the regulator *imposes RoHS* if she responds to noncompliance, detected either by her own testing or by a manufacturer's testing, by preventing the sale of the noncompliant firm's units in the market. We refer to the case in which the regulator imposes RoHS but does not test and instead relies on the manufacturers to test their competitors' products and report violations as *competitive testing*.

Initially, suppose that manufacturers are symmetric: $u_n = u$ and $Q_n = Q$ for $n = 1, .., N$ with $NQ < 1$, so political pressures for fairness compel the regulator to apply the same level of testing to each manufacturer: $t_{Rn} = t_R$ for $n = 1, .., N$. Then manufacturer n's expected profit under cost multiplier θ simplifies to

$$\pi_n = \overline{v}u\left[1 - \Sigma_{m\in\mathcal{N}\setminus n} s\left(e_m, \alpha t_R + \Sigma_{j\in\mathcal{N}\setminus m} t_{jm}\right)Q - Q\right]\ s\left(e_n, \alpha t_R + \Sigma_{m\in\mathcal{N}\setminus n} t_{mn}\right)Q$$

$$- \theta[c(e_n)Q + F(e_n)] - \Sigma_{m\in\mathcal{N}\setminus n} t_{nm}.$$

Because the firms are symmetric, it is natural to focus on symmetric equilibria. Lemma 1 establishes the existence of a unique symmetric equilibrium and describes some of its characteristics. Hereafter we assume that the symmetric firms play this equilibrium.

Let $(\widehat{e}(\theta, t_R), \widehat{t}(\theta, t_R))$ denote the symmetric equilibrium in compliance and testing with cost multiplier θ and regulator's testing expenditure per firm t_R. When a manufacturer applies $\widehat{t}(\theta, t_R)$ to each of his $N-1$ competitors, the manufacturer's total testing expenditure is $\widehat{T}(\theta, t_R) = (N-1)\widehat{t}(\theta, t_R)$, and this $\widehat{T}(\theta, t_R)$ is also the total of the manufacturers' testing expenditures applied to each firm. Henceforth, we describe the symmetric equilibrium in terms of $\widehat{T}(\theta, t_R)$.

Lemma 1 *Suppose the firms are symmetric. Under RoHS, for any testing level by the regulator* $t_R \geq 0$ *and any realized cost multiplier* θ*, there exists a unique symmetric equilibrium in compliance and testing. If the regulator's testing expenditure is small* $t_R \leq \widehat{T}(\theta, 0)/\alpha$*, then testing by the regulator has no effect on the equilibrium compliance and detection probability; in the unique symmetric equilibrium,*

$$\widehat{e}(\theta, t_R) = \widehat{e}(\theta, 0)$$

$$d(\alpha t_R + \widehat{T}(\theta, t_R)) = d(\widehat{T}(\theta, 0)).$$

Otherwise, if the regulator's testing expenditure is large $t_R > \widehat{T}(\theta, 0)/\alpha$*, then in the unique symmetric equilibrium the firms do not test:*

$$\widehat{T}(\theta, t_R) = 0,$$

and testing by the regulator results in greater compliance and a strictly higher detection probability:

$$\widehat{e}(\theta, t_R) \geq \widehat{e}(\theta, 0) \tag{8}$$

$$d(\alpha t_R + \widehat{T}(\theta, t_R)) > d(\widehat{T}(\theta, 0)).$$

For the regulator, spending a small amount on testing ($t_R \leq \widehat{T}(\theta, 0)/\alpha$) is completely ineffective in influencing compliance or detection. At any such testing expenditure by the regulator, the firms' marginal value for testing is positive; consequently, the firms will test so as to bring the detection probability for each firm up to its level without regulator involvement $d(\widehat{T}(\theta, 0))$, leaving the incentives for compliance unchanged. In contrast, high testing expenditures by the regulator ($t_R > \widehat{T}(\theta, 0)/\alpha$), by increasing the probability that a firm's noncompliance will be detected, provide stronger incentives for compliance. At any such testing expenditure by the regulator, the firms' marginal value for testing is negative, and consequently the firms do not test.

We now turn to the central question: should the regulator impose RoHS and if so, should she directly test manufacturers' products for RoHS-compliance? We say that the regulator should impose RoHS if and only if this strictly increases expected social welfare, and should test manufacturers products ($t_R > 0$) if and only if this strictly increases expected social welfare. Expected social welfare under RoHS is the utility the units create less the cost of production, environmental damage, and testing

$$E_\theta\left[\overline{v}u\Sigma_{n=1}^{N}\widetilde{Q}_n(1-\Sigma_{n=1}^{N}\widetilde{Q}_n/2)-N\left[\theta[c(\widehat{e}(\theta,t_R))Q+F(\widehat{e}(\theta,t_R))]+x(1-\widehat{e}(\theta,t_R))Q+\widehat{T}(\theta,t_R)\right]\right]-Nt_R. \tag{9}$$

Note that $\widehat{e}$ and $\widehat{T}$, which depend on t_R, determine the distribution of $\widetilde{Q}_n$ as specified in (2). Without RoHS, anticipating no penalty from noncompliance, the firms do not invest in compliance, and expected social welfare simplifies to

$$\overline{v}u\ NQ(1-NQ/2)-N(E[\theta]c(0)+x)Q.$$

Our main result is that for moderate levels of the environmental cost parameter x, the regulator should impose RoHS and rely on competitive testing.

Theorem 1 *There exist thresholds*

$$0\leq \underline{x}\leq \overline{x} \tag{10}$$

such that the regulator should impose RoHS if and only if $x>\underline{x}$ *and should test if and only* $x>\overline{x}$*. Sufficient but not necessary conditions for*

$$\underline{x}<\overline{x}$$

are that $\alpha<\overline{\alpha}$ *for some* $\overline{\alpha}\in(0,1]$ *and* $\Pr(\widehat{e}(\theta,0)>0)>0$.

Imposing RoHS positively impacts social welfare by reducing environmental damage, but negatively impacts social welfare by imposing testing costs, increasing production costs, and keeping goods out of the hands of consumers. Testing by the regulator amplifies both the positive and negative impacts. When the environmental cost parameter is small $x\leq\underline{x}$, the negative impacts of imposing RoHS outweigh the positive impact from greater compliance. When the environmental cost parameter is large $x>\overline{x}$, to provide strong incentives for compliance the regulator should impose RoHS and directly test the manufacturers. When the environmental cost parameter is moderate, $x\in(\underline{x},\overline{x}]$, the regulator should impose RoHS and rely on competitive testing. The condition $\Pr(\widehat{e}(\theta,0)>0)>0$ means that with positive probability, competitive testing induces some compliance effort. If this condition were violated, a regulator would never impose RoHS and rely solely on competitive testing. We are very confident that $\Pr(\widehat{e}(\theta,0)>0)>0$ is satisfied in practice. When the regulator's testing efficacy is low $\alpha<\overline{\alpha}$, testing by the regulator is socially inefficient in that the regulator's inefficient testing displaces the more efficient testing the manufacturers would exert under competitive testing. This favors competitive testing over regulator testing, which explains why the parameter region $(\underline{x}, \overline{x}]$ is nonempty.

These insights are best illustrated and extended with a numerical study. Throughout the paper, in our numerical studies we focus on the functional forms $F(e) = \overline{F}(-\log(\overline{e}-e)-e)$, $c(e) = \underline{c}$ and $d(t) = \overline{d}(\sqrt{a^2t^2 + 4at} - at)/2$. We assume that

$$\theta = \begin{cases} 1-\Delta & \text{with probability } 1/2 \\ 1+\Delta & \text{with probability } 1/2. \end{cases}$$

The detection function $d(t)$ is increasing in a, and a can be interpreted as a measure of testing efficacy. Parameters are $\alpha = 1$, $\overline{v} = 100$, $u = 1$, $\overline{e} = \overline{d} = 0.99$, $\underline{c} = 40$, and all possible combinations of $\Delta = \{0, 0.1, 0.2, .., 0.9\}$, $\overline{F} = \{0.1, 0.5, 1\}$, $a = \{1, 10, 20\}$ and $N = \{2, 5, 8\}$. For each experiment with $N = 2$, 5, and 8, we set $Q = 0.2$, 0.1 and 0.07, respectively. These are the equilibrium optimal levels of Q for the firms in the median case that $\theta = E[\theta] = 1$, $\overline{F} = 0.5$, and $a = 10$ (see Figure 2 in Section 5).

From Theorem 1, there exists a range of values of the environmental cost parameter for which the regulator should impose RoHS and rely on competitive testing, provided that the inequality $\underline{x} < \overline{x}$ is strict. We observed strict inequality $\underline{x} < \overline{x}$ in almost all (93%) of the parameter settings.[2] Across all parameter settings, the ratio of $\overline{x}/\underline{x}$ had median 2.4 and mean 2.5. The maximum $\overline{x}/\underline{x} = 50$ was attained at the parameter setting with the highest testing efficacy ($a = 20$), lowest cost ($\overline{F} = 0.1$), least competition ($N = 2$) and highest uncertainty for the regulator ($\Delta = 0.9$). For this parameter setting, the equilibrium detection probability in the absence of testing by the regulator was reasonably high: 0.29 in the event $\theta = 0.1$ and 0.5 in the event $\theta = 1.9$. An increase in a increases the competitive equilibrium detection probability and hence compliance, which tends to make testing by the regulator unnecessary. Similarly, a decrease in the number of firms N increases the competitive equilibrium compliance and thus tends to make testing by the regulator unnecessary. The maximal $\overline{x}/\underline{x}$ occurs with minimum N and, conversely, $\underline{x} = \overline{x}$ occurs only with the maximal N.

The large magnitude of the gap between $\underline{x}$ and $\overline{x}$ in our numerical is surprising, given our assumption that the regulator is just as effective as the manufacturers in testing, i.e., $\alpha = 1$. Most surprising is that $\underline{x} < \overline{x}$ when $\Delta = 0$, meaning that the regulator also perfectly knows the cost

[2] We observe $\underline{x} = \overline{x}$ only in cases with low testing efficacy a, high cost $\overline{F}$, high competition (large N), and medium to high levels of the regulator's uncertainty about cost Δ. In these cases, the equilibrium detection probability in the absence of regulatory testing is extremely low. Therefore, if the environmental cost is sufficiently high to justify imposing RoHS, then testing by the regulator is necessary to provide stronger incentives for compliance.

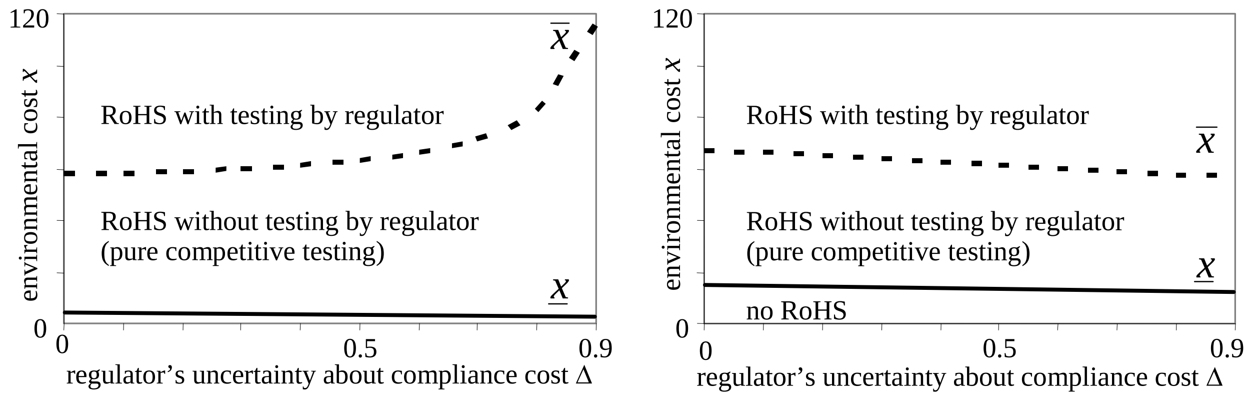

Figure 1: Environmental cost thresholds for the regulator to impose RoHS $\underline{x}$ and to impose RoHS *and* test products for compliance $\overline{x}$, as a function of the regulator's uncertainty about the manufacturer's cost of compliance. In both panels $N = 2$ and $a = 20$. In the left panel $\overline{F} = 0.1$ and in the right panel $\overline{F} = 1$.

of compliance. The explanation is that under RoHS with competitive testing, for low levels of environmental cost x, the manufacturers exert more testing effort (and knock more products out of the market) than is optimal for social welfare, so additional testing by the regulator becomes desirable only at strictly higher levels of the environmental cost parameter. In reality, manufacturers are much better than the regulator at detecting noncompliance ($\alpha \ll 1$). Because $\underline{x}$ is invariant with α but $\overline{x}$ increases sharply with α, our numerical study suggests that the regulator should not test, but rely on competitive testing (at least when the number of firms is not too large).

This conclusion is reinforced by the following counterintuitive but very robust result. For all parameter settings, $\underline{x}$ strictly decreases with Δ. That is, the more uncertain the regulator is about the cost of compliance, the more readily she should impose RoHS. (Indeed, in reality, the regulator is very uncertain about the cost of compliance.) This counterintuitive result occurs because the manufacturers adapt their testing and compliance efforts to the realization of the cost multiplier θ, so that compliance is high (low) when θ is low (high), which becomes increasingly advantageous as we hold $E[\theta] = 1$ and increase the high and low realizations of θ. In contrast, Figure 1 shows that the threshold for regulatory testing $\overline{x}$ may increase or decrease with the regulator's uncertainty about the cost of compliance Δ. For all parameter settings, we observed that $\underline{x}$ increases with the compliance cost multiplier $\overline{F}$ and, if the regulator knows the compliance cost ($\Delta = 0$), then $\overline{x}$ also increases with the compliance cost multiplier $\overline{F}$. (This phenomenon is illustrated in Figure 1; note that $\overline{F}$ is 0.1 in the left panel and 1 in the right panel.) However, when the regulator is uncertain about the compliance cost ($\Delta > 0$), $\overline{x}$ may increase or decrease with the compliance cost multiplier $\overline{F}$. Further, both thresholds $\underline{x}$ and $\overline{x}$ may increase or decrease with the testing efficacy a.

We now turn to the impact of regulation on the profitability of the firms. One might conjecture that a firm would prefer that the regulator not impose RoHS and not test, because such actions increase the likelihood that the firm's products will be blocked from the market. This conjecture is false: in some cases all the firms prefer that the regulator imposes RoHS (with or without regulator testing) instead of not imposing RoHS. The intuition is that imposing RoHS increases the expected price (by limiting the selling quantity) and testing by the regulator saves the firms the cost of testing their competitors. For example, with symmetric firms and parameters $\alpha = 1$, $\overline{v} = 100$, $u = 1$, $\overline{e} = \overline{d} = 0.99$, $\Delta = 0$, $\underline{c} = 40$, $\overline{F} = 5$, $a = 10$, $N = 2$, $Q = 0.45$ and $x \in (28, 71)$, each firm's expected profit is 4.4 without RoHS, is 4.9 under RoHS, and is 5.4 under RoHS with regulator testing $t_R = 0.6$. In this example $\underline{x} = 28$ and $\overline{x} = 71$, so both the firms and society are better off as a result of implementing competitive testing. However, the fact that the firms would be even better off under regulator testing $t_R = 0.6$, suggests that, contrary to conventional wisdom, the firms would lobby for aggressive regulatory testing of their products. Regulators should be wary of such calls for more aggressive regulation, because, as this example (with $x < \overline{x}$) illustrates, it may be detrimental to social welfare.

We have assumed that the regulator can publicly commit to a level of testing expenditure before the firms make their compliance decisions. However, after the firms have made their compliance decisions, the associated environmental costs are "sunk" (invariant with respect to the regulator's testing expenditure). At that point in time, testing by the regulator can only reduce expected social welfare by causing products to be withheld from the market. Therefore, as in Boyer et al. (2000), the regulator might be unable to commit to testing.

In reality, the regulator has great uncertainty about the cost of compliance and is less effective than manufacturers in testing. Therefore, even if the regulator could commit to a positive testing expenditure, Theorem 1 and our numerical study suggest that she should not do so, but instead rely on competitive testing (especially when the market is dominated by a few firms, as is the case in important segments of the electronics industry such as servers, personal computers, and video game consoles). We will henceforth assume that the regulator imposes RoHS but relies on competitive testing. Moreover, because all the manufacturers know the realization of the cost multiplier θ, we will assume without loss of generality that $\theta = 1$. We will write the symmetric equilibrium in compliance and testing as $(\widehat{e}, \widehat{T})$, suppressing the dependency on $\theta = 1$ and $t_R = 0$.

4 Short-Run Equilibrium with Competitive Testing

In this section, we continue to take each manufacturer's quantity $Q_n > 0$ as given, and focus on compliance and testing decisions. As before, we initially focus on the case in which the manufacturers are symmetric; this allows us to perform comparative statics for the unique symmetric equilibrium.

Proposition 1 characterizes the impact of the number of firms and their quality on equilibrium investment levels. Recall that $\widehat{T}$ represents the total equilibrium testing effort both exerted by each firm and applied to each firm.

Proposition 1 *The equilibrium compliance effort $\widehat{e}$ is decreasing in N and increasing in u. There exists $\overline{N}$ such that the equilibrium testing effort $\widehat{T}$ is increasing in N for $N \leq \overline{N}$ and decreasing in N for $N \geq \overline{N}$.*

We begin by explaining the impact of increasing the number of firms N on the total equilibrium testing effort $\widehat{T}$, when the number of firms $N \geq \overline{N}$; although we describe this as the case where the number of firms is "large," for some parameters $\overline{N} = 2$, making this case exhaustive. The total equilibrium testing effort $\widehat{T}$ decreases as the number of firms increases for two reasons. First, as the number of firms increases, each individual competitor has a smaller impact on the overall market and so the value of knocking that competitor out of the market decreases. Second, there is a free rider problem: when one competitor is knocked out of the market, all the remaining firms benefit, and this positive externality causes each firm to underinvest in testing. As the number of firms increases, this free rider problem is exacerbated, weakening the incentive for each firm to test its competitors.

As the number of firms increases, the equilibrium compliance level decreases. The rationale when the number of firms is large $N \geq \overline{N}$ is twofold. First, because as the number of firms increases, less testing effort is applied to each firm, so each firm has a smaller chance of being detected for noncompliance, and consequently has a less incentive to invest in compliance. Second, as the number of firms increases, the market becomes more competitive, decreasing the value of bringing products to market. Because the payoff from compliant production is smaller, each firm has less incentive to invest in compliance. When the number of firms is small $N \leq \overline{N}$, only the second rationale explains why compliance is decreasing in N.

When the number of firms is very small $N \ll \overline{N}$, the level of compliance can be quite high.

Consequently, investments in testing to detect noncompliance tend to be ineffective. As N increases on $N \leq \overline{N}$, the level of compliance decreases, which makes testing investments more likely to pay off, and consequently, the equilibrium testing effort $\widehat{T}$ increases.

Intuitively, as the firms' quality levels increase so that customer willingness to pay increases, the firms have more to lose from being discovered as noncompliant; consequently, the firms invest more in compliance. In our numerical studies we observed that as the quality level increases, the total equilibrium testing effort $\widehat{T}$ also increases.

We conclude that in industries with many manufacturers, each with weak brands, compliance under competitive testing will be low, with consequent environmental costs. This helps explain our numerical observation in §3 that relying on competitive testing is inadequate in terms of social-welfare maximization when the number of firms is large.

Next, we consider asymmetric firms. Under competitive testing, manufacturer n's expected profit simplifies from (4) to

$$\pi_n = \overline{v}\left[u_n\left(1 - \Sigma_{m=n+1}^{N} s\left(e_m, \Sigma_{j\in\mathcal{N}\setminus m} t_{jm}\right) Q_m - Q_n\right) - \Sigma_{m=1}^{n-1} u_m s\left(e_m, \Sigma_{j\in\mathcal{N}\setminus m} t_{jm}\right) Q_m\right]$$

$$\times\, s\left(e_n, \Sigma_{m\in\mathcal{N}\setminus n} t_{mn}\right) Q_n - c(e_n) Q_n - F(e_n) - \Sigma_{m\in\mathcal{N}\setminus n} t_{nm}.$$

By inspection of π_n, we have the following important observations. Manufacturer n's incentive for compliance increases with his own production quantity Q_n and quality u_n, and increases with the other manufacturers' testing of his products $\Sigma_{m\in\mathcal{N}\setminus n} t_{mn}$. Furthermore, every other manufacturer m's incentive to test manufacturer n's products increases with manufacturer m's production quantity Q_m and quality u_m. A common observation in the literature on Cournot oligopoly with vertically differentiated quality is that each firm's production quantity increases with its quality. This suggests that manufacturers with relatively strong brands will draw more testing from their competitors and have higher compliance in equilibrium, whereas manufacturers with weak brands will draw less testing from their competitors and have lower compliance in equilibrium.

The next proposition establishes that if a manufacturer has sufficiently low quality, he does not comply with RoHS, does not test competitors products, and draws less testing from his competitors than other manufacturers with higher quality. Most importantly, that manufacturer with low quality has strictly greater expected profit as a result of the RoHS regulation. The proposition requires two technical assumptions: that the marginal cost of compliance is strictly positive, and small investments in testing yield significantly large detection probabilities.

Proposition 2 *Suppose that $c'(0) + F'(0) > 0$ and $\lim_{t \downarrow 0} d'(t) = \infty$. There exists $u_L > 0$ such that if $u_l \leq u_L$ for $l \in \{1, .., N_L\}$ and $N \geq N_L + 2$, then in any Nash equilibrium, for any $l \in \{1, .., N_L\}$ and $h \in \{N_L + 1, .., N\}$, manufacturer l does not comply, does not test the products of manufacturer h, and draws less testing from its competitors than manufacturer h :*

$$e_l = 0 \tag{11}$$

$$t_{lh} = 0 \tag{12}$$

$$\sum_{j \in \mathcal{N} \backslash l} t_{jl} < \sum_{j \in \mathcal{N} \backslash h} t_{jh}. \tag{13}$$

Furthermore, RoHS strictly increases manufacturer l's expected profit.

In the short run, where the number of firms is fixed, Theorem 1 establishes that imposing RoHS with only competitive testing is socially optimal, provided that the environmental cost of noncompliance x is moderately high. However, Proposition 2 suggests that reliance on competitive testing may have undesirable effects in the longer run. Specifically, Proposition 2's result that RoHS increases expected profit for manufacturers with low perceived quality u implies that this form of regulation increases the incentive for entry by "white-box" manufacturers with weak brands. This is threatening to the environment, especially in light of Proposition 1, which points out that an increase in the number of firms in the market N and/or a reduction in perceived quality u results in lower compliance and greater environmental impacts in equilibrium.

We next examine the effect of RoHS on industry structure in the long run, as firms make entry and production decisions in addition to compliance and testing decisions.

5 Long-run Equilibrium under Competitive Testing

In this section we expand our study to include entry and production quantity decisions, which corresponds to considering the longer-run problem that the firms face. We extend the sequence of events described in §3 so that in the first stage, potential entrants decide whether or not to enter, where entry entails incurring a fixed cost K and allows the entrant to subsequently produce units of quality u. In the second stage, each entrant n observes the number of entering firms N, and then privately invests in production Q_n, compliance e_n and testing t_{nm} for $m \in \mathcal{N} \backslash n$. Although each firm makes these investments sequentially, because these investments are private, from the standpoint

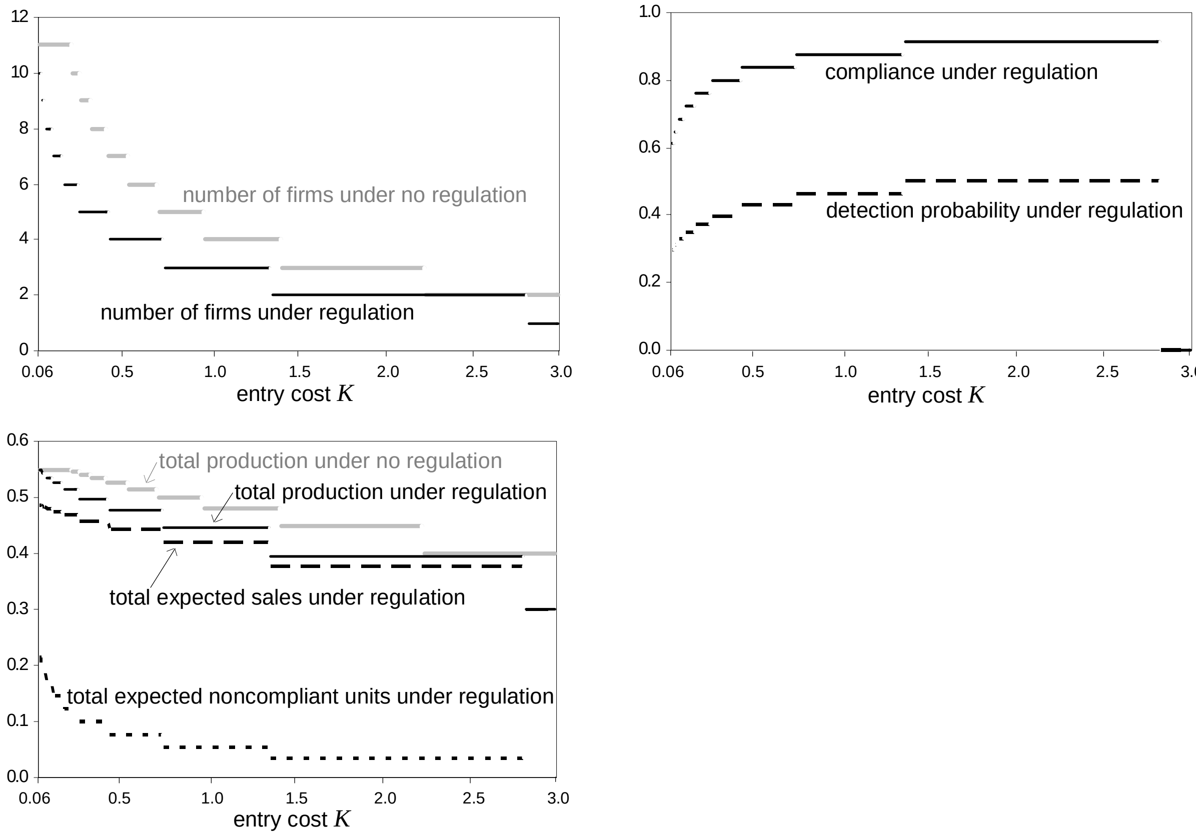

Figure 2: Impact of Entry Cost on Number of Firms, Compliance, Testing, and Quantities.

of characterizing equilibria, it is as if all firms make the three decisions simultaneously. Potential entrants enter in the first stage if and only if they anticipate that their expected profit in the second stage will (weakly) exceed the cost of entry K. Because of the additional complexity introduced by the entry and production decisions, this section presents numerical results. In each instance of our numerical study, regardless of the number of firms that enter, there is a unique symmetric equilibrium in the Stage Two game, and we assume that the firms play this equilibrium.[3]

Figure 2 demonstrates how the firms' entry, compliance and testing decisions depend on the cost of entry. Parameters are $\overline{v} = 100$, $u = 1$, $\overline{e} = \overline{d} = 0.99$, $a = 10$, $\underline{c} = 40$, $\overline{F} = 0.5$, and $K \in [0.06, 3.00]$. Figure 2 is representative of a larger numerical study in which we considered $\overline{v} = 100$, $u = 1$, $\overline{e} = \overline{d} = 0.99$, all parameter combinations of $a = \{1, 10, 20\}$, $\underline{c} = \{10, 20, 40\}$, $\overline{F} = \{0.1, 0.5, 1\}$, and the range of K corresponding to $N \in \{1, 2, .., 11\}$ entrants.

[3] An asymmetric equilibrium might achieve greater social welfare than the symmetric equilibrium when x is large and the cost of compliance is invariant with the production quantity ($c(e) = c$). A firm with relatively low compliance produces relatively little in an asymmetric equilibrium.

Figure 2's top left panel depicts the equilibrium number of firms as a function of the entry cost. In the long-run equilibrium, regulation makes the industry less profitable because each firm faces the prospect that its own products might be withheld from the market, and incurs costs for compliance and for testing its competitors. Consequently, regulation reduces the equilibrium number of firms. As the cost of entry increases, the industry becomes less attractive and fewer firms enter.

Figure 2's top right panel depicts, in the setting with regulation, the compliance e and total industry testing investment per firm T, where the later is measured by the resulting detection probability $d(T)$, as a function of the cost of entry. As the entry cost increases, so that fewer firms enter, the market becomes more attractive to any individual firm, which strengthens the incentive to invest in compliance. Further, with fewer firms, testing expenditure has a larger payoff because the effect of blocking the sale of a competitor's product is more pronounced; this more intensive testing reinforces the incentive to invest in compliance. Consequently, compliance and testing increase in the cost of entry when the cost of entry is not too high. However, when the cost of entry is very high, so that the industry can only support a single firm, then compliance drops to zero because no competing firm tests the monopolist. Similarly, in the setting without regulation, regardless of the entry cost, firms have no incentive for compliance or testing and do not invest in either: $e = T = 0$.

Figure 2's bottom panel depicts the total production NQ under regulation and under no regulation. Under no regulation, this coincides with the total expected sales quantity and total expected noncompliant units because no units are tested and all units produced are noncompliant. However, under regulation, in expectation, only a fraction of total production is converted into sales $s(e,T)NQ$ and only a fraction of the total production is noncompliant $(1-e)NQ$; these quantities are also depicted in the bottom panel. The intuition from the standard Cournot model without regulation carries over to the setting with regulation: as the entry cost increases, so that fewer firms enter, quantity competition becomes less intense, reducing the total production and expected sales quantity. The total expected noncompliant units produced under regulation $(1-e)NQ$ is decreasing in the entry cost, and this occurs for two reasons: Having fewer firms *intensifies competition in testing and compliance* (e is larger) at the same time that it *weakens competition in quantity* (NQ is smaller). The caveat is that as the entry cost increases to level where the industry can only support a single firm, the competition in testing and compliance disappears, so that to the total expected noncompliant quantity jumps up.

In the example above, the manufacturer's compliance cost is due to fixed costs ($F(e)$) rather than variable costs ($c(e)$). If, in addition, compliance increases the cost per unit of production $c(e)$, each firm will produce less and have lower compliance in equilibrium. This decreases the expected sales quantity of competitors, and thus may increase entry despite the adverse increase in production cost.

Our numerical study reinforces the analytical results in the previous section. Namely, these results suggest that in industries with high costs of entry (and correspondingly few firms), competitive testing can be effective in limiting noncompliant production. However, with low cost of entry (and correspondingly many firms), competitive testing will be ineffective. Thus, we obtain the somewhat paradoxical conclusion that in settings that are commonly thought of as being highly competitive, competitive testing fails; it only succeeds in sharply limiting noncompliant production in settings which are less competitive from a product standpoint. The intuition is that highly competitive markets are diffuse and this diffusion undermines the incentive of any individual firm to test its many small competitors.

6 Discussion

Our short-run analysis suggest that in the segments of the electronics industry dominated by a small number of manufacturers with strong brands (e.g., video game consoles), relying on manufacturers to test their competitors' products is effective in encouraging RoHS-compliance. However, in highly competitive consumer electronics markets with many manufacturers we anticipate that the threat of competitive testing will have little positive effect on encouraging compliance.

In the long run, relying on the manufacturers for competitive testing may cause entry by manufacturers with relatively weak brands, and consequently low RoHS-compliance. Even for incumbent manufacturers with strong brands, this increase in competition weakens the incentive for RoHS-compliance. To reduce the incentive for entry and thus increase long-run RoHS compliance, regulators can follow the state of Maine in requiring each brand to register and pay a fixed fee. (In Maine, those fees help to pay for the recovery and recycling of used electronics.) As demonstrated in the numerical study in §5, the total expected noncompliant quantity produced under regulation is decreasing in the entry cost. By increasing the cost of entry, a registration fee reduces the negative environmental impact of noncompliant production. Unfortunately, it also mitigates quantity competition, driving up the expected selling price and making the product available to fewer consumers. The socially optimal fee to register a brand balances these two concerns, with the optimal fee increasing in the environmental cost of noncompliant production.

Another long-run impediment to competitive testing is that manufacturers may develop agreements not to test each others' products, enforced by the explicit or implicit threat "if you report my RoHS-violation now, then in future I will test your products and report any RoHS-violation." Therefore allowing *anonymous* reporting of violations, as does the California Department of Toxic Substances, will encourage competitive testing.

In the long run, manufacturers have a stronger incentive for RoHS compliance than captured in our one-period model in that if a RoHS-violation is detected, the manufacturer's brand and hence future profits will be damaged. This incentive is presumably strongest for manufacturers with a strong reputation and brand, and therefore reinforces our finding that manufacturers with stronger brands have higher RoHS compliance in equilibrium.

In practice, environmental nonprofit organizations are testing big-brand electronics manufacturer's products for RoHS-compliance. Donations to an environmental nonprofit increase with the nonprofit's reputation for efficacy, and hence with positive press coverage. Detection of a RoHS-violation by a big-brand manufacturer will generate much more press coverage than would detection of a RoHS-violation by a small, little-known manufacturer. (For example, Graham-Rowe (2006) covers the detection by Greenpeace of brominated flame retardants in a Hewlett-Packard (HP) computer; the computer was not illegal because it was sold in the EU shortly before the RoHS regulation came into effect, but HP had previously advertised that its products were free of such hazardous substances.) Therefore environmental nonprofit organizations have relatively little incentive to test the products of little-known manufacturers. Testing by nonprofit organizations reinforces our conclusion that manufacturers with stronger brands will have higher RoHS-compliance in equilibrium.

In our model, environment cost is proportional to the quantity of production with restricted hazardous substances, but in reality the environmental cost structure is more complex. Even RoHS-compliant production causes environmental impacts. In particular, U.S. Environmental Protection Agency (EPA) administrators are concerned that manufacturers' substitutes for restricted substances might also be toxic (Lindsay 2006). Moreover, for either a RoHS-compliant product or a non-compliant product, the environmental cost depends upon how the product is treated at the end of its useful life. In the EU, the Waste Electrical and Electronic Equipment (WEEE) directive requires that manufacturers collect and recycle a fraction (50-80% depending on product category) of their products. Recycling reduces some environmental impacts and increases others, but presumably reduces the net environmental cost (Huisman et al. 2003, Mayers et al. 2005). The most fundamental issue is that assigning a dollar value to the environmental impacts of RoHS-compliant versus noncompliant production under various recycling scenarios is very difficult, and requires further research.

Further research is also needed on integrated optimal design of regulation for electronics production and end-of-life management. To maximize expected social welfare, the regulator's budget for RoHS testing and the target fraction of products recycled must be jointly optimized, because RoHS-compliance reduces the net cost of recycling[4] and recycling reduces the environmental cost of noncompliant products and, to lesser extent, RoHS-compliant products. In a model without explicit RoHS, Atasu et al. (2006) characterize the socially optimal fraction of products to recycle. They assume a fixed environmental cost per unit production that is not recycled and zero environmental cost for recycled units. They show that the optimal fraction to recycle increases with the number of competing manufacturers. We have shown that the prevalence of hazardous substances increases with the number of competing manufacturers, which reinforces the need for safe recycling and/or disposal of electronics at end of life.

The U.S. EPA and nonprofit Green Electronics Council have established a website www.epeat.com where electronics manufacturers may voluntarily rank their products as "Gold," "Silver" or "Bronze" based on RoHS compliance, energy efficiency, and other environmental attributes. This system was originally intended to guide U.S. state and federal government procurement, but is also influencing purchases by corporate, nonprofit, and even some individual consumers (Rehfeld 2006). In this voluntary system, manufacturers' incentive to rank products truthfully is the threat of damage to reputation and brand in the event that a violation is detected. Further research is needed to assess how such voluntary systems affect the structure, output, profitability and environmental impacts of the electronics industry.

We conclude by noting that although our model is motivated by the specifics of environmental regulation in the electronics industry, the phenomenon of competitive testing has the potential to play out in any competitive market governed by product-based environmental, health, or safety standards, and our insights apply more broadly to these settings.

[4]For example, elimination of brominated flame retardants allows for plastics to be recycled or safely burned for energy recovery.

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Appendix

Lemmas 2, 3, and 4 are useful in the proofs of Lemma 1 and Theorem 1. Let

$$f_1(e,T) = \overline{v}u(1-e)d'(T)s(e,T)Q^2 - 1$$

$$f_2(\theta,e,T) = [\overline{v}ud(T) - \theta c'(e)]Q - \overline{v}ud(T)[1+(N-1)s(e,T)]Q^2 - \theta F'(e);$$

$f_1(e,T)$ is the first derivative of the manufacturer n's profit function with respect to t_{nm} for $m \in \mathcal{N}\backslash n$ and $f_2(\theta,e,T)$ is the first derivative with respect to e_n, when all manufacturers, including n, choose compliance e and testing per competitor of $t = T/(N-1)$. Define for $T > 0$,

$$\underline{\mathbf{e}}(T) = \left(2d(T) - 1 - \sqrt{1 - 4d(T)/[\overline{v}ud'(T)Q^2]}\right)\Big/\, 2d(T)$$

$$\overline{\mathbf{e}}(T) = \left(2d(T) - 1 + \sqrt{1 - 4d(T)/[\overline{v}ud'(T)Q^2]}\right)\Big/\, 2d(T),$$

and let $\underline{\mathbf{e}}(0) = \lim_{T\downarrow 0}\underline{\mathbf{e}}(T)$ and $\overline{\mathbf{e}}(0) = \lim_{T\downarrow 0}\overline{\mathbf{e}}(T)$. Let $\overline{T}$ denote the unique solution to

$$\frac{d(T)}{d'(T)} = \frac{\overline{v}uQ^2}{4}.$$

If $T > \overline{T}$, then no value of e satisfies $f_1(e,T) = 0$; otherwise, $f_1(e,T) = 0$ has two roots in e : $\underline{\mathbf{e}}(T)$ and $\overline{\mathbf{e}}(T)$. Note that the notation for the root $\overline{\mathbf{e}}(T)$ is distinct from the upper limit on the manufacturer's compliance investment $\overline{e}$. Note that $f_2(\theta,e,T)$ is strictly increasing in T and strictly decreasing in e. Let

$$\underline{T}(\theta) = \inf_{T\geq 0}\{T : f_2(\theta,0,T) > 0\}.$$

If $T > \underline{T}(\theta)$, then let $\tilde{e}(\theta, T)$ denote the unique solution to

$$f_2(\theta, e, T) = 0,$$

and note that

$$\tilde{e}(\theta, T) > 0; \tag{14}$$

otherwise, let $\tilde{e}(\theta, T) = 0$.

Lemma 2 *Suppose the firms are symmetric and consider the case with RoHS and competitive testing* ($t_R = 0$). *If*

$$\lim_{T \downarrow 0} \{\overline{v} u d'(T)^3 Q^2 - d'(T)^2 + d(T) d''(T)\} > 0, \tag{15}$$

is violated, then the unique symmetric equilibrium in compliance and testing $(\widehat{e}(\theta, 0), \widehat{T}(\theta, 0)) = (0, 0)$. *Otherwise, any symmetric equilibrium* $(\widehat{e}(\theta, 0), \widehat{T}(\theta, 0))$ *has* $\widehat{T}(\theta, 0) \in (0, \overline{T}]$ *and one of the following:*

$$\widehat{e}(\theta, 0) = \underline{\mathbf{e}}(\widehat{T}) = \tilde{e}(\theta, \widehat{T}) \tag{16}$$

$$\widehat{e}(\theta, 0) = \bar{\mathbf{e}}(\widehat{T}) = \tilde{e}(\theta, \widehat{T}). \tag{17}$$

Moreover, any solution to (16) *or* (17) *is a symmetric equilibrium. Further,* $\underline{\mathbf{e}}(\cdot)$ *is strictly increasing and* $\bar{\mathbf{e}}(\cdot)$ *is strictly decreasing;* $\tilde{e}(\theta, T)$ *is continuous on* $T \in [0, \infty)$ *and increasing in* T, *strictly so on* $T \in (\underline{T}(\theta), \infty)$. *Finally,* $\tilde{e}(\theta, 0) = 0$; $\underline{\mathbf{e}}(0) < 0$; *and* $\bar{\mathbf{e}}(0) > 0$ *if and only if* (15).

Proof of Lemma 2: The proof proceeds in five steps. First, we establish necessary conditions for a symmetric equilibrium. Second, we show that these conditions are sufficient. Third, we establish properties of the functions $\tilde{e}(\theta, T)$, $\underline{\mathbf{e}}(T)$ and $\bar{\mathbf{e}}(T)$. Fourth, we show that if (15) is violated, then the unique symmetric equilibrium has zero compliance and testing. Fifth, we show that if (15) is satisfied, then a symmetric equilibrium must satisfy (16) or (17).

First, we establish necessary conditions for a symmetric equilibrium. Recall that $T = (N-1)t$. If manufacturer n anticipates that the remaining manufacturers $m \in \mathcal{N} \backslash n$ will choose compliance $e_m = e$ and testing $t_{mj} = t$ for $j \in \mathcal{N} \backslash m$, then for compliance and testing $(e_n, t_{nm}) = (e, t)$ for $m \in \mathcal{N} \backslash n$ to be a best response for manufacturer n, the following first order conditions must be satisfied

$$(\partial/\partial t_{nm})\pi_n|_{e_i=e,t_{ij}=t \text{ for } i\in\mathcal{N} \text{ and } j\in\mathcal{N}\backslash i} = f_1(e,T) \leq 0 \tag{18}$$

$$(\partial/\partial e_n)\pi_n|_{e_i=e,t_{ij}=t \text{ for } i\in\mathcal{N} \text{ and } j\in\mathcal{N}\backslash i} = f_2(\theta,e,T) \leq 0, \tag{19}$$

where (18) must hold with equality if $T > 0$ and (19) must hold with equality if $e > 0$. That is, a symmetric equilibrium satisfies (18)-(19).

Second, we establish that any solution to (18)-(19) is a symmetric equilibrium. If manufacturer n anticipates that the remaining manufacturers $m \in N\backslash n$ will choose compliance $e_m = e$ and testing $t_{mj} = t$ for $j \in N\backslash m$, then any solution to the first order conditions for manufacturer n must have $t_{nm} = t_n$ for $m \in N\backslash n$. Thus, we can write manufacturer n's expected profit under compliance e_n and total testing expenditure $T_n = (N-1)t_n$ as

$$\pi_n = \overline{v}u\left[1-(N-1)s\left(e,[(N-2)T+T_n]/(N-1)\right)Q - Q\right]s(e_n,T)Q - \theta[c(e_n)Q + F(e_n)] - T_n.$$

Inequalities (5) and (6) together imply

$$d''(t) < -[\overline{v}u(N-1)d'(t)^2]/\{(1-\overline{d})\theta[c''(e)Q + F''(e)]\} \text{ for } (e,\theta) \in [0,\overline{e}) \times [\underline{\theta},\overline{\theta}].$$

This, together with the fact that $c(\cdot)$ and $F(\cdot)$ are strictly convex, implies that for any $\theta \in [\underline{\theta},\overline{\theta}]$, π_n is jointly strictly concave in (e_n, T_n), so the first order conditions (18)-(19) are sufficient.

Third, we establish properties of the functions $\tilde{e}(\theta,T)$, $\underline{\mathbf{e}}(T)$ and $\overline{\mathbf{e}}(T)$. Because $d''(T) < -d'(T)^2/d(T)$, $\underline{\mathbf{e}}(\cdot)$ is strictly increasing and $\overline{\mathbf{e}}(\cdot)$ is strictly decreasing. Because $f_2(\theta,\cdot,\cdot)$ is continuous, $\tilde{e}(\theta,T)$ is continuous on $T \in [0,\infty)$. By the implicit function theorem, $\tilde{e}(\theta,T)$ is strictly increasing in T for $T \in (\underline{T}(\theta),\infty)$

$$\frac{\partial\tilde{e}(\theta,T)}{\partial T} = \frac{(\partial/\partial T)f_2(\theta,e,T)}{-(\partial/\partial e)f_2(\theta,e,T)} > 0.$$

By L'Hospital's rule

$$\lim_{T\downarrow 0}\overline{\mathbf{e}}(T) = \lim_{T\downarrow 0}\left(1 - \frac{d'(T)^2 - d(T)d''(T)}{\overline{v}ud'(T)^3Q^2}\right),$$

so $\overline{\mathbf{e}}(0) > 0$ if and only if (15).

Fourth, suppose (15) is violated. Then $f_1(0,0) \leq 0$ and $f_2(\theta,0,0) \leq 0$, so $(\widehat{e}(\theta,0),\widehat{T}(\theta,0)) = (0,0)$ is an equilibrium; it remains to show that it is unique. Because $\overline{\mathbf{e}}(0) \leq 0$ and $\overline{\mathbf{e}}(\cdot)$ is strictly decreasing, for any $T > 0$, $\overline{\mathbf{e}}(T) < 0$. Because $f_1(\cdot,T)$ is strictly concave and $f_1(e,T) = 0$ has two roots in e, $\underline{\mathbf{e}}(T)$ and $\overline{\mathbf{e}}(T)$, $f_1(e,T) < 0$ for $e > \overline{\mathbf{e}}(T)$. Therefore, for any $e \geq 0$ and $T > 0$,

$f_1(e, T) < 0$, which implies that no equilibrium exists with $T > 0$. Because $f_2(\theta, \cdot, 0)$ is strictly decreasing, $f_2(\theta, e, 0) < 0$ for $e > 0$; this implies that any equilibrium with $T = 0$ must have $e = 0$.

Fifth, suppose (15) holds. Because $f_1(0, 0) > 0$, $(e, T) = (0, 0)$ is not an equilibrium. Because $f_2(\theta, e, 0) < 0$ for $e \in (0, \overline{e})$, an equilibrium cannot have $T = 0$. Thus, in any equilibrium (18) must hold with equality. Thus, a symmetric equilibrium must satisfy $\widehat{T} \in (0, \overline{T}]$, and (16) or (17).■

Lemma 3 *Suppose the firms are symmetric. Under RoHS and competitive testing* ($t_R = 0$)*, for any realized cost multiplier* θ*, there exists a unique symmetric equilibrium in compliance and testing.*

Proof of Lemma 3: If (15) is violated, then a symmetric equilibrium exists and is unique (from Lemma 2). Therefore, we restrict attention to the case in which (15) holds, which implies $\bar{\mathbf{e}}(0) > 0$ (from Lemma 2). Further, throughout, we restrict attention to $T \in [0, \overline{T}]$, because no symmetric equilibrium exists with $T > \overline{T}$ (from Lemma 2). We next consider three cases and show that in each, there exists a unique symmetric equilibrium.

Case 1: $\underline{T}(\theta) \geq \overline{T}$

First, suppose $\bar{\mathbf{e}}(\overline{T}) = 0$. Then for $T \in [0, \overline{T})$,

$$\bar{\mathbf{e}}(T) > 0 = \tilde{e}(\theta, T) > \underline{\mathbf{e}}(T),$$

so no equilibrium exists with $T \in [0, \overline{T})$ (from Lemma 2). Further,

$$\bar{\mathbf{e}}(\overline{T}) = \underline{\mathbf{e}}(\overline{T}) = \tilde{e}(\theta, \overline{T}) = 0,$$

so the unique equilibrium is $(\widehat{e}(\theta, 0), \widehat{T}(\theta, 0)) = (0, \overline{T})$ (from Lemma 2).

Second, suppose $\bar{\mathbf{e}}(\overline{T}) < 0$. Then for $T \in [0, \overline{T}]$,

$$\tilde{e}(\theta, T) \geq 0 > \bar{\mathbf{e}}(\overline{T}) = \underline{\mathbf{e}}(\overline{T}) \geq \underline{\mathbf{e}}(T),$$

so there does not exist a solution to (16). However, because $\tilde{e}(\theta, T) = 0$ for $T \in [0, \overline{T}]$, $\bar{\mathbf{e}}(0) > 0$, $\bar{\mathbf{e}}(\overline{T}) < 0$, and $\bar{\mathbf{e}}(\cdot)$ is strictly decreasing, there exists a unique solution to (17) and this is the unique equilibrium (by Lemma 2).

Third, suppose $\bar{\mathbf{e}}(\overline{T}) > 0$. By similar argument, there does not exist a solution to (17), but there exists a unique solution to (16) and this is the unique equilibrium.

Case 2: $\underline{T}(\theta) < \overline{T}$ and $\bar{\mathbf{e}}(\underline{T}(\theta)) \leq 0$

Because for $T \in [0, \overline{T}]$,

$$\tilde{e}(\theta, T) \geq 0 \geq \bar{\mathbf{e}}(\underline{T}(\theta)) > \bar{\mathbf{e}}(\overline{T}) = \underline{\mathbf{e}}(\overline{T}) \geq \underline{\mathbf{e}}(T),$$

there does not exist a solution to (16). However, because $\bar{\mathbf{e}}(0) > 0 = \tilde{e}(\theta, 0)$, $\bar{\mathbf{e}}(\underline{T}(\theta)) \leq 0 = \tilde{e}(\theta, \underline{T}(\theta))$, $\bar{\mathbf{e}}(\cdot)$ is strictly decreasing, and $\tilde{e}(\theta, \cdot)$ is increasing, there exists a unique solution to (17) and this is the unique equilibrium (by Lemma 2).

CASE 3: $\underline{T}(\theta) < \overline{T}$ AND $\bar{\mathbf{e}}(\underline{T}(\theta)) > 0$

The proof for this case proceeds in four steps. First, we show that no symmetric equilibrium exists with $T \leq \underline{T}(\theta)$, which allows us in subsequent steps to restrict attention to $T \in (\underline{T}(\theta), \overline{T}]$. Second, we show that if $f_2(\theta, \underline{\mathbf{e}}(T), T) = 0$ has no roots, then the unique symmetric equilibrium has (17). Third, we show if $f_2(\theta, \underline{\mathbf{e}}(T), T) = 0$ has one root, then the unique symmetric equilibrium has (16). Fourth, we show that $f_2(\theta, \underline{\mathbf{e}}(T), T) = 0$ has at most one root.

First, we establish that

$$d(\underline{T}(\theta)) < 1/2. \tag{20}$$

Inequality (20) is immediate if $\overline{d} \leq 1/2$; otherwise (20) follows from the fact that $f_2(\theta, 0, T)$ is strictly increasing in T and

$$f_2(\theta, 0, T)|_{d(T)=1/2} > \overline{v}u(N-1)Q^2/4 > 0, \tag{21}$$

where the first inequality follows from (7). Inequality (20) implies

$$\underline{\mathbf{e}}(\underline{T}(\theta)) < 0. \tag{22}$$

Because $\tilde{e}(\theta, \underline{T}(\theta)) = 0$, (22) implies that $\underline{\mathbf{e}}(\underline{T}(\theta)) < \tilde{e}(\theta, \underline{T}(\theta))$, or equivalently,

$$f_2(\theta, \underline{\mathbf{e}}(\underline{T}(\theta)), 0) > 0. \tag{23}$$

Because for $T \leq \underline{T}(\theta)$, $\underline{\mathbf{e}}(T) < \tilde{e}(\theta, \underline{T}(\theta)) = 0 < \bar{\mathbf{e}}(\underline{T}(\theta)) \leq \bar{\mathbf{e}}(T)$, there does not exist a solution to either (16) or (17), and therefore no symmetric equilibrium with $T \leq \underline{T}(\theta)$ exists (from Lemma 2). Because no symmetric equilibrium with $T \leq \underline{T}(\theta)$ exists, in the subsequent steps we restrict attention to $T \in (\underline{T}(\theta), \overline{T}]$.

Second, suppose that $f_2(\theta, \underline{\mathbf{e}}(T), T) = 0$ has no roots. This, together with (23) and the observation that $\underline{\mathbf{e}}(\cdot)$ and $f_2(\theta, \cdot, \cdot)$ are continuous implies $f_2(\theta, \underline{\mathbf{e}}(T), T) > 0$, or equivalently,

$$\underline{\mathbf{e}}(T) < \tilde{e}(\theta, T). \tag{24}$$

Because $\underline{\mathbf{e}}(\overline{T}) = \bar{\mathbf{e}}(\overline{T})$, this implies

$$\bar{\mathbf{e}}(\overline{T}) < \tilde{e}(\theta, \overline{T}). \tag{25}$$

Because $\tilde{e}(\theta, \cdot)$ is strictly increasing, $\bar{\mathbf{e}}(\cdot)$ is strictly decreasing, and $\bar{\mathbf{e}}(\underline{T}(\theta)) > \tilde{e}(\theta, \underline{T}(\theta))$, (25) implies that there is a unique $T \in (\underline{T}(\theta), \overline{T})$ such that

$$\bar{\mathbf{e}}(T) = \tilde{e}(\theta, T).$$

This observation, together with (24) and Lemma 2, implies that the unique symmetric equilibrium has (17).

Third, suppose that $f_2(\theta, \underline{\mathbf{e}}(T), T) = 0$ has one root. Then (23) implies $f_2(\theta, \underline{\mathbf{e}}(\overline{T}), \overline{T}) \leq 0$, or equivalently,

$$\underline{\mathbf{e}}(\overline{T}) \geq \tilde{e}(\theta, \overline{T}).$$

Because $\bar{\mathbf{e}}(T) > \underline{\mathbf{e}}(\overline{T})$ for $T < \overline{T}$, this implies

$$\bar{\mathbf{e}}(T) > \tilde{e}(\theta, \overline{T})$$

for $T < \overline{T}$. This observation, together with Lemma 2 and the observation that $\underline{\mathbf{e}}(T) = \tilde{e}(\theta, T)$ has a unique solution, implies that the unique symmetric equilibrium has (16).

Fourth, we show that there exists $\underline{d} > 0$ such that $d''(T) < -\underline{d}$ implies that $f_2(\theta, \underline{\mathbf{e}}(T), T) = 0$ has at most one root. Because of (23), it is sufficient to show that $f_2(\theta, \underline{\mathbf{e}}(\cdot), \cdot)$ is strictly concave. Straightforward, albeit tedious algebra establishes that $c'''(e)Q + F'''(e) \geq 0$ implies

$$\lim_{d \to -\infty} \frac{\partial^2}{\partial T^2} f_2(\theta, \underline{\mathbf{e}}(T), T)|_{d''(T)=d} < 0.$$

Because $\frac{\partial^2}{\partial T^2} f_2(\theta, \underline{\mathbf{e}}(T), T)|_{d''(T)=d}$ is continuous in d, there exists $\underline{d} > 0$ such that $d''(T) < -\underline{d}$ implies that $f_2(\theta, \underline{\mathbf{e}}(T), T)$ is strictly concave.■

Lemma 4 *Suppose the firms are symmetric and that in the case with RoHS and competitive testing* ($t_R = 0$), *the symmetric equilibrium is unique. Then, if the regulator tests* $t_R > 0$, *the unique symmetric equilibrium is*

$$\widehat{T}(\theta, t_R) = \left[\widehat{T}(\theta, 0) - \alpha t_R\right]^+ \tag{26}$$

$$\widehat{e}(\theta, t_R) = \tilde{e}(\theta, \max(\widehat{T}(\theta, 0), \alpha t_R)).$$

Proof of Lemma 4: If each manufacturer applies t^f to its $N-1$ competitors, then the total testing expenditure applied to each firm is $T^f = (N-1)t^f$. If the manufacturers collectively apply testing expenditure T^f to each manufacturer and the regulator applies testing expenditure t_R to each manufacturer, the compliance effort in a symmetric equilibrium is $\tilde{e}(\theta, \alpha t_R + T^f)$.

Because in the base case with no regulator testing there is a unique symmetric equilibrium with compliance and firm testing $(\widehat{e}(\theta,0),\widehat{T}(\theta,0))$, if the regulator announces testing $t_R \le \widehat{T}(\theta,0)/\alpha$, then in the unique symmetric equilibrium the firms apply testing expenditure $T^f = \widehat{T}(\theta,0)-\alpha t_R$ and choose compliance $\widehat{e}(\theta,0)$.

If the regulator announces testing $t_R > \widehat{T}(\theta,0)/\alpha$, then a symmetric equilibrium will have compliance weakly larger than $\widehat{e}(\theta,0)$ (this follows from $\alpha t_R + T^f > \widehat{T}(\theta,0)$ and $\tilde{e}(\theta,T)$ being increasing in T). Suppose that the firms apply strictly positive testing expenditure $T^f > 0$; this implies that there exists an equilibrium in the base case with no regulator testing with compliance weakly greater than $\widehat{e}(\theta,0)$ and testing strictly greater than $\widehat{T}(\theta,0)$, which contradicts that the symmetric equilibrium in the base case is unique. We conclude that in equilibrium, if the regulator announces testing $t_R > \widehat{T}(\theta,0))/\alpha$, the firms do not test $T^f = 0$.■

Proof of Lemma 1: All but (8) is immediate from Lemmas 3 and 4. Inequality (8) follows from Lemma 4 and that observation that $\tilde{e}(\theta,T)$ is increasing in T (from Lemma 2).■

Proof of Theorem 1: The proof proceeds in six steps. In Step 1, we establish some properties of the expected social welfare function. In Steps 2 to 5, we compare the regulator's preference over the three alternatives: imposing RoHS with regulator testing, imposing RoHS without regulator testing, and not imposing RoHS. In Step 6, we establish sufficient conditions for $\underline{x} < \overline{x}$

Step 1: Properties of the regulator's objective function

Consider the relaxed problem in which the regulator first dictates the level of testing, and the individual manufacturers then simultaneously choose compliance. If the regulator chooses testing level T per firm, the manufacturers in the unique symmetric equilibrium choose compliance $\tilde{e}(\theta,T)$. The expected social welfare that results is

$$P(\theta,x,T) \equiv E[\overline{v}u\Sigma_{n=1}^{N}\widetilde{Q}_n(1-\Sigma_{n=1}^{N}\widetilde{Q}_n/2)]-N(\theta[c(\tilde{e}(\theta,T))Q+F(\tilde{e}(\theta,T))]-xN[1-\tilde{e}(\theta,T)]Q-NT,$$

where $\tilde{e}(\theta,T)$ and T determine the distribution of $\widetilde{Q}_n : \widetilde{Q}_n = Q$ with probability $s(\tilde{e}(\theta,T),T)$ and $\widetilde{Q}_n = 0$ otherwise.

Recall that expected social welfare under RoHS, where the regulator first chooses testing level t_R and the manufacturers follow by choosing compliance and testing levels, is given by (9), which we denote $S(x,t_R)$. From Lemma 4 and the observation that $\widehat{e}(\theta,0)=\tilde{e}(\theta,\widehat{T}(\theta,0))$,

$$S(x,t_R) = E_\theta[P(\theta,x,\max(\widehat{T}(\theta,0),\alpha t_R)) - N(1-\alpha)t_R]. \tag{27}$$

From Lemma 2, for every $\theta \in [\underline{\theta},\overline{\theta}]$, $\tilde{e}(\theta,T)$ is increasing in T, strictly so for $T > \underline{T}(\theta)$, so the term $-N(1-\tilde{e}(\theta,T))Q$ in $P(\theta,x,T)$ is increasing in T, strictly so for $T > \underline{T}(\theta)$. Intuitively, an increase in testing reduces the expected quantity of noncompliant production. Furthermore, as the environmental cost parameter x increases, the increase in $-xN(1-\tilde{e}(\theta,T))Q$ with respect to testing T strictly increases. Therefore, expected social welfare $P(\theta,x,T)$ is supermodular in x and T, and is strictly so for $T > \underline{T}(\theta)$. It immediately follows that $S(x,t_R)$ is supermodular in x and t_R.

Step 2: Regulator's preference for imposing RoHS with testing vs. imposing RoHS without testing

In this step, we compare the regulator's preference for imposing RoHS and testing versus imposing RoHS and not testing. Let

$$x_3 = \sup\{x : S(x,0) \geq S(x,t_R) \text{ for } t_R > 0\}.$$

Then for any $x > x_3$, there exists $t_R > 0$ such that

$$S(x,t_R) > S(x,0),$$

so the regulator prefers to impose RoHS and test rather than impose RoHS and not test for $x > x_3$. Because $\tilde{e}(\theta,\cdot)$ is continuous, $S(\cdot,\cdot)$ is continuous. This implies

$$S(x_3,0) \geq S(x_3,t_R) \text{ for } t_R > 0,$$

so, by convention, the regulator prefers to impose RoHS and not test rather than impose RoHS and test for $x = x_3$. For any $x < x_3$ and any $t_R > 0$,

$$\begin{aligned} 0 &\geq S(x_3,t_R) - S(x_3,0) \\ &\geq S(x,t_R) - S(x,0), \end{aligned}$$

where the second inequality follows from supermodularity of $S(\cdot,\cdot)$. Therefore, by convention, the regulator prefers to impose RoHS and not test rather than impose RoHS and test for $x < x_3$.

If $\Pr(\widehat{T}(\theta,0) > 0) = 0$, then social welfare is identical when the regulator does not impose RoHS and when the regulator imposes RoHS without testing, so by convention the regulator does not impose RoHS without testing. Therefore the statement of the proposition regarding when the manufacturer imposes RoHS and when the manufacturer tests holds with $\underline{x} = \overline{x} = x_3$. In the sequel, we assume that $\Pr(\widehat{T}(\theta,0) > 0) > 0$.

Step 3: Regulator's preference for imposing RoHS with testing vs. not imposing

RoHS

In this step, we compare the regulator's preference for imposing RoHS with testing versus not imposing RoHS. Let

$$x_2 = \sup\{x : E_\theta[P(\theta, x, 0)] \geq S(x, t_R) \text{ for } t_R > 0\}.$$

Then for any $x > x_2$, there exists $t_R > 0$ such that

$$S(x, t_R) > E_\theta[P(\theta, x, 0)],$$

so the regulator prefers to impose RoHS and test rather than not impose RoHS for $x > x_2$.

Because $S(\cdot, \cdot)$ and $E_\theta[P(\theta, \cdot, 0)]$ are continuous,

$$E_\theta[P(\theta, x_2, 0)] \geq S(x_2, t_R) \text{ for } t_R > 0,$$

so, by convention, the regulator prefers to not impose RoHS rather than impose RoHS and test for $x = x_2$. For any $x < x_2$ and any $t_R > 0$,

$$\begin{aligned}
0 &\geq S(x_2, t_R) - E_\theta[P(\theta, x_2, 0)] \\
&= S(x_2, t_R) - S(x_2, 0) + E_\theta[P(\theta, x_2, \widehat{T}(\theta, 0))] - E_\theta[P(\theta, x_2, 0)] \\
&\geq S(x, t_R) - S(x, 0) + E_\theta[P(\theta, x, \widehat{T}(\theta, 0))] - E_\theta[P(\theta, x, 0)] \\
&= S(x, t_R) - E_\theta[P(\theta, x, 0)],
\end{aligned}$$

where the equalities follow from (27) and the second inequality follows from supermodularity of $S(\cdot, \cdot)$ and $P(\theta, \cdot, \cdot)$. Therefore, by convention, the regulator prefers to not impose RoHS rather than impose RoHS and test for $x < x_2$.

Step 4: Regulator's preference for imposing RoHS without testing vs. not imposing RoHS

In this step, we compare the regulator's preference for imposing RoHS without testing versus not imposing RoHS. First, suppose that $\Pr(\widehat{e}(\theta, 0) > 0) > 0$, or equivalently $\Pr(\widehat{T}(\theta, 0) > \underline{T}(\theta)) > 0$. In this case, let x_1 denote the unique solution to

$$E_\theta[P(\theta, x, \widehat{T}(\theta, 0))] = E_\theta[P(\theta, x, 0)].$$

By convention, the regulator prefers to not impose RoHS rather than impose RoHS without testing for $x = x_1$. For $x > x_1$,

$$E_\theta[P(\theta, x, \widehat{T}(\theta, 0))] - E_\theta[P(\theta, x, 0)]$$

$$> E_\theta[P(\theta, x_1, \widehat{T}(\theta, 0))] - E_\theta[P(\theta, x_1, 0)] = 0,$$

where the inequality follows because $P(\theta, \cdot, \cdot)$ is strictly supermodular for θ such that $\widehat{T}(\theta, 0) > \underline{T}(\theta)$. Thus, the regulator prefers to impose RoHS without testing rather than to not impose RoHS for $x > x_1$. For $x < x_1$,

$$0 = E_\theta[P(\theta, x_1, \widehat{T}(\theta, 0))] - E_\theta[P(\theta, x_1, 0)]$$

$$> E_\theta[P(\theta, x, \widehat{T}(\theta, 0))] - E_\theta[P(\theta, x, 0)],$$

so the regulator prefers not to impose RoHS rather than to impose RoHS without testing for $x < x_1$.

Second, suppose that $\Pr(\widehat{e}(\theta, 0) > 0) = 0$. Then imposing RoHS without regulator testing only has the effect of causing the system to incur testing costs and of reducing the expected utility generated by sold units, without the benefit of increased compliance. Therefore, the regulator always prefers not to impose RoHS than rather to impose RoHS without testing. In this case, we define $x_1 = \infty$, so that we can say, consistent with the first case, that the regulator prefers not to impose RoHS rather than to impose RoHS with testing if and only if $x < x_1$.

Step 5: Regulator's overall preference

If $x_1 \leq x_3$, then the the statement of the proposition regarding when the manufacturer imposes RoHS and when the manufacturer tests holds with $\underline{x} = x_1$ and $\overline{x} = x_3$. If $x_1 > x_3$, then $x_2 \in [x_3, x_1]$ and the statement holds with $\underline{x} = \overline{x} = x_2$.

Step 6: Sufficient conditions for $\underline{x} < \overline{x}$

Note that $\Pr(\widehat{e}(\theta, 0) > 0) > 0$ implies $\Pr(\widehat{T}(\theta, 0) > 0) > 0$ and $x_1 < \infty$ (from Step 4). Further, observe that x_1 is invariant to α. Because as $\alpha \to 0$, $x_3 \to \infty$, there exists $\overline{\alpha} \in (0, 1]$ such that if $\alpha < \overline{\alpha}$, $x_1 < x_3$, which (by Step 5) implies $\underline{x} < \overline{x}$. The condition $\alpha < \overline{\alpha}$ is not necessary for $\underline{x} < \overline{x}$. Examples with $\alpha = 1$ and $\underline{x} < \overline{x}$ appear in Figure 1.■

Proof of Proposition 1: First, we demonstrate the comparative statics for the number of firms N. Because we have normalized $\theta = 1$, we suppress the dependence of $\tilde{e}$, $\widehat{e}$ and f_2 on θ. By the implicit function theorem, $\tilde{e}(T)$ is decreasing in N. Let

$$\tilde{N} = \max_{N \in \{2,3,..\}} \left\{ N : \tilde{e}(\overline{T}) \geq 1 - \frac{1}{2d(\overline{T})} \right\}.$$

With some abuse of notation, let $(\widehat{e}(N), \widehat{T}(N))$ denote the unique symmetric equilibrium. If $N \leq \tilde{N}$, then $\widehat{T}$ is the unique solution to

$$\bar{\mathbf{e}}(T) - \tilde{e}(T) = 0.$$

Further,

$$\bar{\mathbf{e}}(T) - \tilde{e}(T) \geq 0 \text{ if and only if } T \in [0, \widehat{T}]. \tag{28}$$

For any $N_0 < N_1 \leq \tilde{N}$,

$$\begin{aligned} 0 &= \left[\bar{\mathbf{e}}(\widehat{T}(N_0)) - \tilde{e}(\widehat{T}(N_0))\right] |_{N=N_0} \\ &\leq \left[\bar{\mathbf{e}}(\widehat{T}(N_0)) - \tilde{e}(\widehat{T}(N_0))\right] |_{N=N_1}, \end{aligned}$$

where the inequality follows because $\tilde{e}(T)$ is decreasing in N. This implies that

$$\widehat{T}(N_0) \leq \widehat{T}(N_1) \tag{29}$$

(from (28)). Thus,

$$\widehat{e}(N_0) = \bar{\mathbf{e}}(\widehat{T}(N_0)) \geq \bar{\mathbf{e}}(\widehat{T}(N_1)) = \widehat{e}(N_1), \tag{30}$$

where the inequality follows from (29) and the fact that $\bar{\mathbf{e}}(\cdot)$ is decreasing. By similar argument, for any $\tilde{N} < N_2 < N_3$,

$$\widehat{T}(N_2) \geq \widehat{T}(N_3) \tag{31}$$

$$\widehat{e}(N_2) \geq \widehat{e}(N_3). \tag{32}$$

Further, for any $N_1 \leq \tilde{N} < N_2$,

$$\widehat{e}(N_1) \geq 1 - \frac{1}{2d(\overline{T})} \geq \widehat{e}(N_2). \tag{33}$$

Together (30), (32) and (33) imply that $\widehat{e}$ is decreasing in N. Together (29) and (31) imply that $\widehat{T}$ is increasing in N for $N \leq \overline{N}$ and decreasing in N for $N \geq \overline{N}$, where $\overline{N} = \arg\max_{N \in \{2,3,..\}}\{\widehat{T}\}$.

Second, we demonstrate the comparative statics for the quality level u. Note that $\underline{\mathbf{e}}(T)$ is strictly decreasing in u, $\bar{\mathbf{e}}(T)$ is increasing in u, and by the implicit function theorem, $\tilde{e}(T)$ is increasing in u. If $1 - 1/[2d(\overline{T})] > 0$, then let $\tilde{u}$ denote the unique value of u such that

$$\tilde{e}(\overline{T}) = 1 - \frac{1}{2d(\overline{T})},$$

and otherwise, let $\tilde{u} = 0$. With some abuse of notation, let $(\widehat{e}(u), \widehat{T}(u))$ denote the unique symmetric equilibrium. For any $\{u_a, u_b\} < \tilde{u}$, let $\tilde{T}(u_a, u_b)$ denote a solution to

$$\underline{\mathbf{e}}(T)|_{u=u_a} - \tilde{e}(T)|_{u=u_b} = 0. \tag{34}$$

Note that when $u_a = u_b = u$, there is only one solution to (34) and $\widehat{T}(u) = \tilde{T}(u, u)$. For any $u_0 < u_1 < \tilde{u}$, we will establish that

$$\widehat{T}(u_0) \leq \tilde{T}(u_0, u_1). \tag{35}$$

The proof is by contradiction. Suppose that $\widehat{T}(u_0) > \tilde{T}(u_0, u_1)$. Then

$$\begin{aligned} \underline{\mathbf{e}}(\tilde{T}(u_0, u_1))|_{u=u_0} &< \tilde{e}(\tilde{T}(u_0, u_1))|_{u=u_0} \\ &\leq \tilde{e}(\tilde{T}(u_0, u_1))|_{u=u_1}, \end{aligned} \tag{36}$$

where the first inequality holds because of the continuity of $\underline{\mathbf{e}}(\cdot)$ and $\tilde{e}(\cdot)$, $\underline{\mathbf{e}}(0) < \tilde{e}(0)$, and uniqueness of $(\widehat{e}, \widehat{T})$ imply $[\underline{\mathbf{e}}(T) - \tilde{e}(T)]|_{u=u_0} < 0$ for $T \in [0, \widehat{T})$; the second inequality holds because $\tilde{e}(T)$ is increasing in u. Because (36) contradicts the definition of $\tilde{T}(u_0, u_1)$, we have established (35). By similar argument,

$$\tilde{T}(u_0, u_1) \leq \widehat{T}(u_1). \tag{37}$$

We conclude that

$$\widehat{e}(u_0) = \underline{\mathbf{e}}(\widehat{T}(u_0))|_{u=u_o} \leq \underline{\mathbf{e}}(\tilde{T}(u_0, u_1))|_{u=u_o} = \tilde{e}(\tilde{T}(u_0, u_1))|_{u=u_1} \leq \tilde{e}(\widehat{T}(u_1))|_{u=u_1} = \widehat{e}(u_1), \tag{38}$$

where the first inequality follows from (35) and $\underline{\mathbf{e}}(\cdot)$ being increasing; the second inequality follows from (37) and $\tilde{e}(\cdot)$ being increasing. By similar argument, for any $\tilde{u} < u_2 < u_3$,

$$\widehat{e}(u_2) \leq \widehat{e}(u_3). \tag{39}$$

Because $\widehat{e}(u)$ is continuous in u, (38) and (39) imply that $\widehat{e}$ is increasing in u.■

Internet Appendix

Proof of Proposition 2: We adopt the abbreviated notation for success probability $s_n \equiv s(e_n, \Sigma_{j\in\mathcal{N}\setminus n} t_{jn})$ and note that

$$s_n \geq 1 - \overline{d} > 0 \text{ for } n \in \mathcal{N}. \tag{40}$$

Any Nash equilibrium must satisfy the following first order necessary conditions for the optimality of manufacturer n's compliance and testing strategy. For every $n \in \{1,..,N\}$ and $m \in \{1,..,N\}\setminus n$,

$$\frac{\partial \pi_n}{\partial e_n} = \overline{v}[u_n(1 - \Sigma_{m=n+1}^{N} s_m Q_m - Q_n) - \Sigma_{m=1}^{n-1} u_m s_m Q_m] d\left(\Sigma_{m\in\mathcal{N}\setminus n} t_{mn}\right) Q_n - c'(e_n)Q_n - F'(e_n) \leq 0 \tag{41}$$

$$\frac{\partial \pi_n}{\partial t_{nm}} = \overline{v}\min(u_n, u_m) d'(\Sigma_{j\in\mathcal{N}\setminus m} t_{jm})(1 - e_m) Q_m s_n Q_n - 1 \leq 0, \tag{42}$$

where (41) must hold with equality if $e_n > 0$ and (42) must hold with equality if $t_{nm} > 0$.

To establish (11), we can choose

$$u_L \leq \min_{l\in 1,..,N_L} \left[\frac{F'(0) + c'(0)Q_l}{\overline{v}(1 - \Sigma_{m=l+1}^{N}(1 - \overline{d})Q_m - Q_l)} \right]. \tag{43}$$

Then for $l \in \{1,..,N_L\}$, $u_l \leq u_L$, (40) and (41) imply that $e_l = 0$. Our assumptions that $F'(0) + c'(0) > 0$, $Q_n > 0$ and $\Sigma_{n=1}^{N} Q_n < 1$ guarantee that the right hand side of (43) is strictly positive.

Next, we will establish (13). Our assumption that $\lim_{e_n \uparrow \overline{e}} [c(e_n) + F(e_n)] = \infty$ for $\overline{e} \in (0,1)$ guarantees that

$$e_n < \overline{e} < 1. \tag{44}$$

With (40), (44) and our assumptions $u_n > 0$, $Q_n > 0$ and $\lim_{t\downarrow 0} d'(t) = \infty$, the first order condition on testing (42) implies that

$$\Sigma_{j\in\mathcal{N}\setminus m} t_{jm} > 0 \text{ for every } m \in \mathcal{N}$$

and

$$\max_{n\in\mathcal{N}\setminus m} \left[\overline{v}\min(u_n, u_m) d'(\Sigma_{j\in\mathcal{N}\setminus m} t_{jm})(1 - e_m) Q_m s_n Q_n\right] = 1 \text{ for every } m \in \mathcal{N}. \tag{45}$$

To use (45), the first order condition on testing (42) and concavity of the detection function $d(\cdot)$

to establish (13), we need to show that for any $l \in \{1,..,N_L\}$ and $h \in \{N_L+1,..,N\}$

$$\max_{n\in\mathcal{N}\setminus l}\left[\min(u_n,u_l)(1-e_l)Q_l s_n Q_n\right] < \max_{n\in\mathcal{N}\setminus h}\left[\min(u_n,u_h)(1-e_h)Q_h s_n Q_n\right]. \tag{46}$$

In words, the maximal manufacturer's incentive for testing manufacturer l is strictly lower than the maximal manufacturer's incentive for testing manufacturer h. Because $e_l = 0$, the left hand side of (46) satisfies

$$\max_{n\in\mathcal{N}\setminus l}\left[\min(u_n,u_l)(1-e_l)Q_l s_n Q_n\right] \leq u_l \max_{n\in\{1,..,N_L\}}[Q_n]\max_{n\in\mathcal{N}}[Q_n]. \tag{47}$$

We can choose

$$u_L < u_{N_L+1}(1-\overline{e})(1-\overline{d})\frac{\min_{n\in\{N_L+1,..,N\}}[Q_n]}{\max_{n\in\{1,..,N_L\}}[Q_n]}. \tag{48}$$

Our assumptions that $u_n > 0$, $Q_n > 0$, $\overline{d} < 1$ and $\overline{e} < 1$ make the right hand side of (48) strictly positive. Then $u_l \leq u_L$ implies

$$\arg\max_{n\in\mathcal{N}\setminus h}\left[\min(u_n,u_h)(1-e_h)Q_h s_n Q_n\right] \in \{N_L+1,..,N\}. \tag{49}$$

Using (40), (44) and (49), the right hand side of (46) satisfies

$$\max_{n\in\mathcal{N}\setminus h}\left[\min(u_n,u_h)(1-e_h)Q_h s_n Q_n\right] \geq u_{N_L+1}(1-\overline{e})(1-\overline{d})\left(\min_{n\in\{N_L+1,..,N\}}[Q_n]\right)^2.$$

Therefore (46) holds if

$$u_l \max_{n\in\{1,..,N_L\}}[Q_n]\max_{n\in\mathcal{N}}[Q_n] < u_{N_L+1}(1-\overline{e})(1-\overline{d})\left(\min_{n\in\{N_L+1,..,N\}}[Q_n]\right)^2.$$

We can choose

$$u_L < u_{N_L+1}(1-\overline{e})(1-\overline{d})\frac{\left(\min_{n\in\{N_L+1,..,N\}}[Q_n]\right)^2}{\max_{n\in\{1,..,N_L\}}[Q_n]\max_{n\in\mathcal{N}}[Q_n]}. \tag{50}$$

Then $u_l \leq u_L$ implies (46) and hence (13). Our assumptions that $u_n > 0$, $Q_n > 0$, $\overline{d} < 1$ and $\overline{e} < 1$ make the right hand side of (50) strictly positive.

Similarly, to use (45) and the first order condition on testing (42) to establish (12), we need to show that for every $l \in \{1,..,N_L\}$ and $h \in \{N_L+1,..,N\}$,

$$\min(u_l,u_h)s_l Q_l < \max_{n\in\mathcal{N}\setminus h}\left[\min(u_n,u_h)s_n Q_n\right]. \tag{51}$$

In words, some manufacturer with index in $\{N_L+1,..,N\}$ has strictly greater incentive to test manufacturer h than does manufacturer l. Inequality (51) will ensure that the inequality in (42) is strict for $(n,m) = (l,h)$. The left hand side of (51) satisfies

$$\min(u_l, u_h) s_l Q_l \le u_l \max_{n \in \{1,..,N_L\}} [Q_n].$$

Together (48) and $u_l \le u_L$ imply

$$\arg\max_{n \in \mathcal{N} \setminus h} [\min(u_n, u_h) s_n Q_n] \in \{N_L + 1, .., N\}, \tag{52}$$

so the right hand side of (51) satisfies

$$\max_{n \in \mathcal{N} \setminus h} [\min(u_n, u_h) s_n Q_n] \ge u_{N_L+1}(1 - \overline{d}) \max_{n \in \{N_L+1,..,N\}} [Q_n].$$

Therefore (51) holds if

$$u_l \max_{n \in \{1,..,N_L\}} [Q_n] < u_{N_L+1}(1 - \overline{d}) \max_{n \in \{N_L+1,..,N\}} [Q_n].$$

We can choose

$$u_L < u_{N_L+1}(1 - \overline{d}) \frac{\max_{n \in \{N_L+1,..,N\}} [Q_n]}{\max_{n \in \{1,..,N_L\}} [Q_n]}. \tag{53}$$

Then $u_l \le u_L$ implies (51) and hence (12). Our assumptions that $u_n > 0$, $Q_n > 0$, and $\overline{d} < 1$ make the right hand side of (53) strictly positive.

We will conclude the proof by showing that manufacturer l has strictly greater expected profit due to regulation. Observe for each firm $h \in \{N_L + 1, .., N\}$,

$$\max_{n \in \mathcal{N} \setminus h} [\overline{v} \min(u_n, u_h)(1 - e_h) Q_h s_n Q_n] \ge \overline{v} u_{N_L+1}(1 - \overline{e})(1 - \overline{d}) \left(\max_{n \in \{N_L+1,..,N\}} [Q_n] \right)^2,$$

and let $\underline{t}$ denote the unique solution to

$$d'(\underline{t}) = \left[\overline{v} u_{N_L+1}(1 - \overline{e})(1 - \overline{d}) \left(\max_{n \in \{N_L+1,..,N\}} [Q_n] \right)^2 \right]^{-1}. \tag{54}$$

Then (45), the first order condition on testing (42) and strict concavity of the detection function $d(\cdot)$ guarantee that testing of manufacturer h satisfies

$$\Sigma_{j \in \mathcal{N} \setminus h} \, t_{jh} \ge \underline{t} > 0$$

and with (44) that

$$s_h \le 1 - d(\underline{t})(1 - \overline{e}) \equiv \overline{s} < 1. \tag{55}$$

Recall (47) and let $\bar{t}$ denote the unique solution to

$$d'(\bar{t}) = \left[u_L \max_{n\in\{1,..,N_L\}} [Q_n] \max_{n\in\mathcal{N}} [Q_n] \right]^{-1}.$$

Then (45), the first order condition on testing (42), and strict concavity of the detection function $d(\cdot)$ guarantee that for $l \in \{1,..,N_L\}$ with $u_l \leq u_L$, testing of manufacturer l satisfies

$$\Sigma_{j\in\mathcal{N}\setminus l}\, t_{jl} \leq \bar{t}.$$

Because $d(0) = 0$, we can choose u_L strictly positive but sufficiently small that

$$d\left(\Sigma_{j\in\mathcal{N}\setminus l}\, t_{jl}\right) \leq d(\bar{t}) < \Sigma_{m=N_L+1}^{N}(1-\bar{s})Q_m. \tag{56}$$

With no regulation, manufacturer $l \in \{1,..,N_L\}$ would have profit

$$\pi_l^{NR} = \bar{v}\left[u_l\left(1-\Sigma_{m=l}^{N}Q_m\right) - \Sigma_{m=1}^{l-1}u_mQ_m\right]Q_l - c(0)Q_l.$$

With regulation and $u_l \leq u_L$, manufacturer l sets $e_l = 0$ and $t_{lh} = 0$ for all $h \in \{N_L+1,..,N\}$. Manufacturer l may also choose not to test other firms with low quality, i.e., to set $t_{lm} = 0$ for all $m \in \{1,..,N_L\}\setminus l$. (In constructing a lower bound on manufacturer l's profit under regulation, we will assume $s_m = 1$ for $m \in \{1,..,N_L\}\setminus l$ so the decision to set $t_{lm} = 0$ maximizes that lower bound.) Therefore, regulation increases manufacturer l's expected profit by

$$\begin{aligned}
\pi_l - \pi_l^{NR} \geq\ & \bar{v}\left[u_l\left(1-\Sigma_{m=N_L+1}^{N}s_mQ_m - \Sigma_{m=l}^{N_L}Q_m\right) - \Sigma_{m=1}^{l-1}u_mQ_m\right]s_lQ_l \\
& - \bar{v}\left[u_l\left(1-\Sigma_{m=l}^{N}Q_m\right) - \Sigma_{m=1}^{l-1}u_mQ_m\right]Q_l \\
\geq\ & \bar{v}u_lQ_l[(s_l-1) + \Sigma_{m=N_L+1}^{N}Q_m(1-s_ms_l))] \\
\geq\ & \bar{v}u_lQ_l[\Sigma_{m=N_L+1}^{N}Q_m(1-\bar{s}) - d(\Sigma_{j\in\mathcal{N}\setminus l}\, t_{jl})] \\
>\ & 0,
\end{aligned}$$

where the third inequality follows from $s_l = 1 - d(\Sigma_{j\in\mathcal{N}\setminus l}\, t_{jl}) < 1$ and (55) and the final strict inequality follows from (56).■

Disclosure As A Regulatory Instrument For The Environment: A Study of The Toxic Release Inventory In the Printed Circuit Board Industry

Linda T.M. Bui*
Jennifer F. Helgeson**

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*Associate Professor, Department of Economics, Brandeis University. E-mail: ltbui@brandeis.edu.
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Disclosure As a Regulatory Instrument for the Environment: A Study of the Toxic Release Inventory In the Printed Circuit Board Industry

I. Introduction:

In this paper we study the effect of the "Toxic Release Inventory" ("TRI") on toxic emissions by the printed circuit board industry between 1988-2003. The creation of the TRI in the 1986 U.S. Federal Emergency Planning, Community Right-to-Know Act (EPCRA) was a direct response to the tragedy in Bhopal, India in 1984, when the accidental release of methyl isocyanate at a Union Carbide plant left tens of thousands dead. It was adopted to enhance the ability of communities, health care workers, and emergency personnel to prepare to deal with a chemical accident of that nature. It requires all manufacturing plants with 10 or more full time employees that use or manufacture more than a threshold level of any listed toxic substance to report their toxic releases for inclusion in a publicly maintained database.

Since the onset of TRI reporting in 1987, toxic releases nationwide have fallen by more than 40%,[1] and in some industries by more than 90%. As a result, the TRI is no longer regarded as just a mechanism by which to disseminate information; it is now viewed as one of the most successful regulatory mechanisms for controlling pollution. The apparent success of the TRI has led 34 states (as of 2003) to adopt expanded community right-to-know laws aimed specifically at toxic emissions. So it is important to understand whether mandatory disclosure of private polluting behavior truly is as effective a regulatory mechanism as a casual glance at the trend in reported emissions suggests.

The objective of this paper, then, is to develop evidence of the impact on toxic releases of public disclosure of polluting behavior through the TRI. But there are several obstacles to any such effort. One fundamental problem is that before its adoption there was no tracking of toxic releases. Consequently, it is not obvious whether the well-documented decline in reported releases since the advent of the TRI is attributable to the disclosure required by the TRI; or whether other factors,

[1] This is an underestimate of the actual reduction (nationwide) in releases as both industries and chemicals have been added since the start of reporting in 1987.

independent of disclosure, contributed to that decline. In fact, while widely believed to be the case, there is no direct evidence that the reductions in TRI-listed releases were actually induced by the TRI. At best, what one can hope for is indirect evidence as to how TRI releases may have been affected by disclosure rules. But even that is important, as many states rely solely on disclosure to control toxic releases.

We study the printed circuit board (PCB) industry (SIC 3672, NAICS 334412). PCB production is among the largest contributors to pollution in the microelectronics industry, an industry that is changing rapidly in both market structure and technology. One interesting aspect of the industry is that the changes in market structure that have occurred – decreasing concentration and an increasing number of foreign producers competing on cost – would make it *less* likely for the regulatory approach of the TRI to be successful, yet reported toxic releases by PCB manufacturers fell by more than 96% between 1988-2003, a decline that is not attributable solely to foreign competition. We find that the PCB industry became significantly cleaner in terms of the production of pollution per unit of output – going from 0.03 lbs/board in 1988 to 0.004 lbs/board in 2003.

Why? Our work suggests that a number of factors contributed to both the levels and changes in TRI releases in the PCB industry. Reductions can be explained, at least in part, by attrition of the dirtiest plants; it is unclear, however, whether plant exit was the result of TRI reporting requirements, or resulted from changes in market conditions.

Formal command and control regulations for air and water pollutants covered under the Clean Air Act (CAA) and Clean Water Act (CWA) also affected TRI levels. Levels of TRI releases are significantly lower in counties deemed to be in "non-attainment status" for the criteria air pollutants – areas where national ambient air quality standards are not met for those pollutants – and, in the absence of that classification, we estimate that TRI releases would have been on the order of 125% - 245% higher than current levels. We also find evidence that *reductions* in TRI releases are larger in counties that have recently gone from attainment to non-attainment status, although we cannot estimate these reductions with great accuracy due to small numbers of observations. TRI air reductions, however, also are greater in attainment counties than non-attainment counties. On the whole, although facilities located in attainment counties were, on average, much dirtier in 1988 than their counterparts located in non-attainment counties, by 2003, facilities in attainment counties had “caught up” with non-attainment facilities in terms of TRI levels.

The PCB industry is water-pollution intensive and many of its emissions are regulated under the CWA. Hence it has been characterized by high water pollution abatement expenditures. This explains why TRI water releases, as initially reported in 1988, were quite small – making up only 6% of its over-all toxic releases (by weight). Between 1988-2003, TRI water pollutants fell by essentially 100% for pollutants that were simultaneously regulated under the CWA, and 97% for all other TRI water releases. We also find that facilities with higher proportions of CWA-regulated pollutants (relative to over-all TRI water releases) have lower levels of TRI releases. We take this as strong evidence that CWA regulations had an important and beneficial effect on TRI water releases. Similar results are found for hazardous air pollutants.

Equally important are state level TRI policies. We find that reductions in TRI releases are significantly larger in states that have adopted environmental policies that have state-wide reduction goals for TRI releases, even though the adopting states generally do not have penalties for non-compliance. TRI air reductions are also larger in states that have out-reach programs to educate polluters about pollution prevention methods. This latter result is of particular interest, as it suggests one avenue by which regulators may enhance the effectiveness of a regulatory disclosure program for pollution. It is important to note that in neither case are the state-level programs “formal” in nature: they do not prescribe mandatory abatement levels, nor do they prescribe the adoption of specific abatement technologies. The mere “suggestion” seems to be enough to induce measurable firm response. One could infer from this that firms may believe that if they do not respond to a more informal regulatory approach that more standard responses, in the form of command and control strategies, may be adopted in the future.

As a whole, our findings show that although some of the reduction in TRI releases in the PCB industry are the result of several different formal regulatory policies, a significant fraction of those reductions appear to be due, either directly or indirectly, to the use of TRI mandatory disclosure rules. Although it is not clear exactly through what mechanism mandatory disclosure may have induced changes in firm behavior, we find that the effectiveness of disclosure is enhanced by the threat of future formal regulation and causes firms to look more similar to one another (with respect to pollution releases) and, to a lesser extent, that information provision may also improve the effectiveness of the TRI.

The balance of the paper is organized as follows. Section II briefly summarizes the background and literature, and section III describes the data. Section IV and V describe estimation methods and results bearing on two questions: (I) did PCB facilities get cleaner, and (ii) why? Section VI concludes.

II. BACKGROUND

A. The Printed Circuit Board Industry

"Printed circuit" or "wire" boards (PCBs) are the boards on which electronic chips and other electronic components are interconnected. PCBs function as the backbone of consumer and industrial electronics, and are found in virtually all electronic devices: they are the building blocks for products as diverse as computers, clocks, toasters, cellphones, airplanes, and cars. Although developments in such semi-conductor components as memory chips and microprocessors garner the public attention, PCBs have quietly evolved to meet the needs of those components, including changes in their size, density, weight, strength, and power requirements.

The demand for PCBs is driven largely by the demand for computers, communications, and consumer electronics. Prismark Associates estimated that in 2003, over 70% of PCB demand was attributable to these three sectors: 35.4% from computers (e.g. motherboards, video cards), 22.2% from communications equipment (e.g. cell phones, switches, routers), and 15% from consumer electronics (e.g. play stations, mp3 players, ipods) (pg. 202, 2005 report). Because of the close relationship between PCBs and end-use electronics, the PCB industry is affected by the business cycles governing those markets. That was clearly illustrated by the PCB market post 2000, when the industry suffered one of its largest declines, due primarily to the dramatic slowdown in the growth of telecommunications and an inventory glut in the microelectronics industry.

The structure of the PCB industry has changed dramatically over the past 50 years. PCBs initially were produced in "captive" facilities, owned by large, original equipment manufacturers (OEMs), principle among domestic producers being Western Electric (AT&T), RCA, Digital Equipment, IBM, and Hewlett Packard. As the industry became more cost competitive, however, independent producers of PCBs started to emerge as important players. By the mid to late 1980's, over 95% of domestic PCB producers were independent. In 1994, only 14 companies had annual sales of over $50M, while over 500 had annual sales of under $5M. PCB production today continues to be dominated by small and medium sized independent firms (sales of under $10M). One potential consequence of this change in market structure is its impact on the industry's ability to conduct research and development into cleaner technologies and processes both to reduce pollution emissions and limit waste production.

In 2002, there were approximately 936 producers of PCBs in the United States, of which 415 had fewer than 10 full time employees, and only 41 had over 250 full time employees. The total value of 2002 shipments was approximately $6.1B. (U.S. COM, Industry series, 2002.) Production can be found in 22 states, but is heavily concentrated in just six: California, Minnesota, Texas, Illinois, Massachusetts, and Arizona. Since the 1990's, moreover, the production of PCBs has steadily moved out of the U.S. (as well as Europe and to some extent Japan) to the economically developing regions of Asia, primarily Taiwan, South Korea, and China. That has been precipitated by the increasing cost competitiveness of the industry. In 2000, four of the top ten PCB manufacturers worldwide were U.S. companies (Sanmina, Viasystems, Multek, and Tyco PCB). By 2003, however, there were no U.S. firms in the top 10: all were from Japan, Taiwan, and South Korea, with the highest ranked U.S. company (Viasystems Group, ranked 11th) generating sales of just over 1/3 of the top ranked company (Nippon Mektron). Although competition has led to significantly lower costs for consumer electronics, environmental consequences are of concern. Of particular concern is that, in the absence of formal regulation of toxic releases, domestic facilities that must compete internationally will be less inclined to adopt costly pollution abatement strategies, at least voluntarily.

B. Production

The production of a printed circuit board basically consists of a transferring a circuit design to a blank board, consisting of a non-conductive "substrate" to which has been added a covering of copper. The unwanted copper is then removed from the board either by etching it in acid or machine milling. Once this process is completed, only the desired conductive "traces" or "tracks" – the circuitry – are left on the board. The majority of PCBs have "through-hole" construction: holes are drilled through the board and used to attach components using solder. Since the late 1980s, surface-mount technology has started to grow in popularity as a method for mounting components. Surface-mounted devices are physically much smaller and lighter, and are said to be more amenable to an automated assembly line production than their through-hole counterparts.

PCBs can be single-, double-, or multi-layered, depending upon their complexity. The mechanical-chemical process used to produce PCBs has remained fairly stable over the past several decades, and is well understood. (An individual with a laser printer, household iron, electric drill, copper plated board, and a few chemicals easily obtained from a local hardware store can make a properly functioning printed circuit board at home.) What has changed dramatically, however, is the process equipment used to achieve the end results.

Toxic wastes are generated both in the production and disposal of PCBs. Both waste streams are considered to be of importance and have influenced the way in which PCBs are manufactured. In production, toxic releases principally are generated during the multiple cleaning processes. In the disposal of PCBs, a major concern is the leaching of lead from solder on used boards into landfills. The European Union and Japan recently have adopted regulations that prohibit the local sale of PCBs that use lead solder. Because this is an international industry, U.S. manufacturers have had to alter their production process to produce lead-free boards.

III. THE DATA

A. Data sources:

The principal data for this project is derived from the Toxic Release Inventory. The data set that we use consists of all plants reporting to the TRI with an SIC code of 3672 between the years 1988-2003. This yields an unbalanced panel of 3604 plant-year observations. The TRI provides basic information on each plant, including name and location. Toxic releases are given in total pounds, broken down by chemical name and media (e.g., as air releases, water releases, or as solid waste deposited either to a landfill or injected into an underground well). Releases are also categorized by whether they are released or treated "on-site" or "off-site."

Given both the addition and de-listing of TRI substances during the study period, we restrict our analysis to the stable set of chemicals that were included for all reporting years 1988-2003. This leads to the exclusion of 12 chemicals that were reported in our sample (8 of which were added in 1994 or 1995, and 4 of which were de-listed). As a result, we only include 58 of the 70 different chemicals that were reported as released by the PCB industry during the period under study.

Company Characteristics. An important add-on program that affected facility-level TRI releases was the so-called "TRI 33/50" program (See Arora and Cason [1996], Khanna and Damon [1999]), under which companies voluntarily agreed to reduce toxic releases for 17 specified TRI substances (from their 1988 baselines) by 33% by 1992, and 50% by 1995. Economy-wide participation in this program was at the invitation of the EPA. The EPA sent invitations to participate to over 7,500 companies – 5,000 in 1991, and an additional 2,500 over the ensuing three years. The target companies included those on the "top 600" polluters list. We control for parent company participation in the TRI 33/50 with the variable PC3350, constructed using EPA data for SIC 36 to take on the value of 1 if a facility's parent company was listed as a participant. Although participation occurred at the facility level (as opposed to the parent company level), our maintained assumption is that all facility level releases would be affected if their parent company was a participant. In total, 20 parent companies in our sample (an average of 7% of facilities in the sample per year) participated in the 33/50 program. Because of the possible endogeneity between company participation and TRI level, we instrument for 33/50 participation with the percentage of 33/50 chemical releases to total TRI releases in 1987 by company.

Whether a company is publicly held could also, in principle, affect facility level releases, and so we include that information in our data set. In particular, publicly held companies may face more pressure from investors to clean up than do privately held companies. Previous studies suggest that for publicly held companies, TRI announcements have had significant negative effects on company valuation when the news is considered "bad." (See Hamilton [1995], Khanna et al. [1998].) To allow for that possibility, we use the parent company information provided by the TRI, correcting the data and supplementing it where necessary, to determine the facility's "ultimate" parent. We then determined whether the facility belonged to a publicly held company traded on a U.S. stock exchange. The latter primarily were derived from searches for parent company names for SIC 36 contained on the Securities and Exchange Commission's website (www.sec.gov).

B. *Other Federal Regulations*:

Several TRI substances are also regulated under other environmental statutes and programs, some involving more formal, command and control type regulation. It is therefore important to consider the possible impact of these regulations on TRI releases. The principal other such programs are described briefly below.

Clean Air Act – Non-Attainment Status: The 1970 Clean Air Act Amendments designated as in "non-attainment" status counties that did not meet the national ambient air quality standards set out in the CAA. Improvements in air quality in non-attainment counties was very slow through the 1970s. As a result, the 1977 Clean Air Act Amendments explicitly provided relief under which non-attainment regions were given until 1987 to meet the national standards. However, as many areas did not achieve that goal even by 1987, specific remedies were adopted, geared to the differing "severity of non-compliance" in the 1990 Clean Air Act Amendments. The remedies prescribed for polluters in non-attainment regions may broadly be described as required adoption of strict technology-based emissions standards for existing stationary sources, as well as lowest-available emissions control equipment for all new sources of pollution. For our purposes, we categorize a county as being in "non-attainment" if it is out of attainment for *any* criterion air pollutant. Data are taken from the EPA website and matched by county to TRI data. Approximately 75% of plant-year observations in the data set are located in non-attainment regions, suggesting that PCB facilities are generally found in air pollution intensive areas of the country.

Clean Air Act: Hazardous Air Pollutants: An additional consideration that may be important for analyzing TRI releases is the regulation pertaining of "hazardous" emissions. A number of TRI substances are also regulated by the Clean Air Act as hazardous air pollutants (HAPs). The 1990 Clean Air Act amendments lists 189 substances that are regulated with specific technology standards if a facility exceeds more than 10 tons/year of a single listed hazardous substance or 25 tons/year of any combination of listed substances. The technology standard is based upon the "maximum achievable control technology" (MACT) that is currently available. Only specifically enumerated industries and processes actually are required to comply with the national emissions standards for hazardous air pollutants (NESHAPs).

On July 16, 1992, the initial list of industries that would be regulated for HAPs was published in the Federal Register. Included in that list was the semi-conductor industry (SIC 3674, NAICS 334413). Because several PCB facilities report both 3672 and 3674 as relevant SIC codes, HAP regulations may affect their TRI releases. Proposed rules for SIC 3674 were promulgated on May 8, 2002, and final rules were published on May 22, 2003. The compliance date for those technology based standards was fixed as May 22, 2006.

Of the 58 TRI listed substances we study, 20 must also comply with NESHAP requirements. Regulatory data for hazardous air pollutants are taken from the federal statutes pertaining to the specific pollutants/media.

Clean Water Act: As summarized in the EPA Sector Notebook Project for the Electronics and Computer Industry, under the CWA the PCB industry must provide "quantifiable" data only for discharges of "priority" pollutants (those listed in Appendix D of 40 CFR 122) which the applicant knows or has reason to believe will be discharged in greater than trace amounts; and "quantitative" testing for "non-conventional" or "hazardous pollutants" (e.g. butyl acetate, xylene, formaldehyde, tin-total, nitrate/nitrates, titanium-total, and chlorine-total residue). Technology-based effluent standards also exist for certain discharges associated with specific processes in the electronics and semi-conductor industries. (Sector Notebook 101.)

In all, 21 chemicals released as water emissions by the PCB industry are on the CWA priority list; an additional 3 fall into the category of "non-conventional or hazardous" water pollutants. Over the sample period, by weight, the CWA regulated substances were on average 73% of total TRI water releases.

C. State-Level Regulations and Programs:

To investigate how differences in state-level regulation of toxic pollution might affect TRI releases, we construct a data set on state level regulatory activity pertaining to pollution prevention programs (PPP), expanded Community Right-to-Know legislation, and toxic use reduction acts (TURA) that directly address toxic releases. That data set compiles information from the Right-to-Know Planning Guide (1997, the Bureau of National Affairs, 0-871-931-1/97), the 1999 State TRI Program Assessment, and several state environmental websites. A state regulatory variable, *REG1*, consists of all states that had adopted (as of 2003) any type of regulation affecting toxic releases with a specified state-wide reduction goal. These goals ranged from target reductions of 10% to 70% to be met over varying lengths of time. (Enforcement mechanisms to penalize non-compliance often do not exist in these states.) We also construct a state regulatory variable, *REG2*, which consists of states that have TRI-specific programs that provide community and industry "outreach" programs that are intended to enhance community understanding of toxic pollutants in their neighborhood and/or to assist industry in providing pollution prevention information, but have no specified TRI target reduction goals.

For both *REG1* and *REG2*, we use of several instruments and explicitly test for possible endogeneity. The instruments include 1988 state-level expenditures on natural resources and education, 1988 state-level TRI releases net of PCB releases, as well as the 1988 voting record of state-level legislators on environmental issues as compiled by scorecard.com. In both cases, exogeneity of the variables could not be rejected at any reasonable level of significance.

D. Sample characteristics:

Summary statistics for the unbalanced panel are provided in Table 1. The sample consists of 3604 plant-year observations between 1988-2003. We omit 1987 TRI data in light of questions about the quality of the TRI information collected that year. In the sample, the initially reported average level of all toxic releases was just under 45,000 lbs per plant year, of which 58% were in the form of air releases. TRI (annual) per plant water releases, measured at their initial level and averaged over the entire sample, are extremely low – 813 lbs and 194.3 lbs per plant-year, respectively. Initial and average reported air releases were 25,954 lbs and 9,009 lbs per plant-year, respectively. (The balance consisted of solid wastes either land filled or injected into an underground well.) It is somewhat surprising to find air to be the dominant source of TRI pollution in an industry generally regarded as water-pollution intensive, although this might reflect that the industry had already undertaken serious water pollution control prior to the start of TRI reporting. That is consistent with the fact that pollution abatement expenditures (as measured by the Pollution Abatement Control Expenditure (PACE) Survey) in the PCB industry are significantly higher for water pollution than air. In 1999, capital expenditures for water pollution control made up 45% of all pollution capital expenditures by SIC 3672, whereas for air it was 3%. Operating and maintenance costs for water pollution control in 1999 were 78.5% of total pollution operating and maintenance costs compared to 4.5% for air. (These proportions are stable throughout the 1990s.) The residuals in both cases were expenditures for solid waste and mixed media.

IV. DID THE PCB INDUSTRY GET CLEANER?

The first step in our analysis is to determine whether or not facilities in the PCB industry actually got cleaner. To do so, we first look at the reported aggregate emissions (for the stable set of TRI pollutants) for the entire industry between 1988-2003 (Figure 1). Although over-all the industry showed a decline in TRI releases of more than 96% from 1988 levels, the decline was not monotonic. Both 1998 and 2000 showed spikes in emissions. The cause of these spikes can be found in Figure 2, which shows the aggregate production of PCBs in the U.S. for rigid and flexible boards. Domestic production of PCBs grew steadily in the 1990s, reaching a peak in 2000, with jumps in 1998 and 2000. Post 2000 shows a dramatic slowdown in the industry, one that reflects the overall slowdown in the electronics sector. Combining these figures leads to a more informative view of toxic releases for the PCB industry. Figure 3 depicts TRI releases normalized by output: national aggregate toxic pollution intensity measured by pounds of toxic releases per PCB board produced declined significantly during this period. Identical results are found when TRI releases are normalized by total value of shipments rather than the number of boards produced (see Figure 4). Thus we conclude that the decline in TRI releases were not due to changes in output alone.

One possible complication to the interpretation proposed above involves exit. Plant closures, particularly during the latter part of our sample period, may at least in part be attributed to an over-all trend of PCB production moving to the developing parts of Asia as the result of intense cost competition in PCB production. If the (presumably less-efficient) exiting plants are also the dirtier plants in the sample, to the extent that their attrition is unrelated to TRI reporting, it might complicate the interpretation of the industry-level data.[2] To investigate this further, we look at the unbalanced panels of TRI reporters that remain in the sample through 2003 (irrespective of when they entered the

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[2] Note that exit from the sample may occur because (1) the plant falls below the reporting threshold; (2) the plant no longer has more than 10 full time employees, or (3) the plant shuts down. The TRI does not provide information on the causation of the plant's exit. In general, we are not concerned about the interpretation of our results if a plant exits as a result of TRI regulation although the efficiency and welfare implications may depend upon where exiting firms end up. However, if a plant exits the sample for some other reason, we must consider what types of plants are exiting and how that might affect the interpretation of the effectiveness of the TRI.

sample) and compare them with those that exited the sample. (See Table 2.) What we observe is that facilities that remained in the panel were much cleaner on all accounts – statistically significantly cleaner at the 5% significance level. Initial levels of total releases were approximately 1/3rd the size for remaining plants than exiting plants, although the distribution of facility-years is approximately the same across both groups with respect to being publicly owned, 33/50 participants, and location.

Figure 5 displays the patterns of change in aggregate TRI releases for the unbalanced panel. (Unfortunately, firm-level output or TVS is not available so we cannot observe TRI releases normalized by either measure to obtain a more informative picture of toxic pollution intensity.) What we do see, however, is that over-all releases by firms in the panel *increased* between 1988-1990, jumping significantly in 1990, a year in which PCB production was falling. After 1990, releases fell significantly, and the pattern of reductions looks more like that of the aggregate picture in Figure 1. (The spikes in un-normalized releases in 1998 and 2000 probably reflect the increases in output during those years.) If we further confine ourselves to just those facilities that remain in the sample for the entire period (only 24 of 597 facilities), we find that between 1988 and 2003, these facilities exhibited an 82.7% reduction in releases.

Taken together, there is strong evidence that the PCB industry has become cleaner over time with respect to toxic releases. The industry released less per unit of output and per dollar of shipment, clear indicators that industry-wide toxic pollution intensity has fallen. These reductions cannot be fully attributed to the exit of dirty facilities. Although we find that exiting facilities are significantly dirtier than remaining facilities, so that exit *did* contribute to the aggregate decline in releases, the remaining facilities also showed significant declines of the same general magnitude.

V. UNDERSTANDING THE REDUCTION IN TOXIC RELEASES.

A. Basic Framework:

We turn next to the question of how much of these reductions can be explained by environmental regulations and programs. To better understand the role that company characteristics, and state and federal environmental programs have on TRI releases, we estimated both a reduced-form and a "first-difference" model:

(1)
$$TRI_{it} = \beta_0 + \beta_1 public_{i,t} + \beta_2 pc3350_{i,t} + \beta_3 post3350_{i,t} + \beta_4 NON_{i,t} + \beta_5 SRANK_{i,t-2} + \beta_6 SREG1_{i,t} + \beta_7 SREG2_{i,t} + \delta_t + \epsilon_{it}$$

(2)
$$\Delta TRI_{it} = \alpha_0 + \alpha_1 public_{it} + \alpha_2 pc3350_{i,t} + \alpha_3 post3350_{it} + \alpha_4 NON_{i,t} + \sum_{j=0}^{2} \Gamma NONCH_{i,t-j} + \alpha_5 SRANK_{i,t-2} + \alpha_6 SREG1_{i,t} + \alpha_7 SREG2_{i,t} + \delta_t + \psi_{it}$$

where:

public = 1 if the parent company is publicly traded at time t;

pc3350 = 1 if the parent company is a TRI 33/50 participant at time t;

post3350 = 1 if the parent company is a TRI 33/50 participant and the year > 1995 (the target year for the 50% reduction to be met);

NON = 1 if the facility is located in a non-attainment county at time t;

NONCH = 1 if the facility is located in a county that has changed from attainment to non-attainment status at time t-j (in the current year, 1 year ago, or 2 years ago);

SRANK2 = the facility's state ranking within the PCB industry as determined by TRI data in year t-2;

SREG1 = SRANK2 X REG1, where REG1 =1 if the facility is located in a state with the most stringent TRI regulations, including numeric reduction goals;

SREG2 = SRANK2 X REG2, where REG2 =1 if the facility is located in a state with additional TRI regulations, but no numeric reduction goals.

The data used in the estimation of (1) and (2) consist of facility level observations for which we have at least 3 years' worth of data for consecutive years (to allow for the lag structure), reducing the over-all number of observations used in the estimation to 1939. All specifications include a full set of year indicators (δ) to allow for aggregate time effects. Robust errors that allow for cluster effects at the facility level are reported for all regressions. Summary statistics for the reduced set of observations are given in Table 3; our regression results, summarized in Table 4, are discussed below.

B. Aggregate TRI Results:

33/50 Participation: Not surprisingly, we find that aggregate facility-level TRI releases are larger for facilities whose parent company participate in the 33/50 program. This simply reflects the fact that it was the dirtiest TRI polluters who were invited to participate in the program (see column 1, Table 4). However, we do not find any statistically significant effect of participation after 1995 – the year by which participants were supposed to have achieved their 50% reductions. This is what one would have expected a priori: everything else being equal, if the program had an effect on PCB facilities the difference in releases between participants and non-participants should be smaller. Similar results are found for the two different first-difference models estimated (columns 2-4, Table 4). Although reductions are larger for 33/50 participants – which is what one would expect if the marginal cost of abatement is rising – reductions are not significantly different post 1995.

Public Ownership: Interestingly, we find that facilities that have publicly held (US) parent companies also tend to be dirtier and do not reduce aggregate TRI releases any faster than privately held facilities. Public accountability does not appear to have any statistically significant effect on TRI releases, which seems counter to the underlying assumptions of the event-study analyses done of stock market returns and TRI behavior.

CAA Non-Attainment Status: One important determinant of aggregate TRI levels is whether a facility is located in a non-attainment county. We find that facilities located in those regions have average annual releases (over the sample) that are more than 10,600 lbs smaller than those located in attainment regions. This, alone, suggests that in the *absence* of those regulations, TRI releases would be between 125%-245% higher than their current levels.

Looking at the estimates from the first-difference models (Table 4, columns 2 and 3), we find that reductions in releases are much smaller in non-attainment regions than in attainment regions. This is not so surprising if the marginal cost of abatement is rising, and because of prior abatement efforts, facilities in non-attainment regions are cleaner than attainment facilities. However, we find that changes in attainment status – in particular, moving from attainment to non-attainment – may also matter. Although we cannot estimate the effect with precision, we do find that the coefficient estimate on changes in attainment status in the first-difference model are consistently negative. This may be due to the small number of counties (affecting fewer than 19 facilities) that change attainment status in our data. But, these results are suggestive that reductions in releases may be larger for facilities located in counties that have gone from attainment to non-attainment status in the preceding 2 years.

What these results imply from a policy perspective is that the formal regulations that exist in non-attainment counties have provided non-trivial, positive environmental externalities in the form of reductions in toxic releases. Those externalities are important determinants for the over-all level of TRI releases, and may be important for future reductions in releases as well.

The regression results, alone, however, do not tell the entire story of the relationship between releases and non-attainment status. Looking at the simple descriptive statistics of TRI releases over time in attainment and non-attainment counties, we observe that mean facility releases are more than six times as high in 1990 in attainment counties than non-attainment counties (Table 5). In fact, between 1990 and 2003, the mean level of releases fell by 67% in non-attainment counties and by 97% in attainment counties. And by 2002, the mean level of TRI releases in attainment counties is marginally *lower* than the mean level of releases in non-attainment counties. So, not only are the reductions in releases much faster in attainment than non-attainment regions, over time, those facilities "catch up" with their non-attainment counterparts. Although it is not clear via what mechanism TRI may have induced this clean up, what seems evident is that clean-up did occur at the dirtier plants – at least up to the point at which plants in attainment and non-attainment regions were no longer distinguishable from one another.

State Level Regulation: We also find that state level TRI regulations play an important role in determining facility level TRI releases. Because we cannot distinguish between differences in state regulatory policy and their differential use of federal TRI information, we make use of a state "rank" variable, which consists of a facility's ranking within the PCB industry for a given state based on TRI releases from the previous 24 months. This variable allows us to look at the relative level of releases between PCB facilities within a state, taking into account that regulators only have this information at a 2 year lag (as do facilities, themselves). We assume for regulatory purposes that state regulators are more focused on polluters that are outliers – in particular, those that are very large. A facility ranked "1" is the dirtiest PCB facility in a given state. We also construct variables that interact the state ranking variable with indicator variables used to capture a state's TRI regulatory "stringency." Two indicators are used: REG1 states are those with both numeric targets for TRI reductions and "compliance" dates; REG2 states are those with additional TRI regulations but do not have specified reduction goals.

In states with no additional state TRI regulations, on average, the expected difference in TRI releases between PCB facilities differing by a rank-order of 1 is approximately 2000 lbs. All other things being equal, this difference falls to only 325 lbs in states with the most stringent state-level TRI regulations (REG1). The difference in releases for states with some additional TRI regulations (REG2) but no reduction goals is not statistically significant. There is a greater compression in the distribution of the magnitude of TRI releases in the more stringently regulated states, suggesting that reductions are more responsive in these states. This is consistent with the findings for the first-differenced models, as well. The positive (and significant) coefficient on the state ranking variable simply reflects that reductions are smaller for cleaner facilities (those with a nominally higher rank-order) – exactly what one would expect. The negative (and significant) coefficient on the interaction term between state ranking and REG1 indicates that the reduction in releases in these states are also more compressed: the second dirtiest plant's reductions in releases are 125 lbs smaller than the dirtiest plant's reductions; whereas in states with no additional regulations, the difference in reductions is almost 545 lbs.

The fact that PCB facilities within states with the most stringent TRI regulations are cleaner and tend to look more similar to one another is telling. Not only does it provide evidence that the additional state-level regulations affected plant-level response, it also suggests that facilities did not want to "stand out" as being much dirtier compared to others. That is true even though we use a very weak measure of state ranking (based on ranking within an industry and not across all facilities, regardless of industry, within the state). The state rank variable, in effect, captures one way in which states make use of TRI information: to learn who is polluting, and how much they are polluting.

Because there is no reason to believe, a priori that different pollution media should respond in the same way to TRI reporting, we next take a closer look at TRI air and water releases separately.

C. Air Releases:

Air releases make up the largest component of toxic releases from PCB facilities. However, not all facilities reported air releases in our sample (429 left-censored observations, 1510 uncensored observations). To account for this, we estimate a Tobit model for air releases in addition to the models of equations (1) and (2). Regression results are presented in Table 6, with marginal effects conditional on reporting non-zero air releases provided for the Tobit regression.

Both the pooled OLS and Tobit models for air releases provide results that are, for the most part, consistent with our findings for aggregate TRI releases. We find that participation in the 33/50 program is associated with significantly dirtier facilities, but post 1995, air releases actually increased for these facilities. Publicly held facilities also are dirtier, on average, by approximately 2800 lbs, than privately held facilities. Not surprisingly, air releases in non-attainment counties are significantly smaller than those located in attainment counties – by almost 2000 lbs.

The effects of state ranking and state-level TRI regulations are also similar to those found for aggregate releases. From the Tobit results, we see that facilities located in states with no additional TRI regulations are, on average, 800 lbs dirtier than the facility with the next higher ranking. This difference falls by over 620 lbs to only 180 lbs in states with numeric reduction goals in place for TRI substances. Facilities located in states with additional TRI regulations that do not include specific reduction goals are not found to be significantly different from facilities in states with no additional regulations.

As before, we find that reductions in air releases (columns 3and 4 in Table 6) are much larger for 33/50 participants (approximately 24,000 lbs) than for non-participants. These differences do not increase for the participants post 1995. There is some evidence that the reduction in air releases is smaller for facilities located in non-attainment counties and, although not precisely estimated, we find that reductions are larger in counties that have recently gone from attainment to non-attainment status.

The one significant departure in results that we observe for air releases is the reduction in releases for facilities located in states with at least some additional TRI regulations (REG2). Here, we find that even in REG2 states, there is significant compression in the magnitude of releases between dirty and clean facilities (between 284 lbs and 307 lbs). This is important, as it provides evidence that at least for air releases, even without specified reduction goals, programs that simply provide information about pollution prevention can help facilitate additional abatement in significant amounts, over and above that induced by a stand-alone public disclosure program alone.

D. Hazardous Air Pollutants:

To consider the possible effects of hazardous air pollutant regulations on TRI releases, we start by observing the decline in HAP and non-HAP TRI air pollutants over time. PCB facilities reporting non-zero air releases had average plant level HAPs fall from 2037.5 lbs in 1990 to 744.3 lbs by 2003, or by 64% (or, for non-zero HAP reporting facilities, an average plant-level release of 6,927.4 lbs in 1990 to 1976 lbs in 2003: a 71.5% decline); whereas non-HAPs saw a decline of 97%, falling from a mean level of 16,710 lbs in 1990 to 1992 lbs in 2003. From Figure 6, we can see that the decline in releases differs quite significantly across the two groups of pollutants. (The correlation coefficient between HAP and non-HAP TRI releases is -0.07.)

If HAP regulations had an additional beneficial effect on TRI releases, we would expect that facilities emitting higher proportions of HAP releases would have lower TRI releases, all other things being equal. To test this hypothesis, we re-estimate our air-release model and include the variable, RATIOH, which is the ratio of HAP releases to over-all TRI air releases. We also include a dummy variable, H, which takes on the value of 1 if any HAPs are emitted by the facility. Finally, to control for differences in reductions over time by HAP pollutants, we include year-H interactions terms. The results are summarized in Table 7.

TRI air releases are significantly larger in facilities that emit any HAPs. This may be because larger facilities tend to emit HAPs, or dirtier facilities tend to emit HAPs, or both. But, the higher the proportion of HAPs to over-all air releases, the lower the level of TRI air releases. This is consistent with regulations for HAPs having a beneficial effect on TRI air releases. We estimate that a one-percent increase in this ratio is associated with a decline in TRI air releases of approximately 98 lbs.

E. Water Releases:

Historically, the CWA and its subsequent amendments are a less comprehensive and probably less effective set of regulations than those adopted for air pollution under the CAA. However, as several TRI substances are covered by the CWA, and the PCB industry is generally water pollution intensive, we look at how CWA regulation might have affected toxic water releases.

Only 240 plant-year observations (48 different facilities over 13 years) in our data set report water releases of any sort. PCB-industry wide, TRI-reported water releases for CWA listed substances fell by 62.6% between 1988-2003, with the bulk of the decline occurring in 2002 and

2003. In contrast, *non*-CWA listed water pollutants fell by 99.99% between 1988-2003, with the bulk of reductions occurring after 2000, when aggregate water releases went from 13980 lbs to essentially zero in 2003. CWA listed water releases in 1988, however, averaged under 10 lbs/plant and never exceeded 12 lbs/plant during the sample. Non-CWA listed water pollutants in 1988 averaged 288 lbs/plant and were as high as 839 lbs/plant in 1993. PACE data from the 1990s indicates that the PCB industry spendt the bulk of its abatement expenditures on water pollution. The very low levels of releases for CWA pollutants relative to non-CWA pollutants suggests that much of the abatement for those pollutants occurred prior to 1990. And, as with air releases in attainment and non-attainment counties, we find that although non-CWA listed TRI water pollutants initially started at much higher levels than CWA listed pollutants, their average facility-level releases equalized over time.

As with our analysis of HAPs, we also estimate a simple OLS model, conditional on reporting non-zero TRI water releases, which includes the ratio of CWA releases to over-all TRI water releases (as well as a dummy variable, W for CWA releases and year-W interaction terms) and to see whether over-all water releases are lower for facilities with higher proportions of CWA pollutants. (See Table 8.) Again, we find that facilities with higher proportions of CWA pollutants have significantly lower levels of TRI water releases. We estimate that a one-percent increase in the proportion of CWA pollutants is associated with an additional reduction of approximately 56 lbs of TRI water releases, evidence that the CWA had a beneficial effect on TRI water releases.

VI. Conclusion

The PCB industry has changed dramatically over the past twenty years. Those changes would seemingly mitigate the industry's ability and desire to reduce toxic releases voluntarily. Nevertheless, the industry has exhibited dramatic reductions in reported releases since TRI reporting began, and these reductions are not due simply to the export of production overseas and the resulting exit of dirty plants.

We find evidence of two very different causes for both the observed levels of TRI releases and their reductions over time. The first is firm response to command and control strategies that exist for non-toxic pollutants. In particular, we find that facilities are significantly cleaner in non-attainment regions of the country in which air pollution regulations are more stringent. And although not precisely estimated, our results suggest also that changes in attainment status from attainment to non-attainment also induce larger reductions in TRI releases. That is consistent with a story in which regulation of criteria air pollutants yield a positive externality on the level of toxic releases. Similar patterns are found for hazardous air pollutants and water pollutants regulated under the CWA.

Of particular interest, however, is that although facilities located in attainment regions are initially much dirtier than those located in non-attainment regions, over time, these plants eventually become at least as clean as other plants. That is, attainment facilities "catch-up" with non-attainment facilities in terms of TRI releases. So, through some mechanism that is independent of formal regulation of criteria air pollutants, hazardous air pollutants, or regulated water pollutants, facilities are choosing to reduce their toxic releases to the point at which they are virtually indistinguishable from facilities that have faced more stringent formal environmental regulations and whose toxic releases have been reduced as a direct result of those regulations. If we interpret this as a direct response by firms to TRI reporting requirements, then policy-relevant inferences may be drawn from the findings, most important of which is that, even in the absence of the reductions in TRI releases that are attributable to the regulation of non-toxic pollutants, firm response to the TRI alone would have eventually led to the level of reductions that we have observed to date.

The second cause of the reduction in TRI levels is state regulations and policies that enhance or expand on the federal level program. We find that the distribution of aggregate TRI levels are significantly more compressed in states with TRI programs that include specific numeric reduction goals. However, we do not see the same compression in the distribution of releases in states that only have state-level TRI programs that provide outreach services and pollution prevention information to polluters, except in the case for TRI air releases. We take this as evidence that (1) firms are responding to the potential threat of formal regulation by making themselves look more similar to one another through the compression of the distribution of TRI releases amongst plants; and (2) the threat of potential regulation must be quite clear: target reductions with stated "compliance" dates must exist, even if non-compliance penalties do not. Results for "weaker" state programs appear to be very pollution-media specific, and may be driven by the type of pollution prevention information that is being disseminated.

These findings suggest at least two ways policy makers may increase the likelihood of a success mandatory disclosure program as a regulatory mechanism for pollution control. Increasing the threat of formal regulation through the adoption of credible target reduction goals is one possibility. The other is to provide outreach programs that disseminate research results in pollution prevention. This latter approach is one in which the federal EPA has already started to undertake in certain industries under the Design for the Environment (DfE) program, which facilitates joint research between industry, academia, and the EPA, to study pollution prevention. Further adoption of such programs will only enhance the probability of continued success of such mandatory disclosure programs as the TRI for pollution reduction.

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Table 1: Selected Summary Statistics for TRI Reporting PCB Facilities, 1988-2003

Variable	Mean	Standard Deviation
Total TRI Releases (lbs)	13536.55	62506.34
Initial Reported Release (lbs)		
- Total	44588.06	221076.5
- Air	25953.66	111814.2
- Water	813.80	8964.24
One-Time Release (lbs)	18.26	326.51
33/50 Participants	0.07	0.25
Publicly Traded Company	0.22	0.41
State TRI Program:		
- REG1	0.48	0.50
- REG2	0.08	0.28
Non-Attainment County	0.77	0.42
Number of Observations: 3604		

Table 2. Summary Statistics (Means and Standard Deviations) for "Remaining" and "Exiting" Facilities: 1988-2003

Variable	"Remaining Facilities"	"Exiting Facilities"
Total TRI Releases (lbs)	9200.51	17786.82
	(38322.41)	(79138.19)
Initial Reported Release (lbs)		
- Total	22701.07	66042.11
	(84303.12)	(298182.1)
- Air	15415.94	35282.95
	(71014.69)	(140019)
- Water	315.05	1302.64
	(2842.38)	(12278.7)
One-Time Release (lbs)	13.15	23.27
	(241.06)	(392.60)
33/50 Participants	0.06	0.07
	(0.24)	(0.26)
Publicly Traded Company	0.16	0.28
	(0.36)	(0.45)
State TRI Program		
- REG1	0.47	0.48
	(0.50)	(0.50)
- REG2	0.08	0.09
	(0.27)	(0.29)
Non-Attainment County	0.75	0.79
	(0.43)	(0.41)
Number of Observations:	1784	1820

* Standard errors are given in parentheses.

Table 3: Summary Statistics for Smaller Sample used in Regressions

Variable	Mean	Standard Deviation
Total TRI Releases (lbs)	11348.01	38748.07
Initial Reported Release (lbs)		
- Total	59050.82	222048.5
- Air	35005.38	134097.6
- Water	967.15	10691.31
One-Time Release (lbs)	14.95	333.36
33/50 Participants	0.07	0.26
Publicly Traded Company	0.24	0.43
State TRI Program:		
- REG1	0.48	0.50
- REG2	0.08	0.27
Non-Attainment County	0.77	0.42
Number of Observations: 1939		

Table 4: Aggregate TRI Releases in Levels and First-Differences

Variable	TRI	Δ TRI	Δ TRI
PC 33/50	38,054.45*	-35361.98***	-35,211.17**
	(20,661.97)	(15232.42)	(15,063.69)
PC 33/50 Post 1995	5,737.39	26657.04	26,644.81
	(25,518.74)	(16670.73)	(16,631.37)
Public	9,554.37**	-135.96	-40.63
	(4,541.00)	(2371.12)	(2,352.96)
State Rank	-2,130.56***	586.028***	542.01***
	(376.53)	(193.04)	(189.15)
State Rank X REG1	1,808.82***	-471.03***	-418.58**
	(360.48)	(183.61)	(181.60)
State Rank X REG2	604.92	-224.54	-248.22
	(438.97)	(245.30)	(243.51)
Non-Attainment	-10,664.42**	2951.78	3,326.92
	(4,242.58)	(2407.76)	(2,380.72)
Δ to Non-Attainment (t)			-5,211.48
			(5,553.47)
Δ to Non-Attainment (t-1)			-32,390.80
			(25,003.36)
Δ to Non-Attainment (t-2)			2,986.72
			(4,491.90)
Year Indicators	X		X
Constant	40,932.42***	-27514.98***	-27,132.11**
	(14,077.81)	(11060.11)	(10,862.11)
Observations	1939	1939	1939
R-squared	0.12	0.06	0.07

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 5: Summary Statistics for TRI Air Releases by Year and Attainment Status

Year	Variable	Attainment Counties			Non-Attainment Counties		
		Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
1990	Air	17	47426	75439.04	72	10934.35	23613.39
	Δ Air	17	-11278.94	33626.71	72	-19790.03	81137.19
1991	Air	13	22687.54	29407.92	64	8731.656	18329.98
	Δ Air	13	-18064.15	35783.16	64	-2235.297	10867.37
1992	Air	17	20528.76	29018.94	108	8214.731	18915.04
	Δ Air	17	-2366.471	9037.383	108	-1323.657	12020.9
1993	Air	19	31528.79	59642.6	129	6316.209	13925.97
	Δ Air	19	-20304.95	51710.17	129	-2001.287	10047.71
1994	Air	24	15293.46	27644.09	148	6620.534	15930.86
	Δ Air	24	-13651	29427.77	148	-474.3041	6734.488
1995	Air	24	14741.04	26651.74	139	5937.317	15166.09
	Δ Air	24	286	22090.41	139	-760.5252	7615.996
1996	Air	28	13428.89	23798.3	128	4815.383	11271.18
	Δ Air	28	262.6429	11887.98	128	-1603.367	10773.8
1997	Air	31	10051.1	18752.08	128	4735.875	13362.99
	Δ Air	31	-2301.452	8791.52	128	-137.0313	9926.28
1998	Air	54	5373.907	11736.1	102	6008.461	15018.07
	Δ Air	54	-1633.667	8531.138	102	479.7549	5507.274
1999	Air	38	4123.316	8732.546	113	4108.885	9231.401
	Δ Air	38	-2762.553	6925.607	113	-1391.761	9883.46
2000	Air	45	6424.74	12051.61	104	5670.087	12070.36
	Δ Air	45	817.6291	7364.163	104	1514	6733.275
2001	Air	49	2991.028	5213.909	98	2836.871	7023.721
	Δ Air	49	-3564.835	8881.869	98	-2545.527	9235.026
2002	Air	45	1903.944	3391.161	88	1948.5	6021.893
	Δ Air	45	-1504.204	4290.716	88	-488.5169	3877.711
2003	Air	42	1686.38	3678.789	72	1942.427	6200.945
		42	-97.38686	879.0424	72	-207.2169	935.3694

Table 6: TRI Air Releases

Variable	OLS	Tobit	Δ Air	Δ Air
PC 33/50	18,708.07*	8021.321**	-24,131.86**	-23,928.56**
	(10,467.81)	(4156.2)	(10,188.05)	(9,919.16)
PC 33/50 Post 1995	28,481.93**	12077.68***	8,872.06	8,788.30
	(13,764.65)	(6144)	(12,077.83)	(11,940.20)
Public	5,327.64*	2808.88***	-470.22	-383.21
	(2,826.72)	(1314.2)	(1,616.38)	(1,595.49)
State Rank	-1,228.56***	-799.63***	505.00***	462.86***
	(225.82)	(149.55)	(147.80)	(140.85)
State Rank X REG1	995.02***	623.38***	-423.10***	-373.14***
	(209.74)	(137.8)	(140.43)	(135.56)
State Rank X REG2	155.77	64.80	-284.86*	-308.10*
	(268.22)	(181.29)	(158.60)	(159.09)
Non-Attainment	-4,211.62**	-1883.34**	1,933.28	2,299.74*
	(2,050.66)	(1022.3)	(1,377.85)	(1,323.01)
Δ to Non-Attainment (t)				-2,804.80
				(2,228.48)
Δ to Non-Attainment (t-1)				-28,879.39
				(25,891.92)
Δ to Non-Attainment (t-2)				-1,137.36
				(2,944.18)
Year Indicators	X	X	X	X
Constant	21,714.90***		-18,665.37***	-18,354.83***
	(4,488.39)		(6,906.57)	(6,558.11)
Observations	1939	1939	1939	1939
R-squared	0.20		0.08	0.10

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: TRI Air Releases, Conditional on Reporting Non-Zero Air Releases

Variable	TRI Air (lbs)
PC 33/50	11501.17
	(9439.71)
PC 33/50 Post 1995	30244.84***
	(11937.52)
Public	5098.16**
	(2536.85)
Non-Attainment	-4745.55*
	(2239.66)
RatioH	-9875.75**
	(4218.57)
H	27822.81**
	(12243.32)
State Rank	-1198.29***
	(264.40)
State Rank X REG1	991.38***
	(251.93)
State Rank X REG2	435.14
	(320.06)
Year Indicators	X
H X Year Indicators	X
Constant	16127.37***
	(3587.91)
R-Squared	0.29
Observations	1510

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 8: TRI Water Releases, Conditional on Reporting Non-Zero Water Releases

Variable	TRI Water (lbs)
PC 33/50	-1641.40
	(1512.78)
PC 33/50 Post 1995	-5012.14
	(4678.11)
Public	869.28
	(1368.47)
Non-Attainment	-2655.64
	(2171.64)
RatioW	-5644.30**
	(2850.33)
W	2818.72
	(2092.25)
State Rank	-602.59*
	(360.56)
State Rank X REG1	588.63*
	(352.19)
State Rank X REG2	278.52
	(352.85)
Year Indicators	X
W X Year Indicators	X
Constant	3931.39**
	(2057.11)
R-Squared	0.20
Observations	240

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1. Toxic Releases From the PCB Industry, 1988-2003

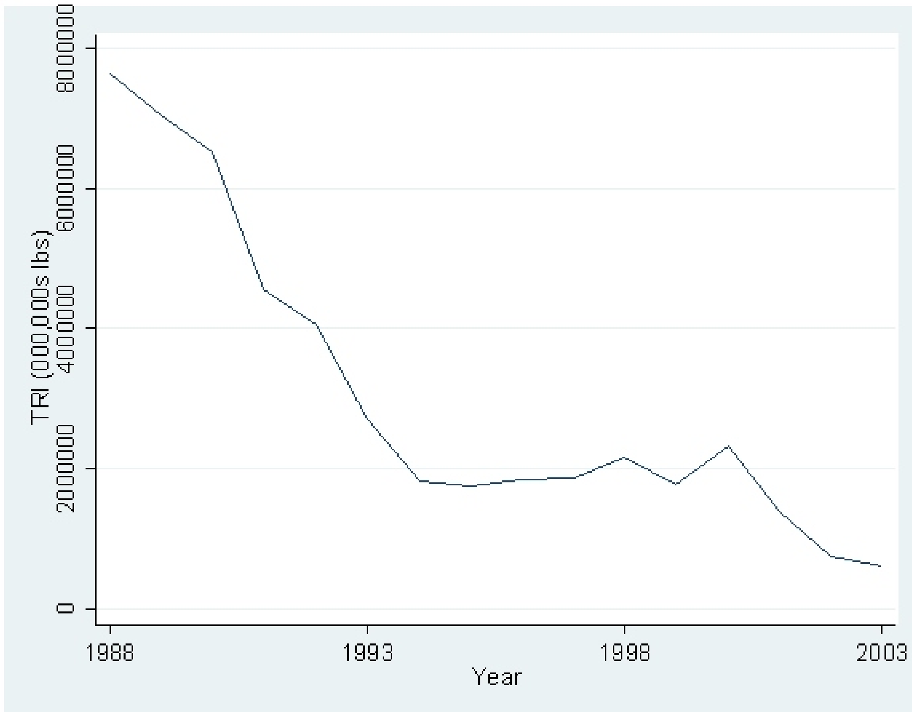


Figure 2. Domestic PCB Production (Rigid and Flexible) in 000,000s of Boards

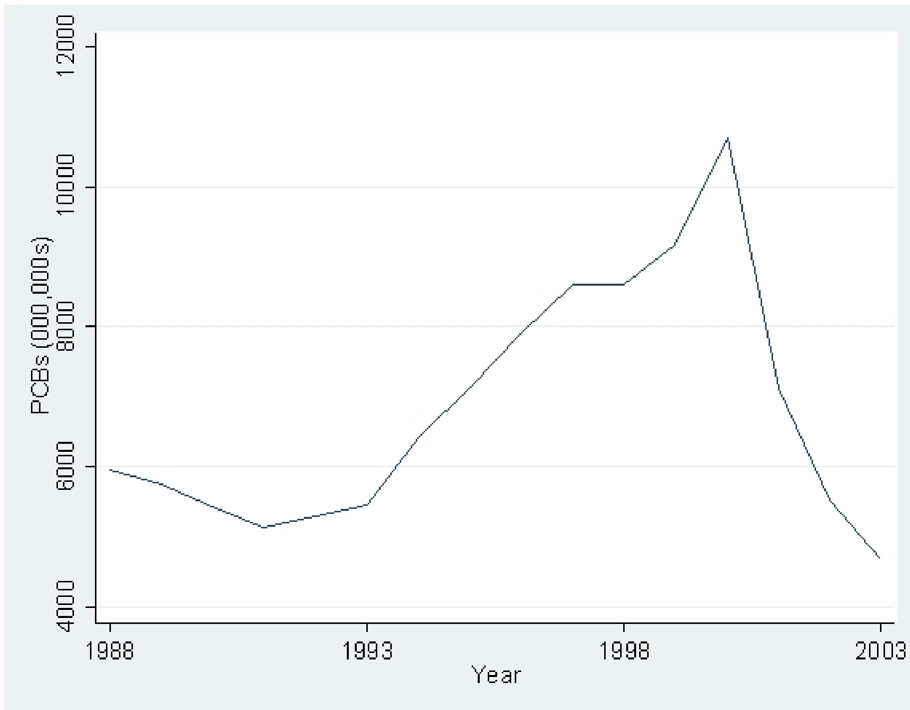


Figure 3. TRI Releases Normalized by Output, 1988-2003

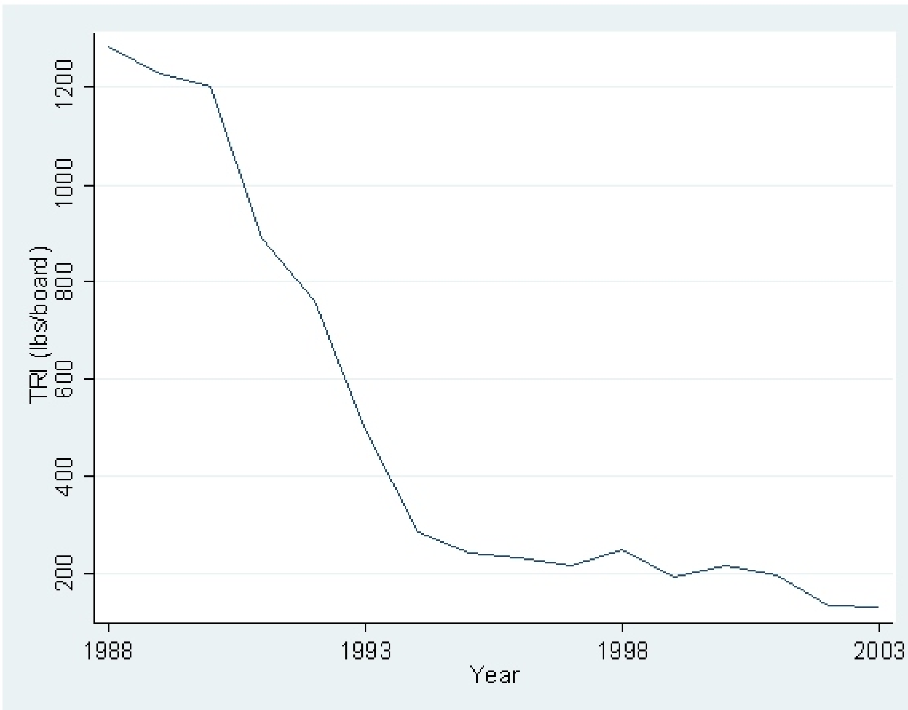


Figure 4. TRI Releases Normalized by TVS, 1988-2003

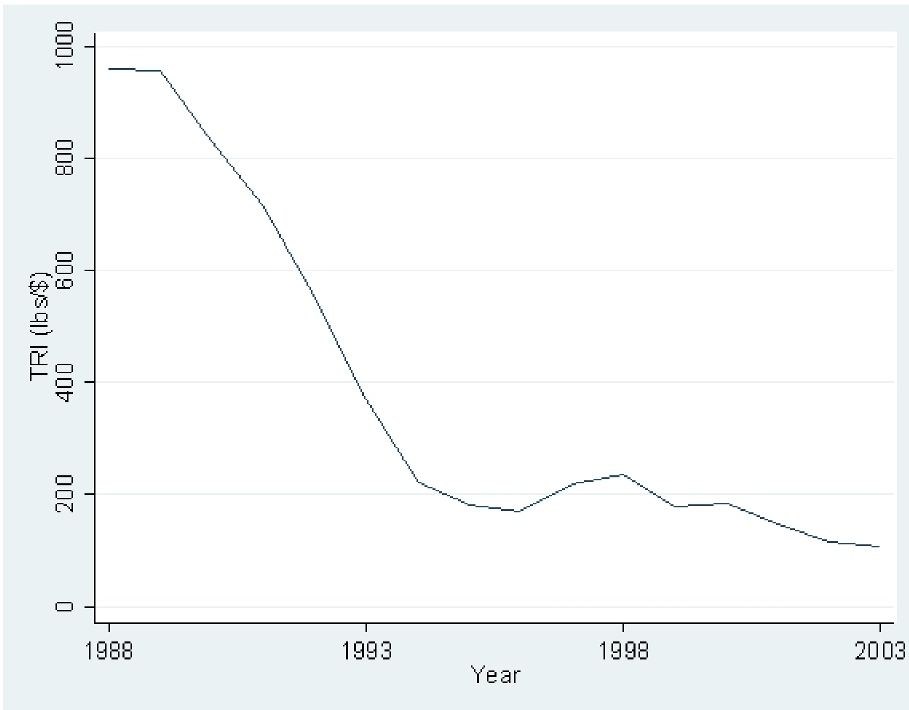


Figure 5. TRI Releases by Non-Exiting ("Remaining") Firms, 1988-2003

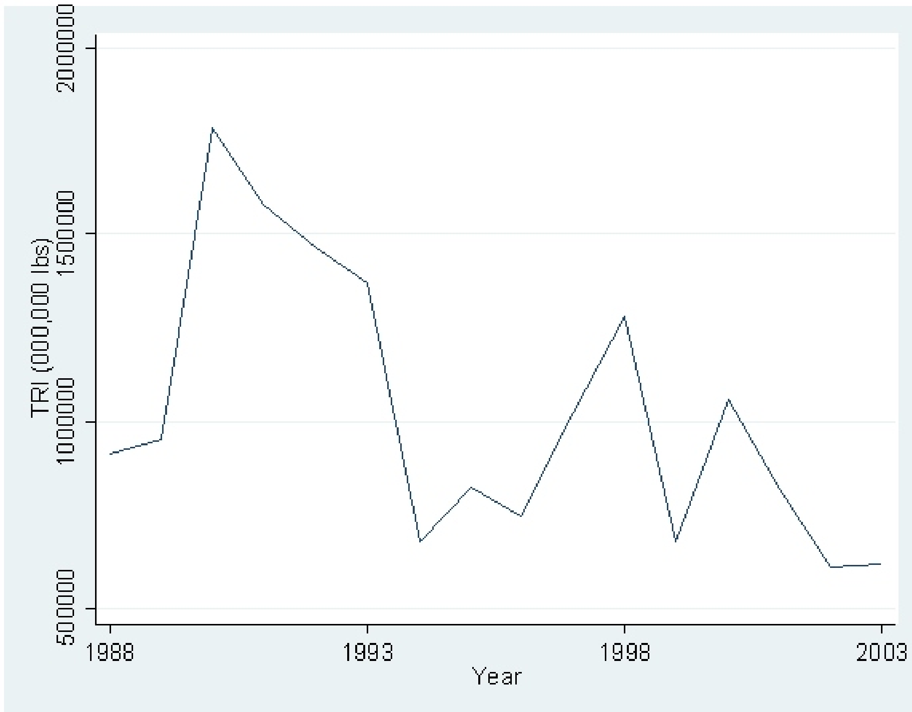
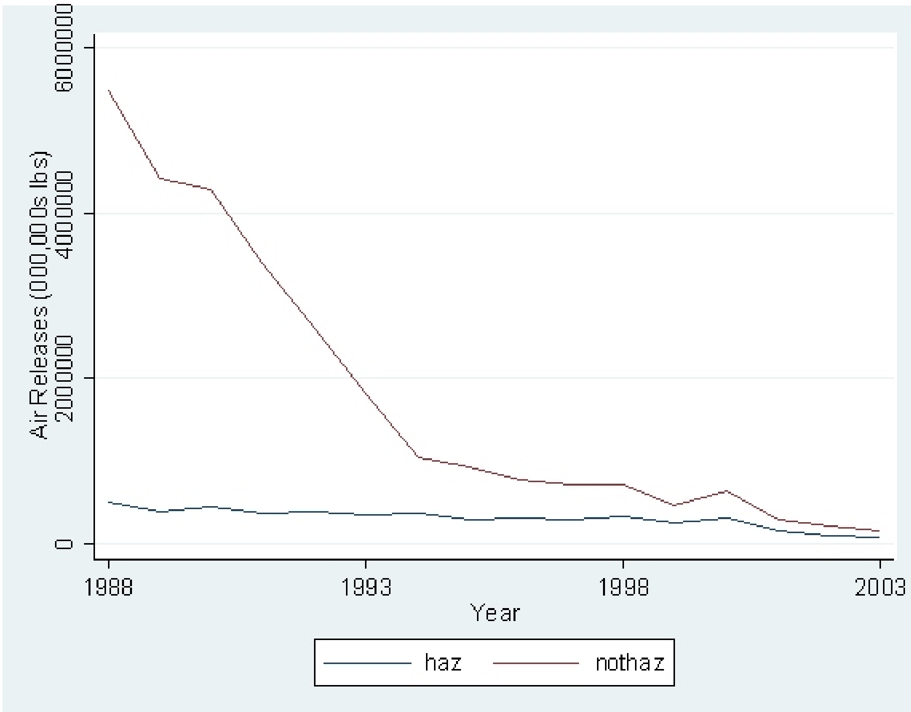


Figure 6. Hazardous and Non-Hazardous Air Releases, 1988-2003



Regulation with Competing Objectives, Self-Reporting, and Imperfect Monitoring

Mary F. Evans*[,ŧ], Scott M. Gilpatric*, and Lirong Liu*

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*Department of Economics, [ŧ]Center for Business and Economic Research, University of Tennessee, Knoxville, Tennessee; mevans12@utk.edu, sgilpatr@utk.edu, lliu5@utk.edu
Please address correspondence to mevans12@utk.edu, 865.974.1700 (phone), 865.974.4601 (fax)

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Abstract
We model the optimal design of programs requiring firms to disclose harmful emissions when disclosure yields both direct and indirect benefits. The indirect benefit arises from the internalization of social costs and resulting reduction in emissions. The direct benefit results from the disclosure of previously private information which is valuable to potentially harmed parties. Previous theoretical and empirical analyses of such programs restrict attention to the former benefit while the stated motivation for such programs highlights the latter benefit. When disclosure yields both direct and indirect benefits, policymakers face a tradeoff between inducing truthful self-reporting and deterring emissions. Internalizing the social costs of emissions, such as through a Pigovian tax, will deter emissions, but may also reduce incentives for firms to truthfully report their emissions.

I. Introduction

Regulatory agencies, including the Environmental Protection Agency (EPA), commonly cite two categories of benefits associated with information disclosure programs. The first, an indirect benefit, arises from the internalization of the social costs of emissions (and consequent reductions in emissions) due to market responses to disclosures or regulatory instruments such as Pigovian taxes on disclosed emissions. The second, a direct benefit, results from the disclosure of previously private information. Referring to information disclosure programs in a recent report that describes the U.S. experience with various environmental policies, the EPA states "The environmental information embodied in these approaches has economic value...even in the absence of any changes in emissions by firms" (p. 153) [23].[1] Timely information about emissions may enable potential damages to be avoided or mitigated both by affected parties and public agencies. For example, disclosure may reduce consumption of contaminated water by alerting individuals of the need for avoidance or proper treatment. Disclosure may also decrease the environmental impacts of a toxic release by accelerating clean-up efforts.

Theoretical analyses have tended to represent the social cost of emissions as a function only of emissions levels, independent of whether the presence and magnitude of emissions are publicly disclosed. The empirical work has followed a similar convention by measuring program success in terms of reductions in emissions. Neither strand of the literature has yet to explicitly account for the possibility that disclosure of harmful emissions may be directly beneficial, outside of any indirect impacts of disclosure requirements on emissions. We develop a theoretical model that attempts to reconcile this

[1] In fact, the report refers to the benefits of disclosure from changes in consumer or producer behavior, such as reduced emissions, as "ancillary" (p. 153).

apparent inconsistency between the stated motivation for information disclosure programs and previous analyses of such programs.

In our model, disclosure of emissions is directly beneficial but actual emissions are imperfectly observable so policymakers face a tradeoff between inducing truthful self-reporting and deterring emissions.[2] Internalizing the social costs of emissions, such as through a Pigovian tax, will deter emissions, but it may also reduce incentives for firms to truthfully disclose their emissions.

When monitoring firm behavior (such as through an audit process) is costly, a policymaker must account for three factors when designing regulatory policy: (1) the benefit of reduced emissions arising from internalizing social costs, (2) the direct social benefit of disclosure of emissions that do occur, and (3) enforcement costs. Previous analyses of environmental compliance have addressed factors (1) and (3) by considering a regulator whose objective is to minimize emissions (Garvie and Keeler [4]; Macho-Stadler and Perez-Castrillo [18]) or to minimize enforcement costs for a given level of compliance (Livernois and McKenna [17]). We model the regulator's objective in a way that accounts for the reduction in social costs arising both from disclosure of emissions and a reduction in the quantity of emissions. This framework is both more general and more representative. In this paper our principal objective is to model the optimal policy choice in this context when the instruments at the regulator's discretion are a tax on

[2] This trade-off is present in other regulatory settings such as consumer product and food safety. Firms are required to disclose product failures and hazards, but the more costly such disclosure (either due to fines or liability exposure) the greater the incentive firms have to conceal such information. Reducing fines or limiting liability costs encourages disclosure but may dull incentives to reduce product defects. However, this tradeoff is not present in some other regulatory settings where information disclosure programs have traditionally been applied, such as income taxation.

(disclosed) emissions and the frequency (or probability) of auditing a firm's disclosure report.

In order to better understand the characteristics of the regulator's trade-off between inducing compliance with disclosure requirements and reducing emissions, we develop a model of firm behavior in the context of an imperfect audit. An imperfect audit reveals some percentage of the firm's actual emissions according to a known probability distribution. Firms then optimize their choice of how much of their true emissions to disclose in order to minimize their expected costs. Firms also choose how much to emit conditional on their expected emissions costs. The regulator in turn optimally chooses the policy parameters based on his expectations about how firms facing a particular regulatory environment will behave.

The model we develop adds to the literature on the role of self reporting in environmental regulation. Malik [19], Swierzbinski [22] and others have shown that incentive-compatible mechanisms for self reporting (in which firms are induced to truthfully report their emissions) can achieve enforcement cost savings and increase social welfare. The benefit of self reporting in these models arises due to the regulator having incomplete information regarding the social costs or private benefits (i.e., abatement costs) of emissions by a particular firm. Unlike these previous models, we assume the regulator has full information in these respects.[3] The social benefit from self reporting in our model arises very differently (and more directly) from the fact that reported emissions cause less social damage than undisclosed emissions. In our model

[3] Section III of the paper presents a variant of our model in which firms have private information.

disclosure of emissions by firms is a desirable end in itself, rather than a mechanism to achieve desirable emissions reductions in a more cost effective manner.[4]

This paper is organized as follows. Section II develops our main model. We first consider the decision facing a representative firm required to disclose emissions subject to a tax enforced through imperfect audits. We then analyze the optimal policy choice of the regulator, who we assume has complete information. Section III relaxes the perfect information assumption and confirms that our main results continue to hold. Section IV concludes with discussion of the implications of our model and possible extensions.

II. The Model

A. The Firm's Problem

We first analyze the decision facing a firm subject to a mandatory information disclosure policy requiring the firm to report a level of emissions to the regulator. The compliance decision for a firm is defined by three factors: 1) the disclosure costs the firm incurs as a function of its reported emissions, 2) the penalty costs the firm incurs as a function of any emissions that are revealed in excess of the level it discloses, and 3) the nature of the auditing program.[5]

[4] Of course regulations requiring self reporting may serve a dual purpose, both to capture direct benefits of disclosure and to achieve enforcement cost savings from information revelation. We focus on the direct benefits of disclosure to keep our model fairly straightforward and make the implications of this regulatory motive most transparent.

[5] Becker's [2] "optimal penalty" model provides the theoretical basis for the literature on environmental compliance. The main insight from his model is that potential offenders respond to the probability of detection as well as the severity of the punishment. See Polinsky and Shavell [20] (and the citations within) for a general review of the enforcement literature. Cohen [3] and Heyes [10] provide reviews of the environmental compliance and enforcement literature.

Firms may face costs associated with emissions (whether disclosed or undisclosed) arising from a variety of sources.[6] Most directly, a firm may be subject to a Pigovian tax on disclosed emissions, and a subsequent penalty on unreported emissions that are later revealed. A firm may also face current or future liability costs associated with emissions, both of which may be reflected immediately in the market valuation of the firm upon the revelation of its emissions.[7] Finally, the firm may face costs associated with the revelation that it failed to disclose emissions when required. The revelation of under-reporting by a firm may be either a direct consequence of regulatory enforcement, or through other mechanisms such as internal whistleblowers, disclosures by the media or environmental watchdog groups, or simply due to random events that bring information into the public domain.

Most previous analyses of environmental compliance assume an error-free audit process (see for example Kaplow and Shavell [14] and Innes [11]), an assumption consistent with the tax compliance literature.[8] We define an audit to be error-free if it reveals, perhaps with some probability less than one, the exact degree of misreporting. Recently, Macho-Stadler and Perez-Castrillo [18] depart from the more common assumption in the literature of an audit that always reveals the exact degree of misreporting by allowing the probability of perfect revelation to be less than one. Notice however that the effect of this assumption is merely to decrease the probability of

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[6] Firms may fail to perfectly comply in some cases simply because it is costly to collect the necessary information (e.g., a firm may bear some cost of simply measuring its own emissions). We ignore the possibility here and simply assume the firm has perfect knowledge of its emissions.

[7] See Hamilton [5], Khanna et al. [15], and Konar and Cohen [16] for empirical evidence on market reactions to releases of the Toxics Release Inventory (TRI).

[8] Malik [19] is an exception. He models a binary compliance decision allowing for errors in auditing the firm's compliance status. In contrast, we model compliance with the information disclosure requirement as a continuous choice in order to focus our analysis on behavioral changes at the intensive, rather than extensive, margin.

detection (the firm now faces a compound probability). Heyes [8] considers a similar audit structure where the probability that an audit (perfectly) detects non-compliance is endogenous. In each of these models, provided an audit occurs, it reveals either no misreporting or the exact degree of misreporting and therefore is consistent with our definition of an error-free audit. The assumption of error-free audits seems best suited to situations where firms make dichotomous choices to comply with a regulation or not. However, in the case of environmental information disclosure requirements, where incurred penalties are likely to vary with the degree of noncompliance, the firm's decision may be more accurately modeled as choosing the optimal degree of compliance. Therefore, we model compliance as a continuous choice and assume the firm faces an imperfect audit, one that reveals a *percentage* of the firm's actual emissions.

We assume firms are homogeneous and consider the problem facing a representative firm. Let e represent the firm's emissions and denote the firm's benefit of emitting as $B(e)$ where $B'(e) > 0$ and $B''(e) < 0$. Let z denote the share of actual emissions reported by the firm, so the reported quantity of emissions is ze. For clarity and tractability, we assume that for each unit of reported emissions, the firm incurs a constant per unit cost, denoted α, which we characterize as the "tax" on emissions. Similarly, if the audit reveals a level of emissions that exceeds reported emissions, the firm incurs a constant per unit cost, denoted β, on the revealed but unreported emissions. We refer to β as the "penalty." [9]

[9] Both disclosure and penalty costs could of course be non-linear. For example, the penalty cost function might increase at an increasing rate with the magnitude of the violation if regulators take the view that large infractions should be punished severely while minor infractions receive a much milder treatment. The linearity assumption renders the model much more tractable and avoids issues associated with the optimal size of a firm as a function of the regulatory environment, which is beyond the scope of our analysis.

The firm is audited with probability *p*. If an audit occurs it reveals a quantity of emissions, denoted *x*. We assume $x = eu$ where *u* is a random variable with cumulative distribution function $F(u)$ and probability density function $f(u)$, which is strictly positive on the interval $[0, b]$ with $b \geq 1$.[10] We assume $f(u)$ has a single mode at one. The model thus allows for the possibility that an audit reveals less or perhaps more than was actually emitted. We do not require that audits be unbiased (i.e., that $E[u] = 1$) or that $f(u)$ be symmetrically distributed around one, but the model encompasses these possibilities. We assume that the audit distribution *F* is independent of the firm's actual emissions. That is, the scale of the firm or its emissions level does not impact the effectiveness of audits, so the audit is equally likely to reveal any given percentage of actual emissions regardless of the firm's true emissions level.

The firm's problem is to choose *e* and *z* to maximize the expected net benefit of emitting. Given our assumptions and the values of α, *p*, and β, the firm faces a constant per unit cost of emitting, denoted μ, with

$$\mu(\alpha, \beta, p) = \alpha z + p\beta \int_z^b (u - z) f(u) dt \,. \tag{1}$$

Therefore the firm's expected net benefit is given by:

$$B(e) - C(e, z) = B(e) - e \cdot \mu(\alpha, \beta, p) = B(e) - e \cdot \left[\alpha z + p\beta \int_z^b (u - z) f(u) dt \right]. \tag{2}$$

[10] Because the audit process has two-sided errors yielding the possibility that emissions are "revealed" in excess of the actual level (as in Harford [6]), it is possible that a firm would find it optimal to over comply, reporting emissions in excess of its actual level. As we discuss below, in our model the regulator will never find it optimal to induce overcompliance from a representative firm. Arora and Gangopadhyay [1], Shimshack and Ward [21], among others explicitly focus on overcompliance with environmental regulations.

It is clear from equation (2) that with a constant tax and penalty and independence between the audit effectiveness and actual emissions levels, the firm's optimal choice of *z* is independent of *e*. Thus, our assumptions allow us to decouple the choices of *e* and *z*. We begin by analyzing the firm's optimal choice of *z*. The first order condition for an interior solution on *z* is given by:

$$\alpha = p\beta \int_{z^*}^{b} dF(u) = p\beta\left[1 - F(z^*)\right] \tag{3}$$

where z^* denotes the optimal reported share of emissions. The first order condition indicates that the firm's optimal report, z^*, equates the marginal cost of reported emissions, α, and the expected marginal benefit of reported emissions. The expected marginal benefit reflects the expected avoided per unit penalty on revealed but unreported emissions. Using equation (3), we can solve for z^* as a function of the policy parameters:

$$z^* = F^{-1}\left(1 - \frac{\alpha}{p\beta}\right)$$

With this we state the following proposition characterizing the firm's optimal choice of *z*. All proofs are given in the appendix.

Proposition 1. Given α, β, and *p*, the firm's optimal choice of *z* will be such that

(*i*) $z^* = 0$ if $\alpha \geq p\beta$

(*ii*) For $p\beta > \alpha$ an interior solution exists with z^* defined by expression (3) above.

(*iii*) For an interior solution, the firm's optimal report, z^*, is decreasing in the tax on reported emissions, α; increasing in the probability of audit, *p*; and increasing in the penalty on revealed but unreported emissions, β.

Note that $p\beta > \alpha$ is required for an interior solution on z^*. That is, in order to elicit reporting in our model, the tax on reported emissions must be below the expected penalty on revealed but unreported emissions.[11] We assume this condition is satisfied and focus attention on an interior solution for z^*.

We now consider the firm's optimal choice of emissions. Given z^*, the firm will choose e^* to maximize $B(e) - C(e, z^*) = B(e) - e \cdot \mu^*$ where $\mu^* = \alpha z^* + p\beta \int_{z^*}^{b} (u - z^*) f(u) dt$. The first order condition with respect to the choice of e is given by:

$$\alpha z^* + p\beta \int_{z^*}^{1} (u - z^*) f(u) du = B'(e^*) \text{ or } \mu^* = B'(e^*) \tag{4}$$

which simply states that the optimal level of emissions occurs where the marginal cost and marginal benefit of emitting are equal. Equation (4) implicitly defines the firm's demand for emissions, as a function of the marginal cost of emitting (given z^*), which we denote $e(\mu^*) = B'^{-1}(\mu^*)$, where $e'(\mu^*) < 0, e''(\mu^*) \geq 0$. Proposition 2 states the comparative static results for the optimal level of emissions, e^*.

Proposition 2. The firm's optimal level of emissions, e^*, decreases with the tax on reported emissions, α; the penalty on revealed but unreported emissions, β; and the probability of audit, *p*.

Proposition 2 confirms the intuitive result that emissions decrease with increases in those factors that raise μ^*, namely the tax, the penalty, and the frequency of audits.

[11] Heyes [9], Innes [11] and Kambhu [13], among others, present models in which fines set below their maximal levels are optimal, which is analogous to setting the tax sufficiently low to induce disclosure in our model. For example, in Kambhu [13] higher penalties lead to lower compliance because they induce regulated firms to take actions that obstruct the enforcement process.

The next section considers the policymaker's problem conditional on the firm responding to changes in policy parameters according to Proposition 2.

In the model of optimal regulatory policy developed below we will employ the fact that the firm's optimized *net* benefit of emitting is $B(e^*) - C(e^*, z^*) = \int_{\mu^*}^{\mu_c^*} e(\rho)d\rho$

where μ_c^* represents the choke price for emissions. This expression simply states that the firm's net benefit of emitting (given z^*) is the area under the firm's emissions demand curve above μ^*. This is denoted area *A* in Figure 1.

B. The Regulator's Problem

The regulator's objective function must account for (1) the welfare loss from emissions in excess of the socially optimal quantity, (2) the direct benefit of information disclosure, and (3) the costs associated with auditing firms.

Let *m* denote the per unit social cost of undisclosed emissions. Let *s* represent the difference between the unit cost of undisclosed emissions and the unit cost of disclosed emissions. We assume $s < m$, allowing for disclosure to increase the range of available private and public mitigation strategies and therefore decrease the social cost of emissions. For a particular level of disclosure, *z*, the per unit social cost of emissions is then given by $m - sz$.

When we assume, as we do in this section, that the regulator has complete information about the effectiveness of the audit process and the firm's demand for emissions, he can infer the firm's true emissions. However, this inference is no longer possible in a model with heterogeneity in the distribution of audit outcomes among firms, and incomplete information on the part of the regulator. Section III confirms that our main results continue to hold under these conditions. We maintain the complete information, homogeneous firms assumptions in this section for ease of exposition and because they allow us to develop a model which is somewhat more general in other respects.[12]

We model the situation facing the regulator as a minimization problem and assume his objective function, denoted *V*, is comprised of three terms: (1) the total damages from emissions net of expected taxes and fines paid by the firm; (2) enforcement costs; (3) the firm's net benefit from emitting. Based on our assumptions, the total social cost of emissions is equal to $e(\mu^*)\cdot(m - sz^*)$. The firm pays expected taxes and fines equal to $e(\mu^*)\cdot \mu^*$. Therefore, the total damages from emissions net of payments by the firm, the first component of *V*, is $e(\mu^*)[m - sz^* - \mu^*]$. We denote the cost of an audit to be *w*, so enforcement costs, the second component, are simply *pw*. As described earlier, the firm's optimized *net* benefit from emissions is represented by $\int_{\mu^*}^{\mu_c} e(\rho)d\rho$. This is the final component of *V*.

Given the three components, the regulator's objective function is:

$$V = e(\mu^*)[m - sz^* - \mu^*] + pw - \int_{\mu^*}^{\mu_c^*} e(\rho)d\rho \tag{5}$$

We assume the regulator minimizes *V* with respect to his choice of α, the tax on reported emissions, and *p*, the audit probability.[13] Therefore, we assume β, the marginal penalty

[12] In particular, the model with heterogeneous firms developed later relies on assuming linear demand for emissions among firms to obtain comparable results.
[13] In modeling the policy choices available to the regulator we have not allowed the regulator to choose a deposit-refund instrument in lieu of a tax. Swierzbinski [22] finds a deposit-refund system to be optimal in

on revealed but unreported emissions, is exogenous. In the context of our model the regulator would always do best to set this penalty as high as possible because doing so achieves the highest compliance given any tax with the least enforcement costs. This fairly standard result leads us to simply assume that the regulator faces some constraint on the magnitude of the penalty that can be imposed.[14]

The first order conditions for an interior solution to the regulator's problem are given by:

$$\frac{\partial V}{\partial \alpha} = 0 \Leftrightarrow e'(\mu^*)\frac{\partial \mu^*}{\partial \alpha}(m - sz^* - \mu^*) = e(\mu^*)s\frac{\partial z^*}{\partial \alpha}. \tag{6}$$

$$\frac{\partial V}{\partial p} = 0 \Leftrightarrow e(\mu^*)s\frac{\partial z^*}{\partial p} - e'(\mu^*)\frac{\partial \mu^*}{\partial p}(m - sz^* - \mu) = w. \tag{7}$$

Equation (6) indicates that the regulator chooses α^* to equate the marginal benefit of a higher tax (due to lower emissions) with the marginal cost of a higher tax (due to less truthful reporting). Similarly equation (7) illustrates that p^* equates the marginal benefit of increased audit frequency (greater disclosure and reduced emissions) and the marginal cost (additional audit resources, *w*).

Both a higher tax and higher audit probability achieve greater internalization of social costs (and thus a reduction in emissions), but each is costly in a different way. A

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a model of regulation with self reporting. However, as discussed earlier, the role of self reporting in Swierzbinski's model is quite different than in ours because it arises as a result of the regulator's uncertainty about a firm's pollution abatement costs (absent any direct benefits of disclosure). A deposit-refund scheme would not be optimal in general in our context because it raises the enforcement cost of internalizing social damages. Although a deposit-refund scheme could be optimal in our context under certain conditions, we've chosen to constrain the regulator to using a Pigovian tax both for simplicity and because deposit-refund mechanisms are not broadly utilized in environmental regulation (particularly in the U.S., see EPA [23])

[14] See, for example, Becker [2] and Harrington [7]. This assumption can also be grounded in the argument that the marginal penalty may include factors which are outside the regulator's control such as the market's reaction to news that a firm underreported its actual emissions or explicit fines and increased liability resulting from an independent judiciary process (Garvie and Keeler [4]).

higher tax reduces disclosure, which is costly when disclosure has direct benefits. A higher audit probability is directly costly as more resources are devoted to enforcement. To understand the interplay between these choices, consider the two extreme cases regarding the value of disclosure. First, suppose disclosure has no direct benefit so $s = 0$. In this case there is no interior solution on α; it is optimal to set $\alpha^* \geq p\beta$ (in which case the firm discloses nothing). This achieves the greatest internalization of social costs (arising entirely through fines rather than taxes) with the least expenditure on enforcement. The optimal audit probability, p^*, will reflect the marginal benefit of reduced emissions resulting from internalization relative to the marginal cost of auditing, and an interior solution will exist for w sufficiently large. At the other extreme, suppose that once emissions are disclosed they are no longer socially harmful, so $s = m$. In such a case the optimal policy involves zero tax on reported emissions. Full compliance with the disclosure requirement can then be achieved with a negligible audit probability. Although this extreme case may seem unrealistic, it conveys important intuition: as s approaches m the optimal policy may be minimal taxation and infrequent auditing. Auditing is costly for the regulator and high compliance rates can still be achieved with a low probability of audit when the tax on reported emissions is also low.

An interior solution in both dimensions of the regulator's choice will exist if s is sufficiently large but strictly less than m (i.e., the costs of emissions are sufficiently reduced but not completely eliminated by disclosure) and if the cost of auditing, w, is sufficiently large. We henceforth assume this is the case and focus our analysis on the comparative statics at an interior solution.

Proposition 3. The regulator's optimal tax, α^*, is increasing in *m*, the per unit social cost of undisclosed emissions and decreasing in *s*, the difference between the per unit social costs of undisclosed and disclosed emissions. The optimal audit probability *p** is decreasing in the cost of auditing, *w*.

The comparative static results regarding the optimal tax are broadly intuitive. The regulator trades-off internalizing social costs with a higher tax against the consequent reduction in disclosure; the more valuable is disclosure (due to higher *s*), the lower the optimal tax. Conversely, the more socially costly all emissions are (as represented by *m*), the higher the optimal tax in order to achieve greater internalization of these costs and lower resulting emissions. The effect of the cost of auditing, *w*, on α^* is ambiguous. A higher cost of auditing, *w*, does not directly affect the optimal tax but will of course reduce the optimal audit probability, *p**. Whether the optimal tax increases or decreases with an increase in *w* depends on how the decrease in the audit probability affects the marginal benefit and cost of the tax. The expression for $\frac{\partial \alpha^*}{\partial w}$ is provided in the appendix.

Unlike the comparative statics for the optimal tax, the directions of the effects of *m* and *s* on the optimal audit frequency are in general ambiguous. Consider first the effect of *m*. As the social cost of emissions rises (holding constant the reduction that occurs due to disclosure, *s*) the marginal benefit of internalizing emissions costs rises. For this reason it seems intuitive that the optimal audit probability would rise as well, since raising *p* increases the internalized cost of emitting. However, an increase in *m* increases the optimal tax α^* as stated in Proposition 3. This in turn increases μ^* and reduces emissions *ceteris paribus*. A reduction in emissions reduces the marginal benefit of achieving a higher percentage of emissions disclosure. This reduces the value of auditing with regards to achieving higher rates of disclosure. If the firm's elasticity of demand for emissions is very high, then the optimal response to an increase in *m* may be to raise the tax to reduce emissions but reduce the audit probability. The comparative static result shows that we cannot exclude the possibility that $\frac{\partial p^*}{\partial m} < 0$. However, were the regulator restricted to choosing only *p*, with α fixed, then we find unambiguously $\frac{\partial p^*}{\partial m} > 0$.

The ambiguity of the effect of an increase in *s* on the optimal audit probability is more easily understood. An increase in *s* has opposing effects on the value of auditing. A higher *s* increases the value of disclosure, which increases the marginal benefit of auditing. However, the higher *s* decreases the value of internalizing the social costs of emissions because the higher *s* reduces the social cost of emissions. This decreases the marginal benefit of auditing. Either effect may dominate. The expression which determines the sign of $\frac{\partial p^*}{\partial s}$ is stated in the appendix.

III. Heterogeneous Firms and Incomplete Information

Our model in the previous section assumes a single firm representative of a homogeneous industry, and complete information on the part of the regulator. While these assumptions greatly simplify the analytics of our model, they also imply that the regulator can infer the firm's actual emissions.[15] In this section, we discuss the issues

[15] Optimal regulatory policy in the context of the tradeoff between deterring emissions and eliciting truthful disclosure is, of course, determined at the margin. Assuming, as we do in section II, that the regulator has complete information about the firm's demand for emissions and about the firm's incentives to truthfully disclose (arising from the effectiveness and probability of audits) implies that the regulator

arising from inference of emissions levels, and relax our assumptions to allow for firm heterogeneity and incomplete information.

Any model that captures the trade-off faced by a regulator between reducing emissions and eliciting truthful disclosure of emissions must entail the regulator's forming some inference regarding firms' behavior. That is, the regulator must infer actual emissions and the extent to which firms' disclosures are untruthful in order to evaluate the marginal benefits and costs of policy changes that affect actual emissions and disclosure. This leads to something of a paradox: why does the regulator value disclosure if he can infer how much a firm will emit?

Most fundamentally, we argue that the reduction of social costs arising from a firm's disclosure of emissions is different from what can be achieved from inferring their presence. While we model disclosed emissions simply as a quantity, in practice emissions disclosure is likely to involve additional, directly beneficial but difficult to infer information involving the nature of emissions, the time and location of releases, etc.[16] The ability to mitigate the harm caused by emissions is likely to be very sensitive to these specific details, perhaps most importantly the immediate knowledge of a release (or even

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also knows exactly what level of actual emissions is optimal for the firm, in addition to knowing what percentage of emissions the firm will optimally disclose. However, the model can be thought of as simply a framework for understanding how a regulator would evaluate policy choices at the margin. In applying the model what is required is that the regulator form beliefs regarding how the truthfulness of disclosure and cost of emitting are affected at the margin by the policy parameters, and how the level of emissions is affected by the cost of emitting (i.e., the elasticity of demand for emissions). A regulator may well be able to estimate these marginal responses without actually having complete information. For example, the regulator may be able to estimate the elasticity of demand for emissions without knowing the entirety of the demand curve.

[16] This suggests several possible extensions that are beyond the scope of the current analysis. For example, one could permit firms to report more detailed information about the characteristics of their emissions and allow the social cost of disclosed emissions to vary with the nature of the information. As noted by an anonymous reviewer, one could also consider a model in which undiscovered and un-inferred emissions are most costly, followed by undiscovered but inferred emissions, and finally disclosed emissions. Both extensions would add additional complexity (and choice variables for the firm and regulator). We've restricted the model to capture what we believe are the most central aspects of policy choice in our context.

prior knowledge in the case of planned releases). A regulator's belief (or even certainty) that a firm is emitting more than it discloses may very well be insufficient to enable mitigation. Furthermore, the regulator presumably could not act to penalize the firm based on inferred emissions since penalties could not be legally enforced on inferred emissions that have not actually been revealed by the audit.

The representative firm model employed in section II implies that the regulator's inference is applicable to a specific firm. We develop a more general model here which entails firm heterogeneity. In this framework the regulator forms inference regarding aggregate industry emissions and average disclosure behavior, but cannot infer any specific firm's emissions level. This allows meaningful analysis of policy tradeoffs but enhances the distinction between disclosed and inferred emissions. In such a context it is clear that the disclosure of emissions by individual firms would enable mitigation of social costs that could not be achieved by inference regarding aggregate industry emissions. We show that in an industry with heterogeneous firms, in which the regulator is able to infer only average industry emissions, the main results of our model continue to hold.

Assume that each firm has private information, represented by the parameter *k*, regarding the distribution of audit outcomes if it is audited.[17] That is, if a *k*-type firm is audited, the audit reveals a quantity of emissions equal to $e \cdot (u+k)$ where *u* is a random variable with probability density function $f(u)$ and cumulative distribution function $F(u)$ on the interval $[1-d, 1+d]$. We assume $f(u)$ is unimodal and symmetric around 1.

[17] There are several other ways in which we might add firm heterogeneity. For example, we could assume that firms differ in their perceived penalties for non-reporting or in their probabilities of being found noncompliant as in Innes [12]. We thank an anonymous referee for suggesting these possibilities to us.

The value of *k* varies across firms and the regulator knows only the distribution of *k*, denoted $G(k)$ with support $[-\varepsilon, \varepsilon]$. The expected value of *k* is assumed to be zero so that on average across firms audits are unbiased. An additional assumption, that $d + \varepsilon < 1$, is required to ensure an interior solution on *z*.

An individual firm's objective remains unchanged—choose the report, *z*, and emissions, *e*, to maximize the expected net benefits of emitting:

$$\underset{e,z}{Max}\left\{ B(e) - e\left[\alpha z + p\beta \int_{z-k}^{d} (u + k - z) f(u) du \right]\right\}.$$

We can solve the first order condition on *z* to obtain an expression for z^*:

$$z^* = F^{-1}\left(1 - \frac{\alpha}{p\beta}\right) + k. \tag{9}$$

Given z^*, the first order condition on *e* can be stated as follows:

$$\alpha z^* + p\beta \int_{z^*-k}^{d} (u + k - z^*) f(u) du = B'(e^*) \text{ or } \mu^* = B'(e^*)$$

where $\mu^* = \alpha z^* + p\beta \int_{z^*-k}^{d} (u + k - z^*) f(u) du$ denotes the marginal cost of emitting given the optimal report. The form of firm heterogeneity we have introduced enters the model fairly simply; the firm-specific audit parameter simply shifts the optimal report, *z**. The unit-cost of emissions, μ^*, for a particular firm depends both directly on *k* and on the resulting *z** (with μ^* of course increasing in *k*). Note however that taking expectations across the industry $E[z^*] = F^{-1}\left(1 - \frac{\alpha}{p\beta}\right)$ and $E[\mu^*] = \alpha E[z^*] + p\beta \int_{E[z^*]}^{d} (u - E[z^*]) f(u) du$.

The fact that the expected values of these key firm choice variables parallel the expressions for *z** and μ^* in the representative firm model of section II will enable us to model the optimal policy of the regulator very similarly. The effects of policy parameters on $E[z*]$ and $E[\mu*]$ (and therefore expected or average total emissions) precisely parallel the results for the representative firm model on $z*$ and $\mu*$ described in Propositions 1 and 2.

Before turning our attention to the problem facing the regulator, note that the regulator is unable to infer a particular firm's true emissions, $e*$, in this context. To see this, let $x*$ represent the *level* of emissions the *k*-type firm (optimally) reports to the regulator where

$$x* = z*e* = \left[F^{-1}\left(1-\frac{\alpha}{p\beta}\right)+k\right]\cdot e(\mu*) \qquad (10)$$

with $\mu* = \alpha z* + p\beta \int_{z*-k}^{d}(u+k-z*)f(u)du$. The presence of *k* in the above expression breaks the inference—each $x*$ value is associated with more than one value of *k*.[18] To understand the intuition, consider two firms, one with a high value of *k* (audits are biased against it) and one with a low value of *k* (audits are biased in its favor). The firm with the high value of *k* will report a higher percentage of its emissions, possibly even more than 100%, but will emit less because its cost of emitting will be higher. The firm with the low

[18] Consider the case where the demand for emissions is linear: $e = a - c\mu$. With a linear demand for emissions, $x* = \left[F^{-1}\left(1-\frac{\alpha}{p\beta}\right)+k\right][a-c\mu*]$. The following two values of *k* yield the same value of $x*$:

$$k = -F^{-1}\left(1-\frac{\alpha}{p\beta}\right)-\frac{(a-c\gamma)+\sqrt{(a-c\gamma)^2-4c\alpha x*}}{-2x*}, -F^{-1}\left(1-\frac{\alpha}{p\beta}\right)+\frac{(a-c\gamma)+\sqrt{(a-c\gamma)^2-4c\alpha x*}}{-2x*}$$

where $\gamma \equiv p\beta \int_{F^{-1}\left(1-\frac{\alpha}{p\beta}\right)}^{b}\left(u-F^{-1}\left(1-\frac{\alpha}{p\beta}\right)\right)f(u)du$.

value of *k* will report a smaller share of actual emissions but will emit more. Because the level of emissions reported to the regulator is given by the product of z^* and e^*, both firms could report the same x^* thus breaking the inference.[19] While the regulator is unable to infer a particular firm's emissions based on its report, he can still infer average emissions since he knows the expected value of *k*.

When firms are heterogeneous and the regulator has incomplete information, the regulator is assumed to choose the optimal tax and audit probability based on his knowledge of expected (or average) firm behavior. That is, the regulator minimizes the expected value of the social welfare function described in Section II:

$$E(V) = E\left[e(\mu^*)[m - sz^* - \mu^*] + pw - \int_{\mu^*}^{\mu_c^*} e(\rho)d\rho \right].$$

This problem is made far more tractable by assuming each firm faces linear demand for emissions:

$$e(\mu^*) = a - c\mu^*.$$

Given this assumption, the regulator's objective function becomes:

$$E(V) = E\left\{ (a - c\mu^*)(m - sz^* - \mu^*) + pw - \frac{1}{2}(a - c\mu^*)\left(\frac{a}{c} - \frac{1}{c}\mu^*\right) \right\}$$

The regulator minimizes $E[V]$ with respect to his choices of the tax, α, and audit probability, *p*. The fact that the respective forms of $E[z^*]$ and $E[\mu^*]$ resemble those of z^* and μ^* in the homogeneous firm model, together with linearity of demand, makes the solution to the regulator's problem in this context closely parallel that discussed in section II. In particular, the comparative static results obtained for an interior solution to

[19] More generally, a firm's reported level of emissions will not be a monotonic function of its *k* parameter.

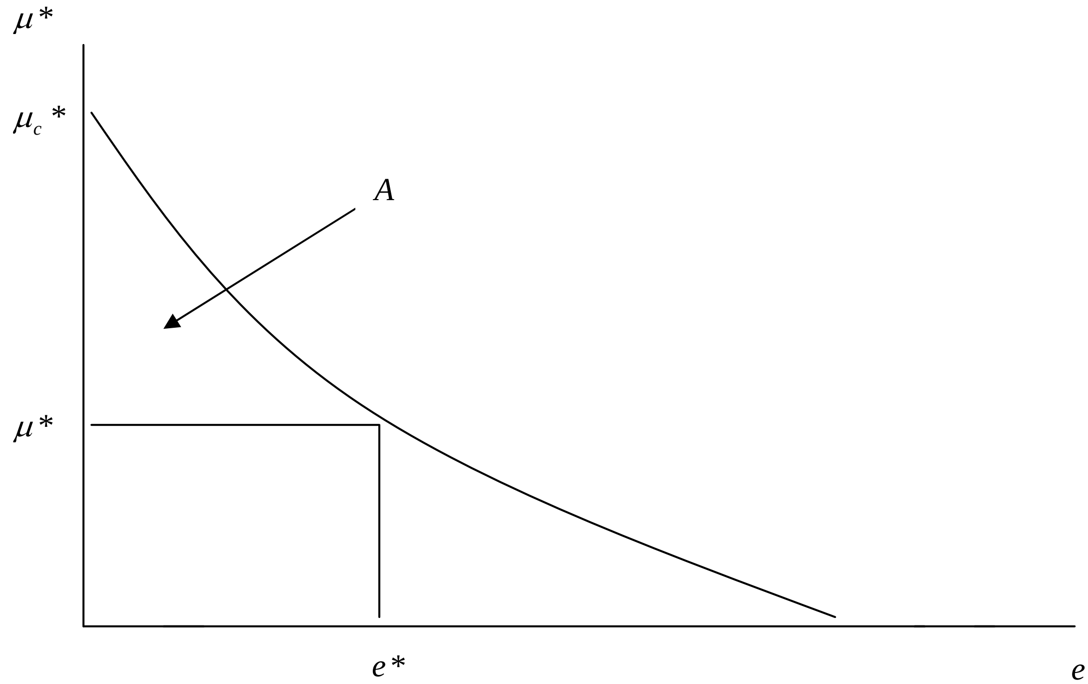
the regulators' problem hold with heterogeneous firm of the type modeled here. These results are formalized in the appendix.

IV. Conclusion

When information disclosure has direct social benefits but is costly for a firm and enforcement is costly and imperfect a regulator must confront the competing objectives of inducing disclosure and internalizing social costs. This tension is clearly present in many environmental regulatory contexts where the harm from emissions can be mitigated if potentially impacted parties have better information about the nature and quantity of emissions. It also exists in other regulatory settings such as product safety regulation. Disclosure of product defects and hazards has direct social benefits, but it is desirable that firms face a cost (either liability or fines) when their products cause harm in order to induce care.

There are certainly many avenues for future work in this area. One could imagine two policymakers, one of whom chooses a tax and the other the audit probability (e.g., legislature and executive or regulatory agency) but who have different objective functions and interact strategically. A regulator may have other policy instruments at his discretion, including choosing the audit probability for a firm in a dynamic setting based on past behavior. One also might consider an endogenous audit process in which the probability of audit is a decreasing function of disclosed emissions. We have not modeled the choice between putting enforcement resources into more frequent audits or more effective audits. Clearly a regulator must achieve an optimal balance, and the model we've developed could provide a framework for exploring this issue. We have assumed that disclosure costs (tax) and penalties are constant per unit, and that audit effectiveness is independent of firm size or total emissions. Relaxing these assumptions significantly complicates the analysis, but could inform important issues regarding how regulation affects industry structure.

Figure 1. Firm's demand for emissions



Appendix

Proofs for Section II

Proof of Proposition 1:

Define $\upsilon \equiv 1-\frac{\alpha}{p\beta}$. The comparative static results for $z^* = F^{-1}\left(1-\frac{\alpha}{p\beta}\right) = F^{-1}(\upsilon)$ where $F(\cdot)$ is monotonically increasing in its augment and $\alpha < p\beta$ for an interior solution are given by:

$$\frac{\partial z^*}{\partial \alpha} = -\frac{1}{p\beta}\left(\frac{1}{f(z^*)}\right) < 0 \quad \text{(A1)}$$

$$\frac{\partial z^*}{\partial p} = \frac{\alpha}{p^2\beta}\left(\frac{1}{f(z^*)}\right) > 0 \quad \text{(A2)}$$

$$\frac{\partial z^*}{\partial \beta} = \frac{\alpha}{p\beta^2}\left(\frac{1}{f(z^*)}\right) > 0 \quad \text{(A3)}$$

Proof of Proposition 2:

The second order condition for minimization is satisfied: $-B''(e^*) > 0$. The comparative static results for e are derived implicitly.

$$\frac{\partial e^*}{\partial \alpha} = \frac{z^*}{B''(e^*)} < 0 \quad \text{(A4)}$$

$$\frac{\partial e^*}{\partial p} = \frac{\beta}{B''(e^*)}\int_{z^*}^{b}(u - z^*)f(u)du < 0 \quad \text{(A5)}$$

$$\frac{\partial e^*}{\partial \beta} = \frac{p}{B''(e^*)}\int_{z^*}^{b}(u - z^*)f(u)du < 0 \quad \text{(A6)}$$

Proof of Proposition 3:

The elements of the Hessian for the regulator's problem are:

$$\begin{aligned}\frac{\partial^2 V}{\partial \alpha^2} \equiv f_{11} &= e'(\mu^*)\left[(m - 3sz^* - \mu^*)\frac{\partial z^*}{\partial \alpha} - (z^*)^2\right] \\ &\quad - se(\mu^*)\frac{\partial^2 z^*}{\partial \alpha^2} + e''(\mu^*)(m - sz^* - \mu^*)(z^*)^2\end{aligned} \quad \text{(A7)}$$

$$\begin{aligned}\frac{\partial^2 V}{\partial p^2} \equiv f_{22} &= e'(\mu^*)\left[(m - sz^* - \mu^*)\frac{\partial^2 \mu^*}{\partial p^2} - 2s\frac{\partial z^*}{\partial p}\frac{\partial \mu^*}{\partial p} - \left(\frac{\partial \mu^*}{\partial p}\right)^2\right] \\ &\quad - se(\mu^*)\frac{\partial^2 z^*}{\partial p^2} + e''(\mu^*)(m - sz^* - \mu^*)\left(\frac{\partial \mu^*}{\partial p}\right)^2 > 0\end{aligned} \quad \text{(A8)}$$

$$\frac{\partial^2 V}{\partial\alpha\partial p} \equiv f_{12} = e'(\mu^*)\left[(m - sz^* - \mu^*)\frac{\partial z^*}{\partial p} - s\frac{\partial z^*}{\partial\alpha}\frac{\partial\mu^*}{\partial p} - sz^*\frac{\partial z^*}{\partial p} - z^*\frac{\partial\mu^*}{\partial p}\right] \qquad \text{(A9)}$$
$$- se(\mu^*)\frac{\partial^2 z^*}{\partial\alpha\partial p} + e''(\mu^*)(m - sz^* - \mu^*)z\frac{\partial\mu^*}{\partial p}$$

For an interior solution, the determinant of the Hessian, denoted $|H|$, must be positive or $|H| = f_{11}f_{22} - (f_{12})^2 > 0$. Therefore for an interior solution to the regulator's problem, $f_{11} > 0$ since $f_{22} > 0$.

The following second order effects are necessary to compute the comparative static results of interest:

$$\frac{\partial^2 V}{\partial\alpha\partial m} \equiv f_{1m} = e'(\mu^*)z^* < 0 \qquad \text{(A10)}$$

$$\frac{\partial^2 V}{\partial p\partial m} \equiv f_{2m} = e'(\mu^*)\frac{\partial\mu^*}{\partial p} < 0 \qquad \text{(A11)}$$

$$\frac{\partial^2 V}{\partial\alpha\partial s} \equiv f_{1s} = -e(\mu^*)\frac{\partial z^*}{\partial\alpha} - e'(\mu^*)(z^*)^2 > 0 \qquad \text{(A12)}$$

$$\frac{\partial^2 V}{\partial p\partial s} \equiv f_{2s} = -e(\mu^*)\frac{\partial z^*}{\partial p} - e'(\mu^*)z^*\frac{\partial\mu^*}{\partial p} \qquad \text{(A13)}$$

$$\frac{\partial^2 V}{\partial\alpha\partial w} \equiv f_{1w} = 0 \qquad \text{(A14)}$$

$$\frac{\partial^2 V}{\partial p\partial w} \equiv f_{2w} = 1 \qquad \text{(A15)}$$

We begin with the comparative static results for the optimal tax on reported emissions, denoted α^*.

$$\frac{\partial\alpha^*}{\partial m} = \frac{1}{|H|}\begin{vmatrix} -f_{1m} & f_{12} \\ -f_{2m} & f_{22}\end{vmatrix} = \frac{1}{|H|}\left[-f_{1m}f_{22} + f_{2m}f_{12}\right] > 0 \text{ given } |H| > 0$$

since

$$-f_{1m}f_{22} + f_{2m}f_{12}$$
$$= se(\mu^*)e'(\mu^*)\left[\frac{\partial\mu^*}{\partial\alpha}\frac{\partial^2 z^*}{\partial\alpha^2} - \frac{\partial\mu^*}{\partial p}\frac{\partial^2 z^*}{\partial\alpha\partial p}\right] \qquad \text{(A16)}$$
$$+ [e(\mu^*)]^2\left[(m - sz^* - \mu^*)\left(\frac{\partial\mu^*}{\partial p}\frac{\partial z^*}{\partial p} - z^*\frac{\partial^2\mu^*}{\partial p^2}\right) + s\frac{\partial\mu^*}{\partial p}\left(\frac{\partial z^*}{\partial p} - \frac{\partial z^*}{\partial\alpha}\right)\right] > 0$$

$$\frac{\partial\alpha^*}{\partial s} = \frac{1}{SOC}\begin{vmatrix} -f_{1s} & f_{12} \\ -f_{2s} & f_{22}\end{vmatrix} = \frac{1}{SOC}\left[-f_{1s}f_{22} + f_{2s}f_{12}\right] < 0 \text{ given } SOC > 0$$

since

$$
\begin{aligned}
&- f_{1s} f_{22} + f_{2s} f_{12} \\
&= s[e(\mu^*)]^2\left(\frac{\alpha^*}{p^*}\psi\frac{\partial z^*}{\partial \alpha}\right) + sz^* e(\mu^*)e'(\mu^*)\left(\frac{\partial \mu^*}{\partial p}\frac{\partial^2 z^*}{\partial \alpha \partial p} - z^*\frac{\partial^2 z^*}{\partial p^2}\right) \\
&+ e(\mu^*)e''(\mu^*)(m - sz^* - \mu^*)\frac{\partial \mu^*}{\partial p}\left[\frac{\partial z^*}{\partial \alpha}\frac{\partial \mu^*}{\partial p} - z^*\frac{\partial z^*}{\partial p}\right] \\
&+ [e'(\mu^*)]^2 z^*(m - sz^* - \mu^*)\left(z^*\frac{\partial^2 \mu^*}{\partial p^2} - \frac{\partial z^*}{\partial p}\frac{\partial \mu^*}{\partial p}\right) \\
&+ sz^*[e'(\mu^*)]^2 \frac{\partial \mu^*}{\partial p}\left[\frac{\partial z^*}{\partial \alpha}\frac{\partial \mu^*}{\partial p} - z^*\frac{\partial z^*}{\partial p}\right] \\
&+ e(\mu^*)e'(\mu^*)\left(s\frac{\partial z^*}{\partial p} + \frac{\partial \mu^*}{\partial p}\right)\left(z^*\frac{\partial z^*}{\partial p} - \frac{\partial z^*}{\partial \alpha}\frac{\partial \mu^*}{\partial p}\right) < 0
\end{aligned}
\tag{A17}
$$

where $\psi \equiv \left[\frac{\partial F(\upsilon)}{\partial \upsilon}\right]^{-1} \frac{1}{(p^*)^2 \beta} > 0$ with $\upsilon \equiv 1 - \frac{\alpha^*}{p^* \beta}$.

The comparative static result for *w* on α^* is generally ambiguous:

$$
\frac{\partial \alpha^*}{\partial w} = \frac{1}{SOC}\begin{vmatrix} -f_{1w} & f_{12} \\ -f_{2w} & f_{22} \end{vmatrix} = \frac{1}{SOC}\left[-f_{1w}f_{22} + f_{2w}f_{12}\right] = \frac{1}{SOC}\left[f_{12}\right]
$$

Given $SOC > 0$, the sign of $\frac{\partial \alpha^*}{\partial w}$ equals the sign of f_{12}, which is given as equation (A9) above.

We now derive the comparative static results for the optimal audit probability, p^*. The comparative static result for *w* on p^* is given by:

$$
\frac{\partial p^*}{\partial w} = \frac{1}{SOC}\begin{vmatrix} -f_{11} & f_{1w} \\ -f_{12} & f_{2w} \end{vmatrix} = \frac{1}{SOC}\left[-f_{11}f_{2w} + f_{12}f_{1w}\right] = \frac{1}{SOC}\left[-f_{11}\right] < 0 \text{ since } f_{11} > 0.
$$

The signs of $\frac{\partial p^*}{\partial m}$ and $\frac{\partial p^*}{\partial s}$ are generally ambiguous. The respective expressions follow:

$$
\begin{aligned}
\frac{\partial p^*}{\partial m} &= \frac{1}{SOC}\begin{vmatrix} -f_{11} & f_{1m} \\ -f_{12} & f_{2m} \end{vmatrix} = \frac{1}{SOC}\left[-f_{11}f_{2m} + f_{12}f_{1m}\right] \\
&= \frac{1}{SOC}\left\{se(\mu^*)e'(\mu^*)\left[\frac{\partial \mu^*}{\partial p}\frac{\partial^2 z^*}{\partial \alpha^2} - z^*\frac{\partial^2 z^*}{\partial \alpha \partial p}\right] + [e(\mu^*)]^2(m - 2sz^* - \mu^*)\left(z^*\frac{\partial z^*}{\partial p} - \frac{\partial z^*}{\partial \alpha}\frac{\partial \mu^*}{\partial p}\right)\right\}
\end{aligned}
$$

$$\frac{\partial p*}{\partial s}=\frac{1}{SOC}\begin{vmatrix}-f_{11} & f_{1s}\\ -f_{12} & f_{2s}\end{vmatrix}=\frac{1}{SOC}\left[-f_{11}f_{2s}+f_{12}f_{1s}\right]$$

$$=\frac{1}{SOC}\Bigg\{s[e(\mu*)]^2\left(\psi\frac{\partial z*}{\partial\alpha}\right)+sz*e(\mu*)e'(\mu*)\left(\frac{\partial\mu*}{\partial\alpha}\frac{\partial^2z*}{\partial\alpha\partial p}-\frac{\partial\mu*}{\partial p}\frac{\partial^2z*}{\partial\alpha^2}\right)$$

$$+e(\mu*)e''(\mu*)(m-sz*-\mu*)z*\left[z*\frac{\partial z*}{\partial p}-\frac{\partial z*}{\partial\alpha}\frac{\partial\mu*}{\partial p}\right]$$

$$+[e'(\mu*)]^2z*(m-sz*-\mu*)\left(\frac{\partial z*}{\partial\alpha}\frac{\partial\mu*}{\partial p}-\frac{\partial z*}{\partial p}\frac{\partial\mu*}{\partial\alpha}\right)$$

$$+s(z*)^2[e'(\mu*)]^2\left[z*\frac{\partial z*}{\partial p}-\frac{\partial z*}{\partial\alpha}\frac{\partial\mu*}{\partial p}\right]+e(\mu*)e'(\mu*)\left(s\frac{\partial z*}{\partial\alpha}+z*\right)\left(\frac{\partial z*}{\partial\alpha}\frac{\partial\mu*}{\partial p}-z*\frac{\partial z*}{\partial p}\right)\Bigg\}$$

Proofs for Section III

Below, we reexamine the model presented in Section II relaxing the homogeneous firms and perfect information assumptions. Consider first the problem facing a *k*-type firm, among many heterogeneous firms. The firm's reported emissions are denoted by ez. The emissions revealed by audit are $x=e\cdot(u+k)$, where k represents the firm's individual characteristic that is unknown to the regulator. k is defined on the support $[-\varepsilon,\varepsilon]$ with mean zero. u is a random variable with probability density function $f(u)$ on the interval $[1-d,1+d]$. $f(u)$ is unimodal and symmetric around 1. The firm is found underreporting if $x>ez$. The expected level of underreporting for a *k*-type firm is

$$\int_{z-k}^{d}[e(u+k)-ez]f(u)du=e\int_{z-k}^{d}(u+k-z)f(u)du$$

The firm's objective function is then

$$\underset{e,z}{Min}\;\; e\cdot\left[\alpha z+p\beta\int_{z-k}^{d}(u+k-z)f(u)du\right]-B(e)$$

The first order conditions for an interior solution on *e* and *z* are given respectively by:

$$\alpha z+p\beta\int_{z-k}^{d}(u+k-z)f(u)du-B'(e*)=0 \qquad \text{(A18)}$$

$$e\left[\alpha-p\beta\int_{z*-k}^{d}f(u)du\right]=0 \qquad \text{(A19)}$$

Solving (A19) for $z*$ yields

$$z*=F^{-1}\left(1-\frac{\alpha}{p\beta}\right)+k\,.$$

Because *k* is a constant, the comparative static results on *z** are the same as in the homogenous firm model (see equations (A1) through (A3) above).
The comparative static results on $e*$ are given as follows:

$$\frac{\partial e^*}{\partial \alpha} = \frac{z^*}{B''(e^*)} < 0 \tag{A20}$$

$$\frac{\partial e^*}{\partial p} = \frac{\beta}{B''(e^*)} \int_{z^*-k}^{d} (u + k - z^*) f(u) du < 0 \tag{A21}$$

$$\frac{\partial e^*}{\partial \beta} = \frac{p}{B''(e^*)} \int_{z^*-k}^{d} (u + k - z^*) f(u) du < 0 \tag{A22}$$

Now consider the regulator's problem when firms' demands for emissions are linear and given by $e(\mu) = a - c\mu$. Given incomplete information on *k*, the regulator now minimizes, $E(V)$, with respect to his choices of α and *p* where

$$E(V) = E\left\{ e(\mu^*)(m - sz^* - \mu^*) - \frac{1}{2} e(\mu^*)\left(\frac{a}{c} - \frac{1}{c}\mu^* \right) + pw \right\}$$

$$= pw + am - \frac{1}{2}\frac{a^2}{c} - asE(z^*) - cmE(\mu^*) + csE(\mu^* \cdot z^*) + \frac{1}{2} cE\left((\mu^*)^2 \right)$$

with $\mu^* = \alpha z^* + p\beta \int_{z^*-k}^{d} (u + k - z^*) f(u) du$ denoting the marginal cost of emitting given the optimal report, *z**.

Define $\phi \equiv F^{-1}\left(1 - \frac{\alpha}{p\beta}\right)$ and $\gamma \equiv p\beta \int_{\phi}^{d} (u - \phi) f(u) du$. Given our notation,

$$E(z^*) = F^{-1}\left(1 - \frac{\alpha}{p\beta}\right) = \phi$$

$$E(\mu^*) = \alpha F^{-1}\left(1 - \frac{\alpha}{p\beta}\right) + p\beta \int_{\phi}^{d} (u - \phi) f(u) du = \alpha\phi + \gamma$$

$$E(z^* \cdot \mu^*) = E[(\phi + k)\cdot(\alpha(\phi + k) + \gamma)] = \alpha\phi^2 + \gamma\phi + \alpha Var(k)$$

$$E\left[(\mu^*)^2\right] = E\left[(\alpha(\phi + k) + \gamma)^2\right] = \gamma^2 + \alpha^2\phi^2 + \alpha^2 Var(k) + 2\alpha\gamma\phi$$

where $Var(k)$ denotes the variance of the random variable *k*.

After substituting the above expressions into $E(V)$, we can write the first order conditions for an interior solution as:

$$\frac{\partial E(V)}{\partial \alpha} \equiv g_1 = -s\frac{\partial \phi}{\partial \alpha}[a - c(\alpha\phi + \gamma)] - c\phi[m - s\phi - (\alpha\phi + \gamma)] + (cs + c\alpha)Var(k) = 0$$

$$\frac{\partial E(V)}{\partial p} \equiv g_2 = w - s\frac{\partial \phi}{\partial p}[a - c(\alpha\phi + \gamma)] - c\frac{\gamma}{p}[m - s\phi - (\alpha\phi + \gamma)] = 0$$

The second order effects follow. Each expression includes a comparison between the second order effect in the heterogeneous firm model (denoted by *g*'s), and the associated second order effect that would obtain in the homogeneous firm model assuming linear demand for emissions (denoted by $\bar{f}$'s). The latter model is a special case of the more general model in Section II of the paper (see equations (A10) through (A15) for the second order effects with a more general demand function).

$$\frac{\partial^2 V}{\partial \alpha^2} \equiv g_{11} = -s\frac{\partial^2 \phi}{\partial \alpha^2}\left[a - c(\alpha\phi+\gamma)\right]$$

$$+c\left[\phi^2 + 2s\phi\frac{\partial \phi}{\partial \alpha} - \left(m - s\phi - (\alpha\phi+\gamma)\right)\frac{\partial \phi}{\partial \alpha}\right] + cVar(k) \qquad \text{(A23)}$$

$$= \bar{f}_{11} + cVar(k)$$

$$\frac{\partial^2 V}{\partial p^2} \equiv g_{22} = -s\frac{\partial^2 \phi}{\partial p^2}\left[a - c(\alpha\phi+\gamma)\right]$$

$$+c\left[\left(\frac{\gamma}{p}\right)^2 + 2\frac{s\gamma}{p}\frac{\partial \phi}{\partial p} + \left(m - s\phi - (\alpha\phi+\gamma)\right)\frac{\alpha}{p}\frac{\partial \phi}{\partial p}\right] = \bar{f}_{22} > 0 \qquad \text{(A24)}$$

$$\frac{\partial^2 V}{\partial \alpha \partial p} \equiv g_{12} = -s\frac{\partial^2 \phi}{\partial \alpha \partial p}\left[a - c(\alpha\phi+\gamma)\right]$$

$$+c\left[\phi\frac{\gamma}{p} + s\frac{\gamma}{p}\frac{\partial \phi}{\partial \alpha} + s\phi\frac{\partial \phi}{\partial p} - \left(m - s\phi - (\alpha\phi+\gamma)\right)\frac{\partial \phi}{\partial p}\right] = \bar{f}_{12} \qquad \text{(A25)}$$

$$\frac{\partial^2 V}{\partial \alpha \partial m} \equiv g_{1m} = -c\phi = \bar{f}_{1m} < 0 \qquad \text{(A26)}$$

$$\frac{\partial^2 V}{\partial p \partial m} \equiv g_{2m} = -c\frac{\gamma}{p} = \bar{f}_{2m} < 0 \qquad \text{(A27)}$$

$$\frac{\partial^2 V}{\partial \alpha \partial s} \equiv g_{1s} = -\frac{\partial \phi}{\partial \alpha}\left[a - c(\alpha\phi+\gamma)\right] + c\phi^2 + cVar(k) = \bar{f}_{1s} + cVar(k) \qquad \text{(A28)}$$

$$\frac{\partial^2 V}{\partial p \partial s} \equiv g_{2s} = -\frac{\partial \phi}{\partial p}\left[a - c(\alpha\phi+\gamma)\right] + c\frac{\gamma}{p}\phi = \bar{f}_{2s} \qquad \text{(A29)}$$

$$\frac{\partial^2 V}{\partial \alpha \partial w} \equiv g_{1w} = 0 = \bar{f}_{1w} \qquad \text{(A30)}$$

$$\frac{\partial^2 V}{\partial p \partial w} \equiv g_{2w} = 1 = \bar{f}_{2w} \qquad \text{(A31)}$$

We now state the comparative static results for the regulator's choice variables in the heterogeneous firms, incomplete information model.

$$\frac{\partial \alpha^*}{\partial m} = \frac{1}{|H|}\begin{vmatrix} -g_{1m} & g_{12} \\ -g_{2m} & g_{22} \end{vmatrix} = \frac{1}{|H|}\left[-g_{1m}g_{22} + g_{2m}g_{12}\right] = \frac{1}{|H|}\left[-\bar{f}_{1m}\bar{f}_{22} + \bar{f}_{2m}\bar{f}_{12}\right] > 0$$

by equation (A16). As above $|H|$ denotes the determinant of the Hessian. For an interior solution, $|H| > 0$ which implies $g_{11} = \bar{f}_{11} + cVar(k) > 0$.

$$\frac{\partial \alpha^*}{\partial s} = \frac{1}{|H|}\begin{vmatrix} -g_{1s} & g_{12} \\ -g_{2s} & g_{22} \end{vmatrix} = \frac{1}{|H|}\left[-g_{1s}g_{22} + g_{2s}g_{12}\right] = \frac{1}{|H|}\left[-\bar{f}_{1s}\bar{f}_{22} + \bar{f}_{2s}\bar{f}_{12}\right] - \frac{1}{|H|}cVar(k)g_{22} < 0$$

since the term in brackets is negative by (A17) and $g_{22} > 0$.

$$\frac{\partial p^*}{\partial w} = \frac{1}{|H|}\begin{vmatrix} -g_{11} & g_{1w} \\ -g_{12} & g_{2w} \end{vmatrix} = \frac{1}{|H|}\left[-g_{11}g_{2w} + g_{12}g_{1w}\right] = \frac{1}{|H|}\left[-g_{11}\right] = \frac{1}{|H|}\left[-\left(\bar{f}_{11} + cVar(k)\right)\right] < 0.$$

The signs of $\frac{\partial \alpha^*}{\partial w}$, $\frac{\partial p^*}{\partial m}$, and $\frac{\partial p^*}{\partial s}$ are generally ambiguous. The respective expressions follow:

$$\frac{\partial \alpha^*}{\partial w} = \frac{1}{|H|}\begin{vmatrix} -g_{1w} & g_{12} \\ -g_{2w} & g_{22} \end{vmatrix} = \frac{1}{|H|}\left[-g_{1w}g_{22} + g_{2w}g_{12}\right] = \frac{1}{|H|}\left[-\bar{f}_{1w}\bar{f}_{22} + \bar{f}_{2w}\bar{f}_{12}\right] = \frac{1}{|H|}\left[\bar{f}_{12}\right]$$

$$\frac{\partial p^*}{\partial m} = \frac{1}{|H|}\begin{vmatrix} -g_{11} & g_{1m} \\ -g_{12} & g_{2m} \end{vmatrix} = \frac{1}{|H|}\left[-g_{11}g_{2m} + g_{12}g_{1m}\right] = \frac{1}{|H|}\left[-\bar{f}_{11}\bar{f}_{2m} + \bar{f}_{12}\bar{f}_{1m}\right] - cVar(k)g_{2m}$$

$$\frac{\partial p^*}{\partial s} = \frac{1}{|H|}\begin{vmatrix} -g_{11} & g_{1s} \\ -g_{12} & g_{2s} \end{vmatrix} = \frac{1}{|H|}\left[-\bar{f}_{11}\bar{f}_{2s} + \bar{f}_{12}\bar{f}_{1s}\right] + \frac{1}{|H|}cVar(k)\left(\bar{f}_{12} - \bar{f}_{2s}\right)$$

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Competing Environmental Labels*

DRAFT: DO NOT CIRCULATE

Carolyn Fischer† and Thomas P. Lyon‡

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Abstract

We study markets in which consumers prefer environmentally friendly products but cannot determine the environmental quality of any given firm's product on their own. A non-governmental organization (NGO) can establish a voluntary standard and label the products of firms whose products comply with the standard. Alternatively, industry can create its own standard and label. We compare the stringency of these two labels, and analyze how they interact.

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†Fellow, Resources for the Future, 1616 P St, NW, Washington, DC 20036. Email: fischer@rff.org.
‡Dow Chair of Sustainable Science, Technology and Commerce, Ross School of Business, University of Michigan, Ann Arbor, MI, 48109. Email: tplyon@umich.edu.

1 Introduction

Global environmental issues such as biodiversity and climate change are increasingly important to citizens around the world, but are extremely difficult for governments to address with standard policy tools. The globalization of trade and the need for international coordination on global issues make harmonised world standards for environmental problems unlikely anytime soon. Global trade law also makes it difficult for governments to attempt to regulate attributes of production processes outside their borders, as opposed to inherent product attributes. In the absence of standards for production behavior related to the environment, many groups have put increasing effort into international market mechanisms such as ecolabeling. In some cases, industry takes the lead in developing labels, as in the case of Starkist's move to dolphin-safe tuna (Reinhardt 2000, pp. 31-34) or the pulp and paper industry's "Totally Chlorine Free" label (US EPA 1998, p. B115). In other cases, non-governmental organizations (NGOs) sponsor labels, such as the "Good Environmental Choice" label created by the Swedish Society for the Conservation of Nature (US EPA, p. B99), or the Forest Stewardship Council (FSC) label, which was created by a coalition of groups. In some cases, industry has responded with its own certification standards that employ alternative criteria. The Sustainable Forestry Initiative (SFI) is perhaps the best known of these, and has generated considerable rancor from environmentalists concerned that the weaker SFI standard is undermining the FSC's effectiveness.

There are a number of reports and articles that present case studies on ecolabels. For example, U.S. EPA (1998) offers a thorough review of global use of ecolabels. Sasser et al.

(2006) present an interesting discussion of the competition between FSC and SFI, and which types of firms tend to participate in one labeling scheme as opposed to the other. Yet despite the growing importance of ecolabels, and of competition between them, there has been little formal economic analysis of their effects. Nimon and Beghin (1999) compare competing government standards for a producer in the "North" and one in the "South" to the case with no standards; they find that the South is more interested in harmonising standards than is the North. Heyes and Maxwell (2004) present an insightful model of the potential interaction between a standard adopted by a "World Environmental Organization" (WEO) subject to political pressures, and an ecolabel promulgated by a non-governmental organization (NGO). They find that if the two labels are mutually exclusive, then the creation of the NGO may reduce welfare by undermining the more socially desirable WEO label. If the two labels coexist, however, then the NGO label is a beneficial complement to that of the WEO. Baksi and Bose (2007) compare NGO labels with self-labeling by individual firms, finding that the latter generally dominate the former if the government is willing to engage in costly monitoring of the self-labels.

Our analysis differs from previous work in that we develop a formal model of the rivalry between an NGO label and an industry-sponsored label in a setting with a large number of competing firms. In our analysis government is responsible for neither setting standards nor for monitoring the performance of labels developed by other organizations. We find that if there is only one label, the NGO adopts a more stringent label than does the industry. Furthermore, industry further relaxes its label if the two labels coexist. However, no general conclusion can be drawn regarding how the NGO label responds to the presence of an industry label; the NGO may tighten or loosen its standards depending upon the distribution of types of firms in the market. Nor is it clear whether environmental damages are higher or lower in the presence of both labels than with the NGO label alone.

The remainder of the paper is organized as follows. Section 2 lays out our basic model, section 3 analyzes the case of a single NGO label and section 4 studies the case of a single industry label. Section 5 compares the two. Section 6 studies the case where the two labels coexist, and section 7 presents simulation results that provide insight into how the NGO label responds to the presence of a competing industry label. Section 8 concludes.

2 Basic Model

The industry consists of a group of n firms that supply a product that sells in a global market. Absent any abatement, each operating firm emits pollutants that impose an external cost on domestic consumers of $Z > 0$. Firms, which are indexed by θ, differ according to their costs of abatement. Each firm chooses its own abatement level s, the cost of which is θs. We assume θ is distributed over $[\underline{\theta}, \overline{\theta}]$ with probability density $f(\theta)$ and cumulative distribution $F(\theta)$. The distribution $F(\theta)$ is common knowledge, but the efficiency of any given firm is not known to other firms or consumers.

There is a large number of consumers, $m > n$, all of whom have "green" preferences. These are captured by assuming that the representative consumer has a willingness-to-pay $p(s)$ with $p'(s) > 0$ and $p''(s) < 0$. For technical reasons that will become apparent below, we assume that $p'(0) < \underline{\theta}$.

If consumers know that a firm has undertaken abatement level s, and the firm has abatement cost θ, then its profits are

$$\pi(\theta, s) = p(s) - \theta s.$$

However, in the absence of any labels, consumers cannot distinguish the abatement levels of any individual firms, so a firm has no incentive to undertake any abatement and aggregate environmental damages are $ZF(\overline{\theta}) = Z$.

We begin with the situation in which firms have only one labeling option, developed by by institution i with standard s^i. That institution would certify all firms that meet or exceed this level, and allow them to display an ecolabel to consumers. A firm of type θ would mitigate to the level required to obtain certification if $p(s^i) - \theta s^i > p(0)$, or if its costs are lower than the corresponding cutoff level θ^i:

$$\theta < \theta^i \equiv \frac{p(s^i) - p(0)}{s^i}. \tag{1}$$

Thus an interval of low-cost firms would choose to be certified. Note that

$$\frac{\partial \theta^i}{\partial s^i} = \frac{s^i p'(s^i) - (p(s^i) - p(0))}{(s^i)^2} = \frac{s^i p'(s^i) - s^i \theta^i}{(s^i)^2} = \frac{p'(s^i) - \theta^i}{s^i} < 0. \tag{2}$$

The concavity of $p(s)$ ensures that the sign of this expression is negative.[1] In other words, as the standard gets more stringent, fewer firms adopt because the cutoff cost rate falls. Since we assume that $p'(0) < \overline{\theta}$, this holds even as $s \to 0$. Note that (2) implicitly imposes an upper bound on the standard that can be imposed, namely $\overline{s}$ defined by

$$\frac{p(\overline{s}) - p(0)}{\overline{s}} = \underline{\theta}.$$

There are a number of assumptions in this model that may be worth exploring in subsequent analysis. We assume the willingness to pay for an unlabeled good (or other labeled good) is unaffected by the presence or stringency of another labeled good. We also assume firms are not initially differentiated according to their environmental quality. There is no exit or entry in the model, and no market power.

3 NGO Label

Suppose the NGO is on its own in developing an ecolabel. The NGO is assumed to have as its objective the minimization of environmental damages, so it chooses its standard s^N (and correspondingly θ^N) to minimize

$$D(s^N) = \int_{\underline{\theta}}^{\theta^N} (Z - s^N) f(\theta) d\theta + \int_{\theta^N}^{\overline{\theta}} Z f(\theta) d\theta = Z - s^N F(\theta^N)$$

[1] This can be shown with a Taylor expansion: $p(0) \cong p(s^N) + p'(s^N)(-s^N) + \frac{1}{2}p''(s^N)(-s^N)^2$, so $s^N p'(s^N) - (p(s^N) - p(0)) \cong \frac{1}{2}p''(s^N)(-s^N)^2 < 0$.

The first-order condition is

$$
\begin{aligned}
\frac{\partial D(s^N)}{\partial s^N} &= -\int_{\underline{\theta}}^{\theta^N} f(\theta)d\theta + \frac{\partial \theta^N}{\partial s^N}(Z - s^N)f(\theta^N) - \frac{\partial \theta^N}{\partial s^N} Z f(\theta^N) \\
&= -F(\theta^N) - \frac{\partial \theta^N}{\partial s^N} s^N f(\theta^N) = 0
\end{aligned}
$$

which implies

$$
p'(s^N) = \theta^N - \frac{F(\theta^N)}{f(\theta^N)}. \tag{3}
$$

Checking the second-order conditions,

$$
\begin{aligned}
\frac{\partial^2 D(s^N)}{\partial (s^N)^2} &= -p''(s^N)f(\theta^N) - (F'(\theta^N) - f(\theta^N) + (p'(s^N) - \theta^N)f'(\theta^N))\frac{\partial \theta^N}{\partial s^N} \\
&= -p''(s^N)f(\theta^N) - (p'(s^N) - \theta^N)^2 \frac{f'(\theta^N)}{s^N} \\
&\simeq -p''(s^N)f(\theta^N) > 0
\end{aligned}
$$

we see an implicit constraint on the distribution to ensure a concave objective function, i.e., that $-p''(s^N)s^N/(p'(s^N) - \theta^N)^2 > f'(\theta^N)/f(\theta^N)$. With the uniform distribution $f'(\theta^N) = 0$, implying $\frac{\partial^2 D(s^N)}{\partial (s^N)^2} = -p''(s^N)f(\theta^N) > 0$.

Industry profits are

$$
\Pi(s^N) = \int_{\underline{\theta}}^{\theta^N} (p(s^N) - \theta s^N) f(\theta)d\theta + \int_{\theta^N}^{\overline{\theta}} p(0)f(\theta)d\theta > \int_{\underline{\theta}}^{\overline{\theta}} p(0)f(\theta)d\theta,
$$

where the inequality follows from the fact that $p(s^N) - \theta s^N > p(0)$ for all firms that adopt the ecolabel.

4 Industry Label

Suppose now that there is no NGO label, and the industry sets its own label instead. The industry sets a standard s^I and firms decide whether or not to mitigate to a level that complies with the standard. A firm of type θ will do so if $\theta < \theta^I$, as previously defined.

The industry is assumed to have as its objective the maximization of industry profits, so it chooses s^I to maximize[2]

$$\Pi(s^I) = \int_{\underline{\theta}}^{\theta^I} (p(s^I) - \theta s^I) f(\theta) d\theta + \int_{\theta^I}^{\overline{\theta}} p(0) f(\theta) d\theta.$$

The first-order condition is

$$\frac{\partial \Pi(s^I)}{\partial s^I} = \int_{\underline{\theta}}^{\theta^I} (p'(s^I) - \theta) f(\theta) d\theta + \frac{\partial \theta^I}{\partial s^I} (p(s^I) - \theta^I s^I - p(0)) f(\theta^I) = 0.$$

From the definition of θ^I we know that $p(s^I) - \theta^I s^I = p(0)$, so the above simplifies to

$$\frac{\partial \Pi(s^I)}{\partial s^I} = \int_{\underline{\theta}}^{\theta^I} (p'(s^I) - \theta) f(\theta) d\theta = 0. \tag{4}$$

[2] An important assumption here is that the label does not change demand for the unlabeled product, so that it only affects profits of the labeled products.

We can rearrange terms to get

$$p'(s^I) = \frac{\int_{\underline{\theta}}^{\theta^I} \theta f(\theta) d\theta}{F(\theta^I)}. \tag{5}$$

Integrating by parts yields

$$\int_{\underline{\theta}}^{\theta^I} \theta f(\theta) d\theta = [\theta F(\theta)]_{\underline{\theta}}^{\theta^I} - \int_{\underline{\theta}}^{\theta^I} F(\theta) d\theta = \theta^I F(\theta^I) - \int_{\underline{\theta}}^{\theta^I} F(\theta) d\theta.$$

Thus the industry's FOC can be rewritten as

$$p'(s^I) = \theta^I - \frac{\int_{\underline{\theta}}^{\theta^I} F(\theta) d\theta}{F(\theta^I)}. \tag{6}$$

Industry profits are

$$\Pi(s^I) = \int_{\underline{\theta}}^{\theta^I} (p(s^I) - \theta s^I) f(\theta) d\theta + \int_{\theta^I}^{\overline{\theta}} p(0) f(\theta) d\theta > \int_{\underline{\theta}}^{\overline{\theta}} p(0) f(\theta) d\theta,$$

where the inequality follows from the fact that $p(s^I) - \theta s^I > p(0)$ for all firms that adopt the ecolabel. Clearly, since industry maximizes profits, industry profits are at least as great as when the NGO sets the ecolabel.

5 Comparing Labels

Now we want to compare the degrees of stringency chosen for the two kinds of labels. To do so we impose the relatively weak assumption that the density $f(\theta)$ is log-concave, which means the natural logarithm of $f(\theta)$ is concave. Bagnoli and Bergstrom (2005) show that this property is satisfied by such familiar distributions as the uniform, the normal, the exponential, and the logistic distributions.

Proposition 1 *If $f(\theta)$ is log-concave, then the NGO always sets a more stringent standard than does the industry.*

Proof. From the two first-order conditions (3) and (6), $s^N > s^I$ if $p'(s^N) < p'(s^I)$, or if for any $\widehat{\theta}$

$$\frac{F(\widehat{\theta})}{f(\widehat{\theta})} > \frac{\int_{\underline{\theta}}^{\widehat{\theta}} F(\theta)d\theta}{F(\widehat{\theta})}. \tag{7}$$

Rearranging terms, this is equivalent to

$$\left[F(\widehat{\theta})\right]^2 > f(\widehat{\theta}) \int_{\underline{\theta}}^{\widehat{\theta}} F(\theta)d\theta. \tag{8}$$

Now define

$$G(x) = \int_{\underline{\theta}}^{x} F(\theta)d\theta,$$

so that $G'(x) = F(x)$ and $G''(x) = f(x)$ for any x in the support of the random variable θ. Given this, we can rewrite (8) as

$$G''(x)G(x) - [G'(x)]^2 < 0. \tag{9}$$

Remark 3 in the Appendix of Bagnoli and Bergstrom (2004) shows that $G(x)$ is log-concave if and only if (9) holds. Furthermore, Theorem 1 of Bagnoli and Bergstrom (2004) establishes that log-concavity is inherited, that is, if $f(x)$ is log-concave, then so are $F(x)$ and $G(x)$. Hence, because $f(x)$ is log-concave, so is $G(x)$, which implies immediately that (9) holds. ■

It may be helpful to present a special case with simple closed-form solutions as a reference point. For this purpose we will work with the assumption that $F(\theta)$ is uniform on $[0,1]$ and that the function $p(s)$ is a simple quadratic that takes the form $p(s) = p(0) + s - s^2/2$. Then the NGO's first-order condition becomes $p'(s) = 1 - s^N = \theta^N - \theta^N = 0$. Thus $s^N = 1$. Using equation (1), we find that $\theta^N = 1/2$, that is, half of the firms elect to be certified with the NGO label. Total abatement is $s^N F(\theta^N) = 1/2$.

For the case with a uniform distribution and quadratic willingness-to-pay, the industry's first-order condition becomes

$$p'(s) = 1 - s^I = \theta^I - \frac{\int_0^{\theta^I} \theta d\theta}{\theta^I} = \frac{\theta^I}{2}.$$

. Thus $s^I = 1 - \theta^I/2$. At the same time, by (1), we know $\theta^I \equiv (p(s^I) - p(0))/s^I = (s^I - (s^I)^2/2)/s = 1 - s^I/2$. Solving these two expressions jointly yields $s^I = 2/3$ and $\theta^I = 2/3$. Total abatement under the industry ecolabel is $s^N F(\theta^N) = 4/9$. Thus, the industry ecolabel is weaker, but attracts more participation, than does the NGO. Total abatement under the industry ecolabel is less than under the NGO ecolabel.

6 Combining NGO and Industry Labels

We turn now to the interaction between the two ecolabels when they coexist. We begin with the case in which the NGO sets a label first, and the industry then responds. We then turn to the opposite case.

6.1 Industry Response

Suppose the NGO has set a standard s^N and the industry chooses a best response. We conduct the analysis by considering first the case where the NGO standard is above the industry response, then the opposite. Throughout we will use subscript “A” for “autarky" to denote standards when only one entity sets a standard, and the subscript “B” to denote the case where both labels exist. Where it will not cause confusion we drop the subscripts in order to economize on notation.

6.1.1 NGO Standard Higher than Industry Response

If industry chooses a standard $s^I < s^N$ then $\theta^I > \theta^N$. Industry profits are then

$$\Pi(s^I; s^N) = \int_{\underline{\theta}}^{\theta^N} (p(s^N) - \theta s^N) f(\theta) d\theta + \int_{\theta^N}^{\theta^I} (p(s^I) - \theta s^I) f(\theta) d\theta + \int_{\theta^I}^{\overline{\theta}} p(0) f(\theta) d\theta$$

At the cutoff cost factor θ^I, the alternative to the industry label is still no label, so $\theta^I \equiv (p(s^I) - p(0))/s^I$ as before.

The first-order condition is now

$$\begin{aligned}\frac{\partial \Pi(s_B^I)}{\partial s^I} &= \int_{\theta^N}^{\theta^I} (p'(s^I) - \theta) f(\theta) d\theta + \frac{\partial \theta^I}{\partial s^I} (p(s^I) - \theta s^I - p(0)) f(\theta^I) \\ &= \int_{\theta^N}^{\theta_B^I} (p'(s_B^I) - \theta) f(\theta) d\theta = 0,\end{aligned}$$

recalling that the second part drops out by the definition of θ^I. Note that this has the same form as (4) except that the lower limit of the integral is now θ^N instead of $\underline{\theta}$. If we evaluate the above condition at the autarky standard we see that:

$$\frac{\partial \Pi(s_B^I)}{\partial s^I} = \int_{\underline{\theta}}^{\theta_A^I} (p'(s_0^I) - \theta) f(\theta) d\theta < \int_{\underline{\theta}}^{\theta_A^I} (p'(s_0^I) - \theta) f(\theta) d\theta = 0.$$

Thus, marginal profits are negative at the autarky standard, due to less participation from competition with the NGO label, which implies that industry wants to choose a lower standard than it would in the absence of an NGO label. We record this result in the following lemma.

Lemma 2 *If the NGO sets a standard s^N, and industry responds with a less stringent standard s_B^I, it must be the case that $s_B^I < s_A^I$.*

6.1.2 NGO Standard Lower than Industry Response

If industry chooses a standard $s^I > s^N$ (and hence $\theta^I < \theta^N$) then industry profits are

$$\Pi(s^N) = \int_{\underline{\theta}}^{\theta^I} (p(s^I) - \theta s^I) f(\theta) d\theta + \int_{\theta^I}^{\theta^N} (p(s^N) - \theta s^N) f(\theta) d\theta + \int_{\theta^N}^{\overline{\theta}} p(0) f(\theta) d\theta.$$

Note that we have two conditions determining which label a firm signs up for. A firm of type θ will choose the NGO standard rather than no standard if $p(s^N) - \theta s^N > p(0)$, or

$$\theta < \theta^N \equiv \frac{p(s^N) - p(0)}{s^N}.$$

A firm of type θ will choose the industry standard rather than the NGO standard if $p(s^I) - \theta s^I > p(s^N) - \theta s^N$, or

$$\theta < \theta_B^I \equiv \frac{p(s^I) - p(s^N)}{s^I - s^N}.$$

Differentiating with respect to s^N we obtain

$$\frac{\partial \theta^I}{\partial s^N} = \frac{p(s^I) - p(s^N) - p'(s^N)(s^I - s^N)}{(s^I - s^N)^2} < 0.$$

The inequality can easily be shown by a geometric argument. If $p(s)$ were linear, then the numerator would be zero. However, $p(s)$ is actually concave, so $p'(s^N)(s^I - s^N) > p(s^I) - p(s^N)$. If $s^N = 0$, then we would have $\theta_B^I = \theta_A^I$, the autarky level. Now, however, we have $s^N > 0$, so $\theta_B^I < \theta_A^I$ for any given level of s^N.

The industry's first-order condition is now

$$\begin{aligned}\frac{\partial \Pi(s^I)}{\partial s^I} &= \int_{\underline{\theta}}^{\theta_A^I}(p'(s^I)-\theta)f(\theta)d\theta + \frac{\partial \theta^I}{\partial s^I}(p(s^I)-\theta^I s^I - (p(s^N)-\theta^I s^N))f(\theta^I) \\ &= \int_{\underline{\theta}}^{\theta_B^I}(p'(s^I)-\theta)f(\theta)d\theta = 0\end{aligned}$$

This condition has exactly the same form as (4), so at first glance it appears as if industry wants to set the same standard as in the absence of the NGO standard. However, since $\theta_B^I < \theta_A^I$, marginal profits are lower than they would be in autarky; therefore, the industry will again choose a weaker standard than in the absence of an NGO label. Hence we have the following lemma.

Lemma 3 *If the NGO sets a standard s^N, and industry responds with a more stringent standard s_B^I, it must be the case that $s_B^I < s_A^I$.*

Combining this result and that of the preceding lemma implies that the industry always chooses to loosen its standard in response to the presence of an NGO label. We present this result in the following proposition.

Proposition 4 *If the NGO sets a standard and then industry responds with a standard s_B^I, it must be the case that $s_B^I < s_A^I$, that is, industry sets a less stringent standard than it would if there were no NGO label.*

6.2 NGO Response

Now suppose industry sets a standard s^I and then the NGO responds with a standard s_B^N.

6.2.1 Industry Standard Lower than NGO Response

If the NGO chooses a higher standard $s_B^N > s^I$ then $\theta^I > \theta^N$. Now, the relevant comparison for the cut-off firm at θ^N is not being unlabeled, but rather adopting the lower industry standard. A firm of type θ will choose the industry standard rather than no standard if $p(s^I) - \theta s^I > p(0)$, or

$$\theta < \theta^I \equiv \frac{p(s^I) - p(0)}{s^I}.$$

A firm of type θ will choose the NGO standard rather than the industry standard if $p(s_B^N) - \theta s_B^N > p(s^I) - \theta s^I$, or

$$\theta < \theta_B^N \equiv \frac{p(s_B^N) - p(s^I)}{s_B^N - s^I} < \theta^I.$$

By the same logic as in the industry case, we can show that $\theta_B^N < \theta_A^N$. In other words, by offering another option besides no label, the industry label reduces participation in the NGO label and lowers the relevant threshold cost for adopting the NGO label. Note that

$$\frac{\partial \theta^N}{\partial s^N} = \frac{(s^N - s^I)p'(s^N) - (s^N - s^I)\theta^N}{(s^N - s^I)^2} = \frac{p'(s^N) - \theta^N}{(s^N - s^I)}.$$

The NGO's objective function is

$$D(s^N; s^I) = \int_{\underline{\theta}}^{\theta^N} (Z - s^N) f(\theta) d\theta + \int_{\theta^N}^{\theta^I} (Z - s^I) f(\theta) d\theta + \int_{\theta^I}^{\overline{\theta}} Z f(\theta) d\theta.$$

Its first-order condition is now

$$\begin{aligned}\frac{\partial D}{\partial s^N} &= -\int_{\underline{\theta}}^{\theta^N} f(\theta)d\theta + \frac{\partial \theta^N}{\partial s^N}(Z - s^N - (Z - s^I))f(\theta^N) = 0. \\ &= -F(\theta^N) - (p'(s^N) - \theta^N)f(\theta^N).\end{aligned}$$

Thus, once again we appear to recover the same first-order condition as in autarky:

$$p'(s^N) = \theta^N - \frac{F(\theta^N)}{f(\theta^N)}.$$

However, recall that $\theta_B^N < \theta_A^N$. This has a direct effect of reducing the first term on the right-hand side of this equation, but it also reduces the cumulative distribution and has an ambiguous impact on the density. Therefore, the NGO may respond to the industry standard by either tightening or loosening its standard, or not at all, depending on the relative size of these factors. If we return to the uniform distribution, we see again that $p'(s^N) = \underline{\theta}$, and thus the NGO does not respond to the presence of a looser industry standard. The benefits of any additional tightening (or loosening) of standards by participants are just offset by changes in participation in the NGO standard.

We summarize these findings in the following lemma.

Lemma 5 *If the industry sets a standard s^I and then the NGO responds with a higher standard $s_B^N > s^I$, it is possible for $s_B^N > s_A^N$ but also possible for $s_B^N \leq s_A^N$.*

6.2.2 Industry Standard Higher than NGO Response

Suppose now that the industry sets a standard, and the NGO responds with a lower one such that $s_B^N < s^I$. In this case,

$$\theta^I \equiv \frac{p(s^I) - p(s^N)}{s^I - s^N} < \theta_B^N \equiv \frac{p(s^N) - p(0)}{s^N}.$$

Damages are

$$D(s^N; s^I) = \int_{\underline{\theta}}^{\theta^I} (Z - s^I) f(\theta) d\theta + \int_{\theta^I}^{\theta^N} (Z - s^N) f(\theta) d\theta + \int_{\theta^N}^{\overline{\theta}} Z f(\theta) d\theta.$$

The NGO's first-order condition is now

$$\begin{aligned} \frac{\partial D}{\partial s^N} &= -\int_{\theta^I}^{\theta^N} f(\theta) d\theta + \frac{\partial \theta^N}{\partial s^N}(Z - s^N - Z)) f(\theta^N) = 0. \\ &= F(\theta^I) - F(\theta^N) - (p'(s^N) - \theta^N) f(\theta^N). \end{aligned}$$

Rearranging terms, we get

$$p'(s_B^N) = \theta^N - \frac{F(\theta^N) - F(\theta^I)}{f(\theta^N)} \tag{10}$$

Comparing this to (3), the NGO's first-order condition under autarky, it is clear that the right-hand side of (10) is strictly larger, since it includes the additional term $F(\theta^I)/f(\theta^N)$. Since $p''(s) < 0$, this implies that $s_B^N < s_A^N$. Thus, the effect of the industry standard is to reduce the share of firms conforming to the NGO standard, so the NGO to responds to the presence of a higher industry standard by lowering its standard, relative to autarky. We summarize this result in the following lemma.

Lemma 6 *If the industry sets a standard s^I and then the NGO responds with a lower standard $s_B^N < s^I$, then $s_B^N < s_A^N$.*

Combining the results of this lemma and the previous one leads to the following proposition regarding how the NGO responds to an industry standard.

Proposition 7 *If the industry sets a standard s^I and the NGO responds with a standard s_B^N, then if $s_B^N < s^I$ it must be the case that $s_B^N < s_A^N$. However, if $s_B^N > s^I$, it is possible for $s_B^N > s_A^N$ but also possible for $s_B^N \leq s_A^N$.*

It is interesting that the NGO's response to the presence of a pre-existing competing label is more contingent than is the industry's response, which is always to relax its standard. Intuition suggests that the most likely scenario is one in which $s_B^I < s_A^I < s_A^N$, and that $s_B^N > s_B^I$, but whether $s_B^N > s_A^N$ or $s_B^N \leq s_A^N$ depends upon details of the probability distribution of θ, as shown in the discussion of Lemma 5 above. Section 7 presents simulation analyses of this issue.

6.3 Effects of Label Competition

It seems unlikely that industry would set a standard higher than the NGO, given that its autarky standard is lower and its response to an NGO standard is to further loosen its own standard. Therefore, we focus on cases in which $s_B^N > s_B^I$. With a uniform distribution, of course,the Nash equilibrium is straightforward, since $s_B^N = s_A^N > s_A^I > s_B^I$.

6.3.1 Damages

It is easy to compare damages between the autarky systems; obviously, since the NGO minimizes damages, they will be lower with an NGO label than with an industry label. However, what happens to damages when the industry introduces its own label alongside the NGO label?

Suppose that $s_B^N = s_A^N > s_B^I$, as in the uniform distribution case; then $\theta_B^N < \theta_A^N < \theta_A^I < \theta_B^I$. The change in damages is

$$\begin{aligned} D(s_A^N; s_B^I) - D(s_A^N; 0) &= \int_{\underline{\theta}}^{\theta_B^N} (Z - s_A^N) f(\theta) d\theta + \int_{\theta_B^N}^{\theta^I} (Z - s_B^I) f(\theta) d\theta \\ &+ \int_{\theta_B^I}^{\overline{\theta}} Z f(\theta) d\theta - \int_{\underline{\theta}}^{\theta_A^N} (Z - s_A^N) f(\theta) d\theta - \int_{\theta_A^N}^{\overline{\theta}} Z f(\theta) d\theta \\ &= \int_{\theta_B^N}^{\theta_A^N} (s_A^N - s^I) f(\theta) d\theta - \int_{\theta_A^N}^{\theta_B^I} (s_B^I) f(\theta) d\theta \end{aligned}$$

Thus, the change in damages depends whether the lost reductions from those firms who switch from the NGO label to the industry one outweigh the additional reductions from former non-adopters who now adopt the industry standards. Note that if $s_B^N \neq s_A^N$, then damages must be lower, since the NGO minimizes damages. Thus, the above evaluation of the change in damages represents an upper bound.

With the uniform distribution, it can be shown that the change in damages is

$$
\begin{aligned}
D(s_A^N; s_B^I) - D(s_A^N; 0) &= f\left((s_A^N - s_B^I)(\theta_A^N - \theta_B^N) - s_B^I(\theta_B^I - \theta_A^N)\right) && (11) \\
&= f\left(s_A^N(\theta_A^N - \theta_B^N) - s_B^I(\theta_B^I - \theta_B^N)\right) = 0 && (12)
\end{aligned}
$$

Thus, in this particular case, adding the industry label to the NGO label does exactly as much good as harm, in terms of environmental damages. This gives us the following proposition.

Proposition 8 *With a uniform distribution $F(\theta)$, adding an industry label to an existing NGO label has no effect on environmental damages.*

6.3.2 Profits

By definition, the addition of an industry-chosen label to a market with an NGO label must weakly raise profits. The question is, how do profits compare to the situation in which the industry chooses the sole label?

Recall that since $s_A^I > s_B^I$, we also have $\theta_B^N < \theta_A^I < \theta_B^I$. Then we can compare

$$
\begin{aligned}
& \Pi(s_B^I; s_A^N) - \Pi(s_A^I; 0) \\
= & \int_{\underline{\theta}}^{\theta_B^N} \underbrace{(p(s_B^N) - p(s_A^I) - \theta(s_B^N - s_A^I))}_{+} f(\theta)d\theta \\
& - \int_{\theta_B^N}^{\theta_A^I} \underbrace{(p(s_A^I) - p(s_B^I) - \theta(s_A^I - s_B^I))}_{+} f(\theta)d\theta + \int_{\theta_A^I}^{\theta_B^I} (p(s_B^I) - \theta s_B^I - p(0)) f(\theta)d\theta \\
> & \int_{\underline{\theta}}^{\theta_B^N} \underbrace{(p(s_B^N) - p(s_A^I) - \theta(s_B^N - s_A^I))}_{+} f(\theta)d\theta - \int_{\theta_B^N}^{\theta_A^I} \underbrace{(p(s_A^I) - p(s_A^I) - \theta(s_A^I - s_A^I))}_{0} f(\theta)d\theta \\
& + \int_{\theta_A^I}^{\theta_A^I} \underbrace{(p(s_A^I) - \theta s_A^I - p(0))}_{0} f(\theta)d\theta > 0
\end{aligned}
$$

Thus, having an NGO standard alongside the industry standard raises profits. The proof relies on the fact that if any firm following the industry standard instead chooses to follow the NGO standard, profits must be higher than otherwise. Subsequently, if the industry chooses to adjust its standard, it only does so if it raises industry profits. Thus, we show that the extra profits from adding the NGO standard are strictly positive when industry sticks with the autarky standard. Those extra profits and the extra participation achieved with the optimal standard necessarily outweigh the lower prices from the looser standard. This yields the following proposition.

Proposition 9 *Industry profits are higher when an industry label and an NGO label coexist than when there exists only the industry label.*

7 Simulations

Our analysis thus far has yielded some sharp results, such as the fact that in autarky the NGO sets a more stringent label than does industry, and that industry weakens its label further if both labels coexist. However, we also showed that it is unclear in general how the NGO responds to the presence of the industry label, and unclear whether environmental damages increase or decrease with label competition. To shed further light on these questions, we conduct simulation analyses.

We consider two possible willingness-to-pay functions, a quadratic function of the form $p(s) = ys - ms^2/2$, with two parameter combinations for y and m, and a logarithmic function of the form $p(s) = \ln(1 + s)$. (We analyzed the former under the assumption of a uniform distribution $F(\theta)$ in section 5 above.) Figure 1 displays these price functions; the parameter combinations $y = 1, m = 1$ follow the log function more closely at low levels of stringency, while the combinations $y = .2, m = .005$ follow the log function better at higher stringency levels. The marginal price functions are quite different, though.

For the density $f(\theta)$, we use the Beta distribution, which is defined as

$$f(\theta; a, b) = \frac{\theta^{a-1}(1-\theta)^{b-1}}{\int_0^1 u^{a-1}(1-u)^{b-1}du} = \frac{\Gamma(a+b)}{\Gamma(a)\Gamma(b)}\theta^{a-1}(1-\theta)^{b-1}.$$

where $\Gamma(u)$ is the gamma function.[3] The Beta distribution is defined on the interval $[0, 1]$, has mean $E(\theta) = a/(a + b)$, and is log-concave if $a \geq 1$ and $b \geq 1$. (Bagnoli and Bergstrom

[3]There is no closed-form representation for the Beta distribution.

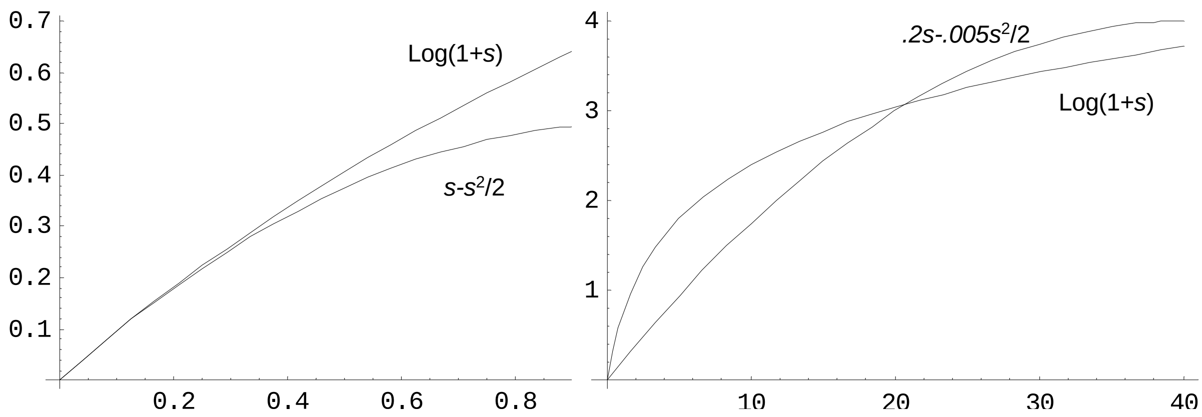

Figure 1: Simulation Price Functions

2005) The Beta distribution is convenient because it can take on a great variety of shapes depending upon the values of a and b. For example, if $a = b$, the density is unimodal with mean 1/2, and if in addition $a = b = 1$, we have the uniform distribution. When $a < b$, the density skews to the left, while if $a > b$, the density skews to the right. Figure two gives examples of different combinations of these distribution parameters.

The first table reports simulation results assuming the log price function and different distribution functions for θ. In all cases, the equilibrium industry standard and price premium is lower than in autarky, while the NGO targets a higher premium than in autarky. Participation rates in the industry label are sometimes slightly higher, sometimes slightly lower with both labels compared to autarky. For the NGO label, however, participation always drops precipitously when the industry label is present. In some cases, there are larger changes in damages (more reductions) with both labels in the market, while in others–notably, for tighter distributions (higher values of a and b)–damages are higher (fewer reductions) with both standards than with the NGO label alone.

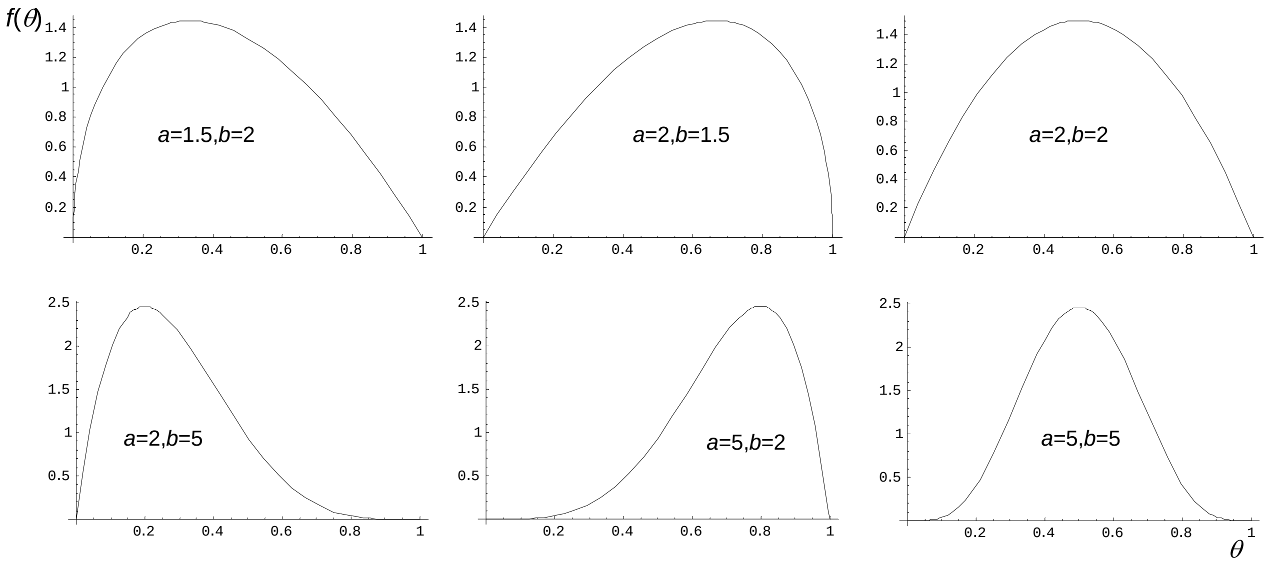

Figure 2: Example Distribution Functions for θ

Figure 3: Simulation Results with Different Distribution Functions ($p(s) = Log[1 + s]$)

Distribution Parameters a	b	*Prices* pIA	pIB	pNA	pNB	*Participation Rates* %IA	%NA	%IB	%NB	*Change in Damages* Industry	NGO	Both
2	5	0.64	0.60	1.23	1.54	82%	29%	80%	5%	-2.75	-4.62	-4.14
1.5	2	0.58	0.55	1.42	1.90	59%	11%	60%	2%	-1.64	-2.71	-3.03
2	2	0.46	0.41	0.89	1.15	59%	22%	60%	5%	-1.12	-1.49	-1.55
5	5	0.34	0.33	0.53	0.81	84%	53%	84%	2%	-1.00	-1.26	-1.06
2	1.5	0.42	0.38	0.80	1.19	51%	20%	52%	3%	-0.83	-1.05	-1.17
5	2	0.21	0.20	0.30	0.67	59%	41%	60%	1%	-0.38	-0.41	-0.40

Figure 4: Simulation Results with Different Price Functions ($a = 2, b = 3$)

Price Function	*Prices*				*Participation Rates*				*Change in Damages*		
	pIA	pIB	pNA	pNB	%IA	%NA	%IB	%NB	Ind.	NGO	Both
Log[1+s]	0.53	0.49	1.03	1.38	71%	25%	70%	4%	-1.67	-2.45	-2.44
(.2-.005s/2)s	2.60	2.55	3.07	3.92	1.4%	1.2%	1.4%	0.0%	-0.23	-0.24	-0.23
(1-s/2)s	.127	.125	.192	.191	90%	71%	88%	3%	-.576	-.688	-.578

The second table reports simulations exploring the role of the price function. In the last case, the NGO responds to the presence of an industry label by loosening its own standard. In all of these cases, damages are higher than with the NGO label alone. Additional simulations using different distributions with the quadratic price forms all produced the result in which damages are most reduced by the NGO label alone.

8 Conclusions

We have presented a formal economic model of voluntary ecolabels developed by an environmental NGO and by industry. We showed that an NGO label is more stringent than an industry ecolabel, assuming there is only one label present in the market at a time. When an NGO label is added to a market with an industry label, industry weakens its standard and industry profits increase. Since the NGO only enters the market if it can reduce damages, environmental quality necessarily improves relative to the industry label alone. However, when an industry label is added to a market with an NGO label, the NGO may strengthen or weaken its label. Furthermore, environmental damages may rise or fall with two labels, relative to a situation with the NGO label by itself. These latter results are sensitive both to the distribution of compliance costs among firms and to the willingness to pay for increasingly stringent standards.

Several simplifications in this analysis merit exploration in further research. We have assumed that consumer willingness to pay for one label depends only on the standard for that label; in reality, ecolabels may function as substitutes, meaning prices would depend on the qualities of the other labels as well. Adding this feature would create additional interactions between competing labeling schemes. We have also assumed that standards set targets for reductions in damages. While this assumption may be applicable for some voluntary programs, many environmental labels set absolute standards, in which case the labeling groups would face more complicated twin distributions of firms by costs and by emissions. We would expect that including these additional complications would tend to reinforce ambiguity in the environmental effectiveness of competing ecolabels.

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Environmental Labeling and Motivation Crowding-Out

Draft Interim Report

Christopher D. Clark, Kimberly L. Jensen, Clifford S. Russell,
Steven T. Yen, and W. Michael Hanemann

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Environmental Labeling and Motivation Crowding-Out

The provision of information has in the last few decades become an important complement to, and even a means of, environmental regulation. There are a variety of information provision programs disseminating different types of information to different audiences. Voluntary environmental labeling or certification programs that provide information about the environmental characteristics of one or more aspects of a product's life cycle to consumers are among the most popular of these programs, having been widely adopted around the world in one form or another (USEPA, 1998, 1994, and 1993).

The United States has not missed this boat. Indeed, the U.S. Environmental Protection Agency (USEPA) and the U.S. Department of Energy (USDOE) were among the first governmental agencies in the world to adopt environmental information programs.[1] While the number of environmental information programs instituted by USEPA and USDOE has continued to grow, they have, for the most part, been limited to providing information on attributes that include not only a "public" benefit for the ambient environment but also a "private" benefit for the individual consumer. A specific example is provided by the ENERGY STAR® program, a rating program for electricity-using equipment and appliances, where increased energy efficiency translates into both reduced emissions from reduced energy demand (public benefit) and savings in electricity bills to the individual consumer (private benefit). This U.S. preference for labels with both public and private attributes is somewhat unusual, with many other nations having adopted programs that focus solely on environmental benefits.

One possible explanation for the difference in approach could be a concern that public benefits alone are not enough to motivate consumer behavior or, at least that labels will be more

[1] Legislation authorizing Energy Guide, pesticide labeling, and the Fuel Economy Information Program were enacted in 1975, while authority for toxic substances labeling was passed in 1976 (Russell, 2001).

effective if the public benefits associated with the label are supplemented with a reminder of associated private benefits. While neo-classical economic theory would seem to provide strong justification for such a concern, recent experimental and empirical results and advances in economic theory cast some doubt on this strategy. This project's work will largely be concerned with the specific challenge provided by the concept of "motivation crowding-out" (MCO), which posits that the presence of extrinsic rewards for a contemplated behavior (such as private benefits) may actually reduce an individual's intrinsic motivation to engage in that behavior (Frey, 1994). For example, Frey and Oberholzer-Gee (1997) found that offering to pay residents to accept a nuclear waste dump in their community reduced their stated willingness to accept the dump. If motivation crowding-out also applies to consumer labeling, then it may mean that labels with purely public attributes will be at least as effective as, if not more effective than, labels with both public and private attributes, as the private benefits may have a tendency to crowd-out the intrinsic motivation associated with the public benefits.

Thus, this research seeks to discover whether, in a controlled setting, consumer responses to different types of environmental labels do exhibit motivation crowding-out. The specific public benefits to be analyzed will be reductions in greenhouse gas emissions, while the private benefits will be energy cost savings. USEPA's ENERGY STAR labeling program will be used to signal the presence of both public and private benefits, while both USEPA's Green Power Partners program and a hypothetical "Energy Savings Manufacturer" program will be used to signal purely public benefits. The products to be analyzed will be refrigerator with various mixes of characteristics or attributes (subject to the outcomes of focus group analysis). Consumer responses to these different labels and to a variety of other product attributes will be collected through an online conjoint analysis (CA) exercise. More generally, this exercise will support an examination of a variety of factors related to consumer responses to these environmental labeling programs.

The remainder of this report is organized as follows. The next section provides some background information on the relevant environmental labeling programs, primarily USEPA's ENERGY STAR and Green Power Partner programs. The objectives and policy relevance of the research are then discussed in more detail. Following this discussion is a broad overview of prior research on a variety of topics related to this research. This in turn leads to a detailed discussion of the economic model that underlies the CA instrument follows. The methods and procedures that will be employed to analyze consumer responses to environmental labels are then discussed. A concluding section offers some thoughts on the relevance of this research for environmental policy.

Policy Background

The ENERGY STAR program, established in 1992, is jointly administered by the Environmental Protection Agency and the Department of Energy. One of the program's activities is to certify those appliances that meet specified energy saving criteria more stringent than the minimum federal requirements. For example, refrigerators became eligible for the ENERGY STAR label in 1996, with ENERGY STAR qualified refrigerator models using at least 15% less energy than required by federal standards. The ENERGY STAR hurdle will be raised to 20% starting in 2008 (USEPA, 2007e). Since its introduction, the ENERGY STAR logo has become widely recognized, with public awareness now exceeding 65%. Further, the program would appear to be having an influence on consumers as survey results indicate that about 66% of the households who had knowingly purchased an ENERGY STAR product in the last six months pointed to the

ENERGY STAR certification as an influence in their purchase decision (USEPA, 2007a). Along the same lines, Banerjee and Solomon (2003) found that, among five popular U.S. eco-labeling programs (ENERGY STAR, Energy Guide, Green-e, Green Seal and Scientific Certification Systems), ENERGY STAR had the highest degree of market influence.

As pointed out earlier, ENERGY STAR products promise two benefits for consumers relative to conventional product models. First, by purchasing an ENERGY STAR certified model, as opposed to another model of a particular product, consumers may expect to save money on future energy purchases, though this is not stated explicitly on the label and no estimates of cost savings are provided.[2] Second, purchasers may perceive that there are public environmental benefits from reduced emissions associated with the avoided electricity use. Or, as ENERGY STAR materials have, at various times, put it “Money Isn’t All You’re Saving” and “Save Energy, Save Money, Protect the Environment.”

The ENERGY STAR label is limited to the effect of the use of the labeled products on energy consumption and the program does not make any claims about the effects on energy consumption or the natural environment associated with the manufacture of the products. An EPA program established in 2001, the Green Power Partnership, does not consider the amount of energy used in manufacturing a product, but it does consider the share of that energy derived from renewable sources (“green power”). To qualify as either a Green Power Partner or a Green Power Leader, a certain percentage of the energy consumed by the firm must come from renewable sources, with the percentage being based on the firm’s baseload, as shown in Table 1.

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[2] For many appliances, consumers can also use the EnergyGuide label which provides information regarding energy consumption on a scale showing a range for similar models and the estimated yearly operating cost based on the national average cost of electricity.

Partners may buy any eligible green power, such as solar, wind, geothermal, biomass, biogas or low-impact hydro resources. Partnership status enables the firm to use a logo in their marketing and promotion materials that identifies it as a Green Power Partner and makes explicit the program's affiliation with EPA (USEPA, 2007c). The program now boasts more than 800 partners that are collectively buying more than 10 billion kilowatt-hours of renewable energy per year (USEPA, 2007c).

Table 1. Purchase Requirements for EPA's Green Power Partner Program.

Baseload or annual electricity use in kilowatt-hours	Percentage of baseload that must come from renewable sources to qualify as a:	
	Green Power Partner	Green Power Leader
≥ 100,000,001 kWh	2%	20%
10,000,001 – 100,000,000 kWh	3%	30%
1,000,001 – 10,000,000 kWh	6%	60%
≤ 1,000,000 kWh	10%	Not applicable

Source: USEPA (2007c).

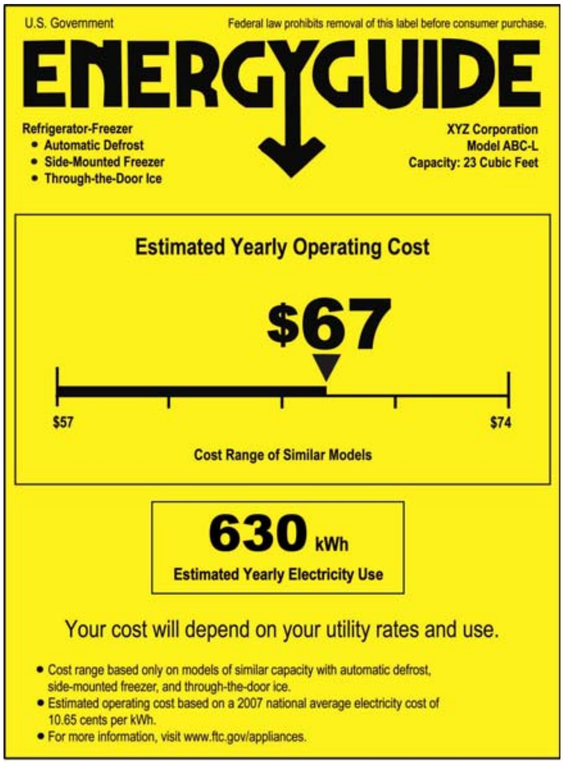
The ENERGY STAR and Green Power Partnership programs are similar in that they both are related to reductions in GHG emissions, albeit in different ways, with ENERGY STAR promoting reductions from reduced energy consumption, while, the Green Power Partnership promotes the consumption of energy from renewable resources. There are also some important differences in the programs as well. While the ENERGY STAR program is concerned with specific products or even particular models of products, the Green Power Partnership is concerned with the environmental characteristics of a particular firm or other organization. An implication of this distinction is that the target audience of the ENERGY STAR program is relatively clear – consumers of the products included in the program. On the other hand, the target audience for the Green Power Partnership program is less clear, although it would certainly seem to include consumers. However, targeting the information provided by the Green Power Partnership to consumers of a particular product – as will be done in this exercise - will require some "interpretation" of the data. For example, making the programs comparable in terms of avoided emissions per unit of product will require that the Green Power Partnership program requirements be converted to a per unit basis. When placed in these equivalent terms, the Green Power Partnership will provide information on what is solely a public benefit to consumers of the product.[3] Also, the timing of these benefits differ, as the reduction in GHG emissions associated the Green Power Partnership all occur at the time of manufacture, while the reduction in emissions with the ENERGY STAR accrue over the lifetime of the product. All of these differences will need to be taken into account in designing the experiment to compare consumer responses to the two different programs.

Finally, information on projected energy consumption of appliances is provided to consumers in the U.S. through the EnergyGuide label. The U.S. Federal Trade Commission was tasked with developing a labeling program for home appliances and energy-using equipment by the Energy Policy and Conservation Act of 1975 and the National Energy Conservation Policy Act of 1979. The intent behind the EnergyGuide label, which was first implemented in 1980, was to improve energy efficiency and assist consumers in making purchase decisions via information provision (Egan, Payne and Thorne, 2000). Based on research performed by the U.S. Department of Energy, the EnergyGuide label shows estimated yearly operating costs for the particular model within a range of similar models and an estimate of the annual electrical consumption associated with the use of the product. A copy of the EnergyGuide label is shown in Figure 1.[4]

[3] The nature of the benefits to other potential recipients of the information likely varies among these different recipients. For example, investors may perceive firms that are Green Power Partners to be good investments because they are likely to face reduced costs in the future as individuals might be more interested in working at such a firm, etc.

[4] The Federal Trade Commission is currently in the process of altering the EnergyGuide label slightly pursuant to 16 C.F.R. Part 305: Appliance Labeling Rule: Notice of Final Amendments To The Appliance Labeling Rule Concerning Disclosures Regarding Energy Consumption and Water Use of Certain Home Appliances and Other Products Required Under The Energy Policy And Conservation Act. The description and image shown here are of the revised label.

Figure 1. EnergyGuide Label



Study Objectives and Relevance

The purpose of this study is to analyze the influence of extrinsic (energy cost savings) and intrinsic rewards (helping the environment) on willingness to pay for consumer products, with a particular focus on testing for the presence of motivation crowding-out (MCO) in these responses. Whether or not consumer responses to environmental label are influenced by MCO is of interest because of the important implications that it can have for the design and marketing of environmental labeling programs. For example, should environmental labeling efforts be limited to, or at least concentrated on, those instances in which there are clear public and private benefits associated with the label or should these efforts include instances where the benefits are more purely public in nature? Similarly, can the presence or absence of MCO inform efforts to market those programs that relate to both public and private benefits, such as ENERGY STAR? What are the likely effects on consumers of emphasizing the combination of public and private benefits from such a program?

The study design will insure that the results will be relevant for evaluating the efficacy of consumer labeling programs, in general, and specific label structures in particular. Some specific questions to be addressed in the study are:

- Does the provision of information about attributes with purely public dimensions have an effect on consumption decisions?
- How do demographic or attitudinal characteristics influence the consumption decision when purely public dimensions are presented?
- What effect does pointing out both the public and private dimensions have on consumption decisions? Is the effect to elicit a greater or lesser response from consumers than a purely public label?
- How do demographic or attitudinal characteristics influence the stated consumption decisions in the presence of label information?

Prior Research

Environmental Labeling or Certification Programs

A variety of programs have been implemented by governmental and non-governmental organizations with the intent of disseminating information about the environmental "attributes" of companies or products.[5] These programs run the gamut from highly-technical, plant-level data about toxic releases to simplistic labels meant to symbolize the environmental "worthiness" of a particular company or product Audiences for the programs include consumers, investors, voters,

[5] For a more detailed overview of programs designed to disseminate environmental information on products and companies than presented here, see Russell, Krarup and Clark (2005), Tietenberg (1998), and USEPA (1993).

neighbors, and local public health and safety officials. The nature of the information provided ranges from raw, technical data, to information that has been distilled into some form of label, grade or certification. The most popular of these programs are the eco-labeling or environmental certification programs that disseminate distilled information about individual products to consumers.[6] These programs typically award the use of a logo to those products or models judged to be less environmentally harmful than comparable products or models, based on a specified set of award criteria (USEPA, 1993).

In general, the provision of environmental information has been shown to "work" in the sense that publicly provided information seems to have influenced some private decisions, which, in turn, has arguably changed environmental practices. This evidence has been most highly developed in the case of a program providing information on individual manufacturing facilities or plants - the U.S. Toxics Release Inventory (e.g., Hamilton, 1995; Hart and Gautum, 1996; Khanna, *et al.*, 1998; Konar and Cohen, 2001; and Konar and Cohen, 1997). However, there is also evidence that environmental labels have prompted changes in consumer behavior. For example, using Danish consumer diary data, Bjørner, *et al,* found statistically significant levels of consumer choice of more expensive, eco-labeled laundry detergents and toilet paper brands (Bjørner *et al*, 2004). Other examples include studies of environmental labels for a variety of products, including electricity (Roe, Teisl, Levy, and Russell, 2001; Roe, Teisl, Rong and Levy, 2001), apparel (Nimon and Beghin, 1999a; Nimon and Beghin, 1999b), food (Grankvist and Biel, 2007; Teisl et al., 2002), wood products (Anderson and Hansen, 2004a, 2004b) and

[6] Prominent examples of environmental certification programs include the European Union's Ecolabel, Germany's Blue Angel, and the Nordic Council's White Swan.

laundry detergents (Henion, 1972).[7] In addition, there are a large number of studies finding that a significant proportion of survey respondents are at least willing to state a willingness to pay a premium for an environmentally labeled product (e.g., Aguilar and Vlosky, 2007; Blend and van Ravenswaay, 1999; Cason and Gangadharan, 2002; Ethier et al., 2000; Grankvist, Dahlstrand, and Biel, 2004; Jensen et al., 2004; Jensen et al, 2003; Johnston et al., 2001; Loureiro, McCluskey, and Mittelhammer, 2002; Moon et al., 2002; Loureiro and Lotade, 2005; O'Brien and Teisl, 2004; Ozanne and Vlosky, 2003; Ozanne and Vlosky, 1997; Veisten, 2007; and Wessells et al., 1999). In addition, there are also a number of papers that examine various aspects of environmental labeling schemes and characteristics (e.g., Kane, *et al.*, 2000; OECD, 1997; Teisl and Roe, 2005; Teisl and Roe, 1998; and USEPA, 1994).

Energy Efficiency and Green Power Labeling

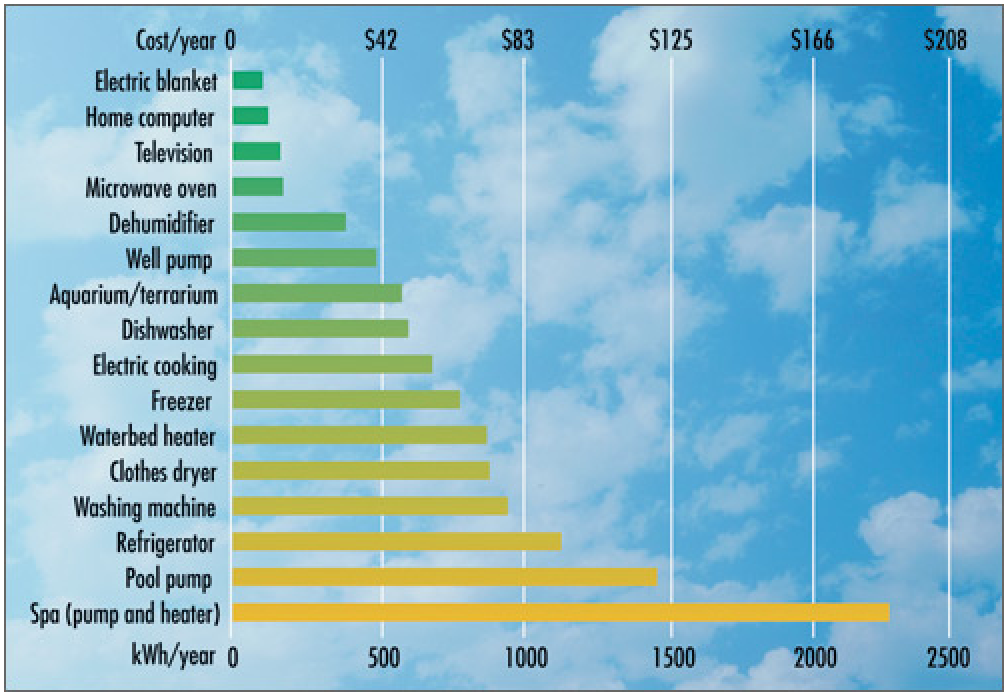
The energy crisis of the 1970's led to widespread recognition of the need to promote energy conservation and efficiency (Crossley, 1983; Frieden and Baker, 1983). Increasing recognition of potential improvements in energy efficiency coupled with the belief that higher energy prices improved the economic rationale for consumer investment in energy saving measures, led many commentators to call for programs to increase awareness of the private benefits of conservation, providing consumers with encouragement to conserve energy. Consumers were also strongly in favor of some form of energy labeling (e.g., Anderson and Claxton, 1979; Bennett and Moore, 1981, Consumer Association, 1978). These sentiments led to the introduction of the EnergyGuide label for appliances in 1980 and a dramatic increase in research on energy conservation (McDougall, et al. 1981; Ritchie and McDougall, 1985),

[7] There are other studies analyzing programs that simultaneously convey information on both public and private product attributes, such as organic food (environment and health) and energy-conserving appliances (environment and expense).

including an extensive literature on factors relevant to a variety of energy conserving behaviors, such as changes in behavior patterns, investments in energy saving technologies and the incorporation of energy consumption characteristics into consumer decision-making regarding appliance purchases (e.g., Dubin and McFadden, 1984; Gately, 1980; Hausman, 1979). In general, the results of this research can be characterized as disappointing, in the sense that participation in energy conserving behaviors seemed lower than might have been expected. Indeed, the difference between those investments in energy efficiency that appear to be in the consumer's own interest and those that consumer actually make has become known as the "efficiency gap" (Golove and Eto, 1996). As a result, research focus turned to trying to understand the barriers to increased energy conservation (e.g., Anderson and Claxton, 1982; Crossley, 1983; DeCanio, 1998; Frieden and Baker, 1983; Golove and Eto, 1996; Hassett and Metcalf, 1996; Hassett and Metcalf, 1993; Hirst and Brown, 1990; Howarth and Anderson, 1993; Komor and Wiggins, 1988; Koomey and Sanstad, 1994; Reddy, 1991). Given the time dimension involved in the benefits (cost savings) of an investment in energy saving technology or an energy efficient appliance, much of this literature has focused on the apparently high discount rates displayed by consumers in foregoing these investments or purchases (e.g., Kooreman, 1996; Kooreman, 1995; Kooreman and Steerneman, 1998; Meier and Whitaker, 1983; Sanstad, Blumstein and Stoft, 1995; Thompson, 1997; Thompson, 2002; and Train, 1985).

An important part of these research efforts has focused on the effects of the EnergyGuide label and similar programs that provide consumer information on the estimated energy consumption of appliance models (e.g., Anderson and Claxton, 1982; BPA, 1988; Chestnut, 1976; Dyer and Maronick, 1988; Egan, Payne and Thorne, 2000; GAO, 1993; Redinger and Staelin, 1980; USEPA, 1989; Verplanken and Weenig, 1993; and Worrall, 1976;). One particular product that has received considerable attention is the refrigerator, likely due in large part to its high relative use of energy. See Figure 2. For example, Moxnes (2004) estimated the effects of energy efficiency standards for refrigerators on customer utility by using conjoint analysis. The results from that study suggested that only standards below 209 kWh per year would result in a reduction in utility. The study found that if only the most efficient refrigerators were allowed on the market, the average customer utility would be reduced by 7%. Greening, Sandstad, and McMahon (1997) considered multiple characteristics in an hedonic study of refrigerator prices, including food compartment volume, freezer compartment volume, annual energy usage, type of outlet purchased from, wire or glass shelves, factory installed ice maker, configuration of refrigerator (for example side-by-side), and region of purchase. Their results did not demonstrate a strong price effect for energy efficiency. Other studies that have investigated consumer inclusion of energy consumption as a factor in evaluating refrigerators include: Anderson and Claxton, 1982; BPA, 1988; Claxton and Anderson, 1980; Meier and Whitaker, 1983; McNeil and Wilkie, 1979; Redinger and Staelin, 1980; Verplanken and Weenig, 1993; and Worrall, 1976.

Figure 2. Energy Consumption of Various Home Appliances



Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www1.eere.energy.gov/consumer/tips/appliances.html.

More recently, researchers have turned their attention to evaluating the ENERGY STAR program (e.g., Bannerjee and Solomon, 2003; Brown, Webber and Koomey, 2002; Geller, et al. 2006; Golberg, Goepfirch and Spielman, 2005; Horowitz, 2001; Howarth, Haddad, and Paton, 2000; Webber, Brown and Koomey, 2000; USEPA, 2007b). These studies suggest that the program is achieving widespread recognition and generating substantial energy savings. For example, Brown, Webber, and Koomey (2002) projected that by 2010 annual carbon emissions would be reduced by 20 million metric tons (44.2 billion pounds, or about 0.8%) as a result of the ENERGY STAR program.

There are also a number of analyses of consumer perceptions of the provision of energy from renewable sources (“green power”) (e.g., Byrnes, Jones and Goodman, 1999; Clark, Kotchen, and Moore, 2003; Farhar and Houston, 1996; Harmon and Starrs, 2004; Holt and Wiser, 1999; Kotchen and Moore, 2004; Kotchen and Moore, 2007; Roe, Teisl, Levy, and

Russell, 2001; Rowlands, Scott and Parker, 2003; Rowlands, Parker and Scott, 2002; Whitehead and Cherry, 2007; Wiser, Bolinger, and Holt, 2000; Zarnikau, 2003). The results have suggested a positive willingness to pay for green power, and several of these studies have revealed a preference for solar and wind over other types of renewable energy. On the other hand, actual participation in green power programs is quite low. For example, in 2005, the average participation rate in utility green pricing programs was about 1.5% (Bird and Swezey, 2006).

Several of the above studies examined the effects of demographics and behaviors on preferences for green power. The findings include:

- that education has positive impacts on consumer preferences (Roe, Teisl, Levy, and Russell, 2001; Rowlands, Scott, and Parker, 2003; Zarnikau, 2003);
- that income plays a positive role (Clark, Kotchen, and Moore, 2003; Kotchen and Moore, 2004; Roe,Teisl, Levy, and Russell, 2001; Rowlands, Scott, and Parker, 2003; Whitehead and Cherry, 2007; Zarnikau, 2003); and
- that environmental behaviors, such as membership in environmental organization, or environmental concerns have a positive influence (Kotchen and Moore, 2004; Roe, Teisl, Levy, and Russell, 2001; Rowlands, Scott, and Parker, 2003).

In addition, Wiser, Fowlie, and Holt (2001) examined the non-residential demand for green power, including that by businesses. Their results suggested that organizational values and civic responsibility were more important motivators than perceived green marketing in the decision to make green power purchases. Thus, only about 10 percent of the respondents had used the fact that they purchased green power in their point-of-sale marketing. The top 25 participants in the Green Power Partnership, which account for about 60% of the green power commitments by Green Power Partners, use about 6.24 billion kWh of green power. This is about 6.6% of net generation of non-hydro renewable electricity (95 billion kWh in 2005) and less than 1% of total net electrical generation.

Zarnikau (2003) found that while gender had no significant effect on willingness to pay for greater energy efficiency, salary and education level had positive influences. Poortinga, Steg, Vlek, and Wiersma (2003) examined household preferences for energy saving measures. People with high environmental concern evaluated the energy-saving measures on average as more acceptable than did people with low environmental concern. Energy saving measures in the home were relatively more acceptable to respondents aged 20 through 39 years, than to those 65 years and older. Couples and families found home energy saving measures relatively more acceptable than singles did. Home measures were also relatively more acceptable to respondents with high and average incomes than for respondents with low incomes.

Similarly, Noblet, Teisl and Rubin (2006) investigate the effects of demographics and environmental attitudes on vehicle selection. Their results suggest that eco-information has an influence on consumers who are selecting vehicles within a class (for example among cars, among SUV's, or among trucks), but not on consumer choice of a particular class. This study also found that if individuals believe their purchase habits may be effective in addressing environmental issues and if they have concerns about air quality, they will be more likely to respond to a label promising positive environmental effects.

Prosocial Behavior and Motivation Crowding-Out

Much of the research on energy labeling and energy conservation has focused on the potential cost savings to consumers. However, for many other types of pro-environmental behaviors (e.g., recycling) and for many other types of labeling programs there are no private benefits such as cost savings for the actor. When attempting to explain why a consumer might prefer a more expensive "green" variety of a good to a less expensive "brown" (but otherwise identical) variety, neo-classical economists often rely on the tautology that if consumers choose the green variety it must be because they have a preference for green products. Psychologists, on the other hand, have expended a great deal of effort in analyzing the motivation for this type of behavior, i.e., undertaking an action with costs, but no readily apparent benefit to the individual. As a result, they have distinguished between two different types of motivation - intrinsic and extrinsic. An intrinsically motivated action is one done solely for the sake of doing it, or where the motivation comes from within the actor herself. An extrinsically motivated action, on the other hand, is an action performed in response to an external stimulus, or where the motivation comes from somewhere other than the actor (Deci, 1971).

Since much of economic theory starts with the assumed ability of extrinsic motivation to affect behavior, economists have, in general, tended to accept these assumptions without much thought. Psychologists, on the other hand, have long questioned the independence of intrinsic and extrinsic motivation, and there is a well-established body of literature asserting that the presence of extrinsic rewards actually has an adverse affect on intrinsic motivation.[8] Psychologists refer to this effect as the "hidden costs of reward."[9] This concept has recently seeped into the economics literature, where it has been termed motivation crowding-out (MCO),

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[8] For an idea of the breadth of the experimental evidence for this effect, see the meta-analysis of 128 different laboratory experiments investigating the effects of a wide variety of extrinsic rewards on intrinsic motivation in Deci, et al, 1999.

[9] "Social psychologists have argued that there are "hidden costs of reward" (Lepper and Greene, 1978), and that monetary rewards may reduce intrinsic motivation (surveys are given in Deci and Ryan, 1985; Lane, 1991). From a rational choice point of view, this reduction of intrinsically motivated activities is straightforward (Frey, 1994): If a person derives intrinsic benefits simply by behaving in an altruistic manner or by living up to her civic duty, paying her for this service reduces her option of indulging in altruistic feelings. Her intrinsic motivation then has a reduced effect on supply." Frey and Oberholzer-Gee, 1997: pp. 746-7.

to illustrate the idea that the presence of extrinsic rewards may reduce or "crowd-out" intrinsic motivation.

In fact, MCO is one of a growing list of behaviors that hard-core micro economists label "non standard", in that they appear to contradict the core assumptions, or the resulting theorems, of the neo classical model of the rational economic actor. What makes MCO especially interesting is that it involves a response to the introduction of economic incentives, designed to encourage prosocial (or otherwise desirable but not "rational" in the narrow sense) behavior that is itself "non standard", such that the incentives in fact discourage the behavior. The earliest example, and the one that has become classic, comes from the world of voluntary actions that make other people better off but have no obvious payoff for the actor…the donation of blood. The observation is that the amount of blood donated is reduced by the introduction of payments to those who donate. (See, for example, Titmuss, 1970, Upton, 1973.) Two questions that probe the standard model are thus raised: (1) Why would a person give blood voluntarily for a zero reward? And (2) Why would this action be discouraged by increasing the reward above zero?

That MCO is a real phenomenon seems beyond question. It has been documented and studied for five decades by psychologists and economists and has been discovered via field work and lab experiments in situations as diverse as the design of work place monitoring and reward systems, the provision of money rewards for performing (or fines for failing to perform) civic duties such as voting, and the introduction of payments for the performance of what had been a voluntary charity solicitation task. (See the review by Frey and Jegen, 2001.) In addition to field based results, laboratory behavioral experiments have been done in sufficient quantity to justify meta analyses. Frey and Jegen characterize that done by Deci, et al., 1999 as the "best available survey"…p. 597. It concludes that the experiments support the existence of the MCO phenomenon.[10]

To come to grips with MCO, it is, therefore, first necessary to gain some understanding of why individuals choose to behave in prosocial ways in the first place. That is, why do people vote; give blood; donate large amounts of money to a huge number of charities covering the good-cause waterfront from art, through education and historic preservation to public broadcasting and wildlife protection? The tangible results from such efforts are in the nature of public good, which the donor can expect to enjoy whether or not s/he contributes, so the strict rational model suggest that free riding will be the standard behavior. Meier (2006) provides a clear and comprehensive survey of the major contenders for recognition as explanations of such behavior. He groups these motivations under three broad headings: (1) those that depend on the expected outcomes of contributing time or effort or money, as in the varieties of altruistic concern for the welfare of others or aversion to inequality per se; (2) those that reflect the actions of others in a sort of social game of reciprocal cooperation; and (3) those that involve the definition of self through actions, both private and public. One is tempted, at least as an economist, to suggest that the third category may actually lie behind the other two. This temptation is encouraged by the definition of one variety of altruism, called "impure" (Andreoni, 1990), in which the prosocial actor receives a private "warm glow" from taking the action, rather than from any outcome or any interaction with others. It is not much of a stretch to see that glow as the radiation from an enhanced self-image. It is also easy to see that self-image and external

[10] Even so, it may be wise to maintain some skepticism of behavioral laboratory evidence involving student subjects and very modest rewards. In the 1980s a nonstandard behavior that was of considerable interest, "preference reversal", was demonstrated regularly by such experiments (for example, Grether and Plott, 1979, Slovic and Lichtenstein, 1983, and Tversky, Slovic and Kahneman, 1990). When Bohm, in the 1990s, designed and carried out an experiment in which the potential gains from acting rationally were substantial, however, the behavior disappeared (Bohm, 1994; Bohm and Lind, 1994).

reputation must be loosely linked, though of course not identical. Certainly most of us prefer to be thought well of to the opposite condition. And being thought well of, while not guaranteeing that we feel good about ourselves, is very likely to encourage that state of mind. So pursuit of self image may well involve at various times and in various situations concern about how, and indeed whether, our actions are perceived by others.

It is in this context of self and public image construction that Bénabou and Tirole (2006) have crafted a model that can give rise to MCO and have explored its implications. At the heart of the model is the matter of signaling, through your actions, to oneself or to others, what sort of person you intend to be. The signals consist, on the one hand, of pure prosocial action…the purchase of a public good; and on the other, the acceptance of a tangible, private reward for taking the action. The first indicates to yourself or to observers that you are likely to be a public-spirited, generous sort of person. The second suggests that you may also (or alternatively, depending perhaps on the scale of the reward) be a typically selfish economic actor. This complex decision setting can give rise to MCO because the presence of the private reward potentially distorts the signal you would like to send yourself or others and therefore makes the choice of the prosocial action less useful as an image or reputation enhancer.

Economic Model

We employ a lightly revised version of the model proposed in Bénabou and Tirole (2006) to motivate our empirical analysis. This model was chosen because it allows us to model individual choice over whether to participate in a prosocial activity taking into account a mix of three different possible sources of motivation – intrinsic, extrinsic and reputational. In this case, the prosocial activity is the choice of a variety of a good that has some positive social connotation over another variety. Thus, choosing the more energy-efficient of two different varieties of an appliance implies a "contribution to the public good" in the sense that it will result in reduced emissions from energy production.[11] The extrinsic motivation for consuming the good is a function of the *private attributes* of the good, denoted by the vector *Y*, and the consumer's preferences over these attributes, denoted by the vector V_Y. The intrinsic motivation for consuming the good is a function of the *public attributes* of the good, denoted by the vector *Z*, and the consumer's preferences over these attributes, denoted by the vector V_Z. The price of the good is denoted by *p*. Thus, the direct benefit of consuming the good can be represented by:

$$V_Z \cdot Z + V_Y \cdot Y - p$$

For simplicity, we assume that the only public attribute is reduced emissions from reduced energy production. Thus, the public attribute vector reduces to a scalar and the direct benefit can be rewritten as:

$$v_z \cdot z + V_Y \cdot Y - p$$

The indirect benefit from consumption of the good is provided by the possibility of a "reputational payoff," if the consumer believes that the choice of one variety over another would either affect her reputation with others or her own self-image. In this way, our consumption choices can be thought of as a way to define ourselves to either ourselves or others. Following Bénabou and Tirole (2006), we assume that the reputational effect depends linearly on posterior expectations of the consumer's preferences over the good's public and private attributes.[12] This indirect benefit is specified as:

[11] Note that the framing of this choice task abstracts from the question of contributing to the public good by reducing consumption altogether. Thus, we limit ourselves to the situation in which the consumer is going to purchase a particular good, the only question is which variety.

[12] These expectations could be your own or those of others who are observing your purchase decisions, from the salesperson or clerk in the store to friends or family members. This latter notion could either imply that your

$$R(z,Y) \equiv x[\gamma_z E(v_z|z,Y) - \gamma_Y E(V_Y|z,Y)]$$

where x (> 0) measures the visibility or salience of the choice and γ_a, $\gamma_y \geq 0$. The nonnegative signs on γ_z and γ_Y reflect the idea that people would like to either appear or consider themselves to be both "*prosocial* (public-spirited) and *disinterested* (not greedy)." Thus, the individual faces the problem of maximizing the direct and indirect benefits over the choice of the *ith* variety or:

$$\max v_z \cdot z_i + v_Y \cdot Y_i - p_i + x[\gamma_z E(v_z|z_i,Y_i) - \gamma_Y E(v_Y|z_i,Y_i)]$$

We assert that the introduction of an environmental labeling program to this choice can have some combination of three different effects:

- By providing a tangible symbol of the social implications of the choice, the label increases the visibility or salience of the choice, thereby increasing reputational effects of the choice by increasing the value of *x*. The effect on x would likely vary depending upon the nature of the program, e.g., visibility of the label, trustworthiness of the sponsor, etc.;
- By providing information on the product's environmental attribute(s), the label is likely to lead consumers to update their expected value for *z*. It is unlikely that consumers will ever know with certainty the extent to which their choice of one variety over another contributes to the social good, but it seems quite likely that a label will alter their beliefs about this contribution[13]; and

preferences are imperfectly revealed to you through your purchase decisions or, following Bénabou and Tirole (2006), that these preferences become inaccessible to you after some time, while your purchase decisions do not. The former would seem to be more in keeping with the approach taken by psychologists, who "would generally view people as unable to discern precisely their own motives even at the time they act" (Bénabou and Tirole 2006, p. 1657).

[13] Some caution is perhaps warranted here as the extent of the contribution may not be all that important given that, for many public goods, any single individual's contribution is unlikely to have more than an infinitesimal impact. For example, see Bénabou and Tirole, 2006, pp. 1657-8, for a decomposition of the intrinsic value to the actor of the actor's contribution to the public good into a concern for the level of the public good and a "joy of giving". Where any single individual's contribution to the public good is miniscule, the actor's motivation is limited to the "joy of giving". Whether the amount of joy is likely to be directly related to the amount of the gift is unclear.

- If the label has a private dimension (e.g., cost savings associated with reduced energy consumption), then the label is also likely to lead to an updating of consumer beliefs over the value of some element in the vector of private attributes *Y*.[14]

Thus, a labeling program with purely public benefits, such as the Green Power Partners program, would increase the visibility or salience of the choice and would likely alter consumer beliefs over the extent of the public benefits provided, but would not likely alter consumer beliefs over the private benefits provided by the different varieties. On the other hand, a labeling program with both public and private benefits, such as the ENERGY STAR program, would likely trigger all three effects. Finally, a more *symbolically neutral* program, such as the EnergyGuide label, would likely alter consumer beliefs over both public and private attributes, but would be unlikely to have as much of an effect on the salience of the choice. In fact, by exclusively focusing on cost and energy savings, the effect of the EnergyGuide label on many consumers might be limited to altering their beliefs over the value of the private attribute. Finally, to the extent that the introduction of a labeling program changes the values of z or y, it would also alter the reputational effects of the choice by altering the expected values of v_y and v_z.

For the single consumer in this model, MCO can be said to occur when the presence of a private benefit effectively "clouds" the signal sent by the consumer's decision to purchase the environmentally superior variety as it is no longer clear whether the consumer was motivated by pursuit of the public good or their own self-interest. Thus, the presence of the private reward increases the expected value of v_y and/or decreases the expected value of v_z. If this negative reputational effect is greater than the increase in utility associated with the private benefit, then the individual becomes more likely to consume an unlabeled variety. Which variety the

[14] Note that this can lead to an alternative explanation for a labeling program with a small private benefit having less of an effect than one with only a public benefit, namely that the labeling program effectively reduced consumer beliefs over the extent of the private benefit.

individual consumes will also depend upon other possible differences between the varieties, such as price and other private benefits.

To empirically test for the presence of MCO, we effectively need to compare two different labeling programs – one with both a public and a private benefit (such as emissions reductions and cost savings associated with energy efficiency) and one with only a public benefit.(such as emissions reductions associated with green power). If there is little or no difference between the public benefits of the programs, then MCO can be said to occur if the consumer would prefer an unlabeled variety when confronted with the labeling program with both a public and a private benefit but would prefer a labeled variety when confronted with the public-benefit-only labeling program.

Methods and Procedures

The Choice Experiment

Data on consumer responses to environmental labels will be collected through a survey containing a hypothetical market experiment referred to as *conjoint analysis* or *contingent choice* (CA).[15] This technique has been widely used by market researchers in the evaluation of new products and markets and is increasingly being employed by environmental economists. CA techniques are based on the premise that commodities can be viewed as bundles of various attributes, an idea dating back at least to Lancaster (1966). In CA studies, respondents are asked to rank or rate a series of these bundles in which some or all of the values or levels of the different attributes are allowed to vary. From these rankings or ratings, marginal rates of substitution between the different attributes can be estimated. Thus, by including price and

[15] Bartels, Fiebig and McCabe (2004) consider the benefits of using stated preference methods to analyze consumer response to an environmental label.

environmental performance as attributes, willingness-to-pay measures for changes in environmental performance may be derived.

CA, as a generic label, actually encompasses a number of specific "stated choice" methodologies (Freeman, 2003), that are differentiated on the basis of the choice task posed to the respondent. In *contingent choice* CA, respondents are asked to choose their most preferred product, or more generally, bundle of attributes, from two or more choices with differing attribute levels. [16] Some contingent choice studies force respondents to choose one of the alternatives and some allow respondents to reject all. *Contingent ranking* asks respondents to rank a set of hypothetical alternatives from "most preferred" to "least preferred." In a c*ontingent rating* exercise, respondents are asked to rate a set of hypothetical alternatives on a numerical scale. The difference between ranking and rating is that the latter asks respondents to supply information about how much they prefer one bundle to another while the former does not. Finally, in *graded pair* or *pairwise rating* surveys, respondents are shown two different alternatives and are asked to indicate the extent of their preference for one of the products over the other on a Likert scale. The exercise is then repeated a number of times with different hypothetical alternatives.

This project will employ contingent choice CA as it most closely replicates the purchase decision faced by actual consumers and, thus, allows us to construct an instrument that has the look and feel of a product design exercise and not an environmental-information-gathering exercise. It is hoped that this context will blunt some of the problems associated with the

[16] Dichotomous choice contingent valuation is essentially a special case of dichotomous choice CA, where the study is limited to two alternatives, one of which is the status quo, and only two variables - price and the environmental quality variable - are allowed to vary. Relaxing these restrictions allows CA to emphasize tradeoffs among hypothetical alternatives over the purchase of an environmental amenity and it has been argued that this change in emphasis deflects emotive responses and, as a result, is less likely to generate protest or symbolic responses.

hypothetical nature of stated choice methods (Freeman, 2003). Figure 3 provides an illustration of how a contingent choice question for different varieties of a refrigerator might look.

Figure 3. Example of a Contingent Choice Question for a Refrigerator.

	If you were shopping for a side-by-side refrigerator/freezer for your home and these were your only options, which would you choose?		
Brand **Size** **Icemaker** **Warranty** **Energy Usage** **Price**	❍ Frigidaire 21.7 cubic feet Icemaker in freezer 2 year warranty ENERGY STAR $1199	❍ GE 25.3 cubic feet Icemaker in freezer 2 year warranty Meets Federal Requirements $1479	❍ Amana 23.9 cubic feet In-door dispenser 1 year warranty ENERGY STAR $1349

Note: The order of these attributes will be randomized across versions of the survey instrument.

The Rest of the Survey

Following the CA exercise, survey respondents will be asked a series of debriefing questions to probe deeper into the basis for the respondent's reaction to the labels, including familiarity with the labeling program, importance of the public or private benefit, extent to which respondent considered nature or timing of emissions reductions, anticipated life expectancy of the appliance, etc. Following these debriefing questions, respondents will be presented with a series of attitudinal questions designed to probe the extent to which respondents are concerned about the environment (Antil, 1984; Granzin and Olsen, 1991; Mainiere and Barnett, 1997; Minton and Rose, 1997; Roberts, 1996; Roberts and Bacon, 1997; Schlegelmilch and Bohen, 1996; Schwepker and Cornwell, 1991; Shetzer, *et al*, 1991). These questions will be patterned upon the New Ecological Paradigm Scale (Clark, Kotchen, and Moore, 2003; Dunlap, Van Liere, Mertig, and Jones, 2000), with respondents being asked to indicate the extent to which they agree with each a series of statements, similar to those shown in Table 2, on a Likert scale (strongly agree, mostly agree, undecided, mostly disagree, strongly disagree). Respondents will also be asked to indicate the extent of their agreement with a set of statements related to altruism, similar to those shown in Table 3.

Table 2. New Ecological Paradigm Statements.

Statement
(1) The balance of nature is very delicate and easily upset.
(2) Plants and animals have as much right as humans to exist.
(3) Humans will eventually learn enough about how nature works to be able to control it.
(4) The so-called ''ecological crisis'' facing humankind has been greatly exaggerated.
(5) If things continue on their present course, we will soon experience a major ecological catastrophe.
(6) Humans were meant to rule over the rest of nature.
(7) The earth is like a spaceship with very limited room and resources.
(8) Human ingenuity will insure that we do not make the earth unlivable.
(9) We are approaching the limit of the number of people the earth can support.
(10) The balance of nature is strong enough to cope with the impacts of modern industrial nations.

Table 3. Example Altruism Statements.

Statement
(1) I worry about conserving energy only when it helps to lower my utility bills.
(2) Contributions to community organizations can greatly improve the lives of others.
(3) The individual alone is responsible for his or her satisfaction in life.
(4) It is my duty to help other people when they are unable to help themselves.
(5) Many of society's problems result from selfish behavior.
(6) Households like mine should not be blamed for environmental problems caused by energy production and use.
(7) My responsibility is to provide only for my family and myself.
(8) Use of renewable energy is the best way to combat global warming.

Using a similar process, respondents will be asked to indicate the extent to which they believe that their consumption decisions can affect the environment (Allen and Dillon, 1979; Berger and Corbin, 1992; Ellen, *et al*, 1991; Obermiller, 1995; Roberts, 1996; Scholder and Cobb-Walgreen, 1991) and how likely they are to participate in specific pro-environmental actions (e.g., recycling) in the future. Exactly which and how many of these statements are included in the final survey version will depend upon a number of factors, not the least of which is the overall length of the instrument.

Finally, respondents will be asked a series of demographic questions. These questions will include household income, age, gender, education level, employment status, type of residence (single family detached house, condominium, apartment, mobile home or other), residence ownership, number in household, number of minors in household, and zip code. A copy of the survey instrument will be available upon request from the authors.

Survey Implementation

The survey will be conducted by computer over the internet. Telephone and computer surveys have certain advantages over the pencil-and-paper variety, as they allow the researcher to retain more control over the administration of the survey, ensure that all questions are answered in the order in which they are given, and provide researchers with flexibility in designing the set of choice tasks faced by respondents (Louvieve, *et al*, 2000). This last advantage is particularly important in CA exercises as it allows the set of choice tasks faced by each respondent to be interactively determined as the respondent progresses through the set, maximizing the amount of information gleaned from a given number of choice tasks. Telephone surveys are not particularly well suited to CA exercises due to the nature of the choice task. Computer surveys have the added advantage of improving accuracy by eliminating the need for manual or scanned data entry. Finally, an important advantage of online surveys is that they can provide relatively inexpensive access to a large sample, which cannot be said for an in-person survey.

For this survey, respondents will be located through a pool maintained by an online marketing firm, contacted by e-mail, and attracted with an offer of a cash incentive or prize drawing conducted by the online marketing firm. While efforts will be made to ensure that the sample is as representative of the general population as is possible, the survey method used will inevitably result in a sampling bias in favor of those people who have access to computers and who have, at one time or other, volunteered to participate in an online survey. While this bias could have important implications for the extrapolation of any willingness-to-pay numbers generated by the survey, there is no reason to think that it would be correlated with individual behavior in response to intrinsic and extrinsic motivation. That said, while it will be possible to compare the sample demographic characteristics to regional or national averages to note any differences and possibly weight the sample to more closely reflect the general population, it will be difficult to determine whether the sample is drawn from a population who is more or less likely to consider an environmental label in their purchase decisions.

Product Selection

We have selected the side-by-side refrigerator/freezer ("refrigerator") to be the focus of our analysis. This selection is based on a number of factors all of which should help to provide a solid base from which to launch this analysis. First, refrigerators are significant consumers of energy relative to other home appliances. Second, the refrigerator is an appliance with which virtually everyone will have a high degree of familiarity. This familiarity should help to ensure that respondents can understand and appreciate differences in the attributes used to distinguish different refrigerator varieties. Third, the refrigerator can be adequately described with a fairly limited number of attributes. Also, the differences in aesthetic or visual qualities that would be difficult to capture in a survey are not as important as they are for many other home appliances, such as the picture quality for a television set or computer monitor. Fourth, consumers strongly associate the ENERGY STAR label with refrigerators, as prior research indicates that among those who recognized the ENERGY STAR label, seventy-four percent of households had seen the label on refrigerators (USEPA, 2007b). Similarly, the ENERGY STAR label appears to have made considerable inroads into the refrigerator market, achieving a 32.9% share of the refrigerator market in 2005 (Sanchez, Webber, Brown and Homan, 2007). Finally, the ENERGY STAR program provides detailed information on refrigerators and, as noted previously, a large number of studies have analyzed consumer response to the provision of information on the energy consumption profiles of refrigerators.[17]

Attribute Identification and Selection

The starting point for identifying, describing and selecting the attributes to describe and distinguish different refrigerator varieties is the information provided by the ENERGY STAR program, which is summarized in Table 4.

Table 4. Refrigerator Attribute Information Provided by ENERGY STAR Materials

Attribute	Description
Brand and Model	The brand and manufacturer model number identify a particular refrigerator. Model numbers often contain wildcard characters, such as *, #, and X, that are placeholders for non-energy attributes, such as color.
Volume (ft3)	The total interior volume of the refrigerator and freezer compartments.
Adjusted Volume (ft3)	The sum of the fresh food compartment volume and the product of an adjustment factor and the net freezer compartment volume used to determine the federal energy conservation standards for refrigerators and freezers.
Configuration	The configuration of the refrigerator or freezer in one of the following types: a. TF: Top Freezer b. BF: Bottom Freezer c. SS: Side-by-Side d. SD: Refrigerator only - single door

[17] Other products considered included all ENERGY STAR qualified products and also water heaters and clothes dryers. This list was narrowed to four candidate products (refrigerator/freezers, water heaters, compact fluorescent lights, and washing machines) and a detailed list of pros and cons developed for each product. On the basis of these lists, it was determined that side-by-side refrigerator/freezers were the best choice.

	e. SR: Refrigerator/Freezer - single door f. UF: Upright Freezer g. CF: Chest Freezer
Defrost Type	Refers to the defrost function. Automatic, manual and partial defrost are the standard types.
Compact	Refers to refrigerators, refrigerator-freezers, and freezers with a total volume of less than 7.75 cubic feet and 36 inches or less in height.
Ice	Whether or not the model has the through-the-door ice feature.
KWH/Year	The estimated annual energy use in kilowatt hours of the refrigerator or freezer under typical conditions.
NAECA Std. (Federal Standard)	The federal standard for energy consumption in kWh/year required of a refrigerator or freezer of that particular volume and configuration. The standard varies depending on the size and configuration of the refrigerator.
% Less Energy	How much less energy the model uses compared to the 2001 NAECA (federal) standard. The ENERGY STAR qualification levels depend on the size and type of refrigerator or freezer.

The literature also provides considerable guidance on refrigerator attributes. For example, Dyer and Maronick (1988) surveyed refrigerator purchasers to determine which attributes or factors purchasers considered important factors in their purchase decisions (Table 5) and how important these attributes were to their selection of a particular refrigerator variety (Table 6).

Table 5. Percentage of Refrigerator Purchasers' Mentioning an Attribute as Important to Purchase Decision

Attribute	Percentage (N=700)
Size	60.1
Color, Appearance	28.4
Price	22.7
Doors-number/position	28.3
Energy efficiency (net)	25.7
Separate meat compartment	13.3
Separate temperature controls	5.5
Brand name	10.7
It was on sale	4.0
Self-Frost/Frost-Free	29.6
Ice-maker/Water dispenser	16.2

Source: Dyer and Maronick (1988)

Table 6. Percentage of Refrigerator Purchasers Ranking Attribute as Extremely Important to Purchase Decision

Attribute	Percentage (N=700)
Size	71.0
Price	58.5
Guarantee/Warranty	60.5
Appearance/Color/Looks	47.7
Yearly amount of energy used	41.8
Yearly energy cost	39.9
Brand name	29.3

Source: Dyer and Maronick (1988)

In addition, Greening, Sanstad, and McMahon (1997) included food compartment volume, freezer compartment volume, annual energy usage, type of outlet purchased from, wire or glass shelves, factory installed ice maker, configuration of refrigerator (for example side-by-side), and region of purchase as characteristics in a hedonic model of refrigerator prices. Shepler (2001) examined the effect of refrigerator attributes on prices and included brand, bottom freezer, sound insulation, water filtration, humidity controls, three drawers, energy saver switch, color, ice maker (none, icemaker ready, factory installed, or through the door ice and water service), type of outlet where purchased, region and city size of purchase location. The projected range of prices from this study was $926 to $2,408 in 1999$. Adjusting these prices by the All Urban Consumers CPI for 2007, the range would be $1,147 to $2,982. USDOE (2005) estimates that the current ENERGY STAR rating adds between $47.17 and $88.12 to the price for a side by side refrigerator with through the door ice service (in 2005 $).

To supplement these results, we performed our own analysis of the 20 top selling refrigerator models at four different online appliance retailers (AJ Madison, Best Buy, Home Depot and Sears). The resulting product attributes and their respective levels are summarized in Tables 7 and 8.

Table 7. Summary of Categorical Product Attributes from Analysis of Top Selling Refrigerators at Select Retailers.

Attribute	Level	Frequency (%)
Brand	Frigidaire	7.4%
	Galaxy	2.5%
	GE	27.2%
	Hotpoint	8.6%
	Inglis	1.2%
	Kenmore	18.5%
	LG	9.9%
	Maytag	14.8%
	Samsung	1.2%
	Whirlpool	8.6%
Retailer	AJ Madison	24.7%
	Best Buy	25.9%
	Home Depot	24.7%
	Sears	24.7%
Noise Control	Yes	61.7%
	No	38.3%
Humidity Control	Yes	80.2%
	No	19.8%
Ice/Water through the Door	Yes	100.0%
	No	0.0%
Finish	Bisque	4.9%
	Black	21.0%
	Satina	2.5%
	Silver	21.0%
	Stainless	24.7%
	White	25.9%
ENERGY STAR	Yes	70.4%
	No	29.6%
Three Drawers	Yes	50.6%
	No	49.4%
Glass Shelving	Yes	98.8%
	No	1.2%
Water Filtration System	Yes	96.3%
	No	3.7%

Table 8. Summary of Numerical Product Attributes from Analysis of Top Selling Refrigerators at Select Retailers.

Attribute	Mean	Median	Minimum	Maximum
Price	$1,067	$1,000	$665	$2070
Cubic Feet	24.8	25.1	21.7	26.0

Further, to help define a realistic set of attribute/price combinations, we used this data to perform a simple linear regression of the attribute levels on price. The results of this regression are summarized in Table 9. Note that for the brand dummy variables, the brands Galaxy, Inglis and Samsung represent the base case, while for the retailer dummy variables, Sears is the base case.

Table 9. Results of Regression of Attribute Levels on Price.

Variables	Coefficients		t	P-value
	Beta	Standard Error		
(Constant)	460.327	429.012	1.073	.287
Whirlpool	187.051	230.942	.810	.421
Frigidaire	-61.478	258.439	-.238	.813
GE	-215.283	224.498	-.959	.341
Hotpoint	-134.871	282.040	-.478	.634
Kenmore	-60.861	242.972	-.250	.803
LG	-62.139	258.460	-.240	.811
Maytag	-235.973	224.607	-1.051	.297
AJ Madison	-147.288	122.819	-1.199	.235
Best Buy	-179.449	118.116	-1.519	.134
Home Depot	-194.160	120.731	-1.608	.113
Stainless Finish	273.049	60.228	4.534	.000
Cubic Feet	13.689	18.517	.739	.462
Noise control	227.560	309.937	.734	.466
Humidity Control	-44.490	182.661	-.244	.808
ENERGY STAR	192.458	93.034	2.069	.043
3 Drawers	120.118	75.726	1.586	.118
Water Filtration System	146.560	158.400	.925	.358

The number of product attributes for this study must be limited to ensure a manageable set of choice tasks. Thus, several refrigerator attributes will be held constant across all of the varieties. The refrigerator configuration will be side-by-side, because nearly 56% of the ENERGY STAR refrigerator models are side-by-side. All side-by-side ENERGY STAR models are automatic defrost and virtually all have ice makers. Thus, all of the varieties in the survey will be automatic defrost and will have an ice maker. Further, the brand will be limited to one of the four mid-range brands - Frigidaire, General Electric, Kenmore, or Whirlpool - that together comprise over 55% of the U.S. market (USEPA, 2007d). The non-environmental product attributes which we will consider including in the choice tasks (i.e., which will be allowed to vary across the different varieties) and our working supposition of their values are as follows:

- Volume (22.5 cu ft , 24.5 cu ft, and 26.5 cu ft);
- Finish (Stainless Steel, Color (white, almond, black, other));
- Shelving (glass, wire, or plastic);
- Noise control (yes or no);
- Water filtration (yes or no);
- Ice and water service through the door (yes or no);
- Humidity-controlled crisper drawer (yes or no);
- Temperature controlled deli-drawer (yes or no);
- Length of limited parts and labor warranty (1 or 2 years); and
- Price ($800, $1,100, $1,400, $1,700, $2,000, $2,300)

Environmental Labels

There will be four different survey versions with the only difference between the four being the environmental label included in the conjoint analysis exercise. Two of the versions will utilize an ENERGY STAR label. Descriptions of the labels will posit the same energy savings and emissions reductions but will differ in terms of the cost savings associated with the energy savings, which in turn, will be based upon different assumed electricity prices. One will be based on some historical low price (e.g., the 10 year low), while the other will be based on a high price corresponding to future electricity price projections. The third survey version will use a Green Power Partnership label, where the emissions reductions will approximate the annual emissions reductions for the ENERGY STAR label. The fourth survey version will use a hypothetical Energy Saving Manufacturer label that will ostensibly be awarded to products that have been manufactured with energy saving manufacturing processes. Once again, the total emissions reductions will approximate the annual savings from the ENERGY STAR program.[18]

[18] The Energy Saving Manufacturer label is included because the public benefits correspond closely to those of the ES - emissions reduction from reduced energy consumption. The Green Power Partners label is included, in part, because it is not fictitious (although it will have to be manipulated to be made applicable to an individual product)

We have chosen to use seal-of-approval type labels for this research because they are the most popular form of environmental label (USEPA, 1998) and because it is well suited to the methodology and approach to be employed in this project. The problem with other label types such as the “report card” (for a description of the report card and other label types, see USEPA, 1993) is that the neutral manner in which they present their environmental information may not provide a basis for intrinsic motivation and, more practically, because they make the coupling of a private and public benefit awkward. The US label that provides the best example of this coupling is the ENERGY STAR (ES).

Respondents will be provided information on the labels via an information or education screen, similar to that shown in Figure 4. The screen will provide respondents a basic idea of the labeling program, with an option to acquire more detailed information or proceed with the survey. The additional information provided will include more details on the label sponsor, the criteria for awarding the label and the process by which the label is awarded. Respondent choice of acquiring more information or proceeding will be recorded and incorporated into the analysis. Similar information screens will appear for the non-environmental attributes.

Figure 4. Example of ENERGY STAR Information Screen.

Another factor that you may consider is whether or not the refrigerator has been awarded an ENERGY STAR® label. All refrigerators sold in the US are required to meet federal guidelines limiting their energy consumption. To be awarded the ENERGY STAR label, the refrigerator must consume at least 20% less energy than the federal guidelines. As a result, an ENERGY STAR refrigerator will, on average, reduce a household’s electricity bill by $14 per year and reduce the emission of carbon dioxide associated with energy production by about 195 pounds per year. Carbon dioxide is a greenhouse gas that contributes to global climate change.
Would you like more information on this attribute or are you willing to proceed with the survey? ❍ **Ready to proceed** ❍ **Would like more information**

and therefore of more interest for public policy reasons, but also to evaluate whether the nature of the emissions reductions is relevant to respondents.

The ENERGY STAR information screen will provide respondents with an estimate of the electricity use reduction, the resulting reduction in electricity costs, and the associated reduction in CO_2 emissions from the purchase of an ENERGY STAR refrigerator as opposed to a refrigerator that simply meets minimum federal standards. These estimates are provided in Table 10. Department of Energy Information Administration (US DOE/EIA, 2006) estimates that average US CO_2 emissions per kWh of net electricity generation are 1.37 pounds, calculated as 2005 emissions of 2.51 billion metric tons (about 5,540 billion pounds) divided by 4,055 billion kWh net generation of electricity.

Table 10. Projected Energy and Emissions Savings with ENERGY STAR Refrigerator

Refrigerator Volume (cubic feet)	22.5	24.5	26.5
Projected Adjusted Volume (cubic feet)[a]	27.47	30.44	32.73
Maximum under Federal Requirements (annual kWh)[b]	683.45	713.4	736.57
Maximum under ENERGY STAR (annual kWh)[c]	546.76	570.72	589.25
Energy Savings with ENERGY STAR (annual kWh)	136.69	142.68	147.31
Energy Cost Savings with ENERGY STAR (annual $)[d]	$14.23	$14.85	$15.34
Reductions in CO_2 emissions with ENERGY STAR (annual pounds)	187.27	195.47	201.81

[a] The adjusted volume is based upon the freezer compartment to fresh compartment volume of similarly sized ENERGY STAR side-by-side models. The formula for the adjusted volume (AV) is AV= V*(1-f)+V*f*1.63, where V is volume and f is the proportion of volume taken by the freezer.

[b] The formula to calculate the federal requirement (FR) is FR ≤ 10.10*AV+406.0 kWh (USDOE/EERE, 2005).

[c] The new (2008) ENERGY STAR requirement of 20% reduction is used.

[d] The energy cost savings are calculated at 10.41 cents per kWh (EIA national average residential energy price for electricity year-to-date through June 2007 (USDOE/EIA, 2006).

Examples of initial efforts to construct information screens for the other two programs are shown in Figures 5 and 6.

Figure 5. Example of Green Power Partner Information Screen.

Another factor that you may consider is whether or not the refrigerator has been manufactured by a company that participates in the Green Power Partner program. To participate in the Green Power Partner program, a specified percentage of the annual electricity requirements of the manufacturer must come from renewable sources such as solar, wind, geothermal, biogas, biomass, or low-impact small hydroelectric sources. It is estimated that by meeting the requirements of the program, a refrigerator manufacturer will reduce the emission of carbon dioxide associated with energy production by about 195 pounds for every refrigerator produced.

Carbon dioxide is a greenhouse gas that contributes to global climate change.
Would you like more information on this attribute or are you willing to proceed with the survey? ❍ **Ready to proceed** ❍ **Would like more information**

Figure 6. Example of Energy Saving Manufacturer Information Screen.

Another factor that you may consider is whether or not the refrigerator has been manufactured by a company that participates in the Energy Savers program. To participate in the Energy Savers program, the manufacturer must reduce energy consumption by installing energy-saving technologies or adopting energy-saving practices. It is estimated that by meeting the requirements of the program, a refrigerator manufacturer will reduce the emission of carbon dioxide associated with energy production by about 195 pounds for every refrigerator produced. Carbon dioxide is a greenhouse gas that contributes to global climate change.
Would you like more information on this attribute or are you willing to proceed with the survey? ❍ **Ready to proceed** ❍ **Would like more information**

Focus Group Analyses

Three different rounds of focus group meetings will be conducted to evaluate the product and attribute selections, the descriptions of the environmental labels, and the choice experiments and actual survey instrument. The first round will be used to evaluate and guide our decisions on product choice and attribute specification. As for product selection, we will focus on a refrigerator and the various attributes that can be used to differentiate different varieties of refrigerators to the focus groups. If, after the analysis, we determine that refrigerators are not a viable option, we will repeat the process for another appliance. Thus, the final product and attribute selection will not be made until after we have vetted the product and attributes with a focus group.

Since the choice task can not include all possible attributes, a primary goal of the focus group work will be to determine which attributes to include in the choice tasks, which to hold constant across all versions and which can be reasonably ignored. Our expectation is that any attribute that consumers would "expect" to see in connection with a description of different varieties of the product will be either included in the choice task or included in a description of the product the respondents are being asked to evaluate (i.e, held constant across the choice tasks). An important part of this analysis will be evaluating respondent understanding and response to the different attributes. Thus, this analysis will also be used to ensure that attribute descriptions will be clearly understood by survey respondents.

The second round of the focus group meetings will concentrate on the environmental labeling attributes to be included in the analysis. This attribute warrants its own focus group acitivy because it is central to the project and because of the complex issues surrounding consumer understanding and perception of the various labels. The primary intent here will be to insure that the label descriptions are as clear and cogent as is possible. The effort will likely proceed in two stages, with the first involving open-ended sessions designed to better understand how people think about the underlying issues of energy savings and associated cost savings and emissions reductions. The second session will be used to evaluate specific descriptions of the labels and their relevance to these issues.

The third round of the focus group meetings will be used to evaluate the full survey instrument, emphasizing the ability of respondents to navigate the choice tasks. The intent will be to ensure that all aspects of the survey are easily and correctly understood, and that there are no technical, technological or other problems associated with respondent completion of the survey. This approach will consist of question-and-answer sessions with individuals who have completed the choice tasks and an online pre-test of the survey instrument itself.

A Priori Hypotheses

The test of the MCO hypothesis will be that WTP implied by the choices made for the public-benefit-only labels (GPP and ESM) is greater than that for the low private benefit ES label (ES_L), but less than that for the high private benefit ES (ES_H) label [*i.e.*, WTP(ES_H) > WTP(GPP, ESM) > WTP(ES_L)]. Including both the GPP and the ESM labels not only makes for a more robust test of MCO, but it also would allow us to test for differences in consumer perceptions in how the emissions reductions were generated (renewable energy or energy conservation).

One concern about this approach is that there is a difference in the flow of emissions reductions over time between the ES program - where energy savings and hence reductions would presumably occur over the life of the product - and the GPP and ESM programs, where the energy savings and reduction would ostensibly occur only during the construction of the product. Since individuals are likely to discount future emissions reductions at different rates (between zero and infinity) and have different expectations as to the life of the appliance, it would be extremely difficult to equate the "one-time" reductions from the GPP and ESM programs with the flow of reductions associated with the ES label. However, we do not think that this is as problematic as it might first appear. First, we believe that the actual amounts of emissions reductions will make little or no difference to consumers as they have little context by which to judge these reductions and because their production choice implies an infinitesimal contribution to the public good, i.e., environmental quality.[19] Second, it is not all that clear that the contribution to the public good through the purchase of a GPP or ESM product should be considered a "one-time" reduction. After all, the appliance has already been constructed when it

[19] See earlier discussion of why the "joy of giving" may be the important thing. Alternatively, thinking back to our discussions of the underlying economic model (i.e., Bénabou and Tirole (2005)), the important thing to the consumer is to somehow define herself as "environmentally responsible" and choosing the environmentally superior option may accomplish this task regardless of how superior it in fact is.

is purchased. By purchasing a labeled appliance (be that label ES, GPP, or ESM), the consumer is not only having some (perhaps infinitesimally small) direct impact, but is also in a sense "voting" for emissions reductions with some not completely unreasonable belief that her vote may have some influence on: manufacturer decisions over whether to produce or market more or less labeled varieties; retailer decisions over whether to stock or market more or less labeled varieties; the decisions of other consumers, or policymakers. Thus, it is plausible that the consumer may be motivated not only by the direct impact but also by an expected value of their vote that is equal to the probability that it will influence the actions of another multiplied by the effect of such actions on emissions. Further, the latter may well outweigh the former. To the extent that the latter does serve as a motivator, then the value of the vote (in terms of emissions reductions) will accrue in the future, which means that the reductions associated with the GPP and ESM labels are not simple one-time events.

For the purposes of testing the MCO hypothesis, what seems to be important is that the present value of the discounted emissions savings from the ES program are at least as great as the savings from the GPP and ESM programs. If this can assumed to be true, then it can be argued that $WTP(ES_H) > WTP(GPP, ESM) > WTP(ES_L)$ implies MCO regardless of how respondents to the ES label discount future emissions reductions. If respondents did not believe this to be true, then it could be argued that the higher willingness to pay for GPP and ESM labeled varieties were a function of the higher emissions reductions perceived to be associated with these labels.

One key to this test is that the increase in extrinsic motivation associated with higher level of the private benefit compensates for any loss in intrinsic motivation associated with the presence of the private benefit. Otherwise, we will not be able to distinguish between MCO and stronger preferences for the nature of the contribution to the public good associated with the GPP or ESM programs. Thus, the cost savings associated with the ES_H program will need to be set at a fairly high level.

An additional point is that we are largely ignoring the EnergyGuide label. For the ES versions of the survey, the energy efficiency of the non-labeled varieties of the appliance will be constrained to meeting the minimum federal requirements. Thus, by describing the energy and cost savings of the ES variety over the variety that only meets the minimum federal requirements, we will essentially be providing the same information that a comparison of the EnergyGuide labels for the two varieties would provide. For the GPP and ESM versions of the survey, the (universal) description of the appliance being evaluated will contain either information on energy cost and consumption or will simply state that the appliance meets the federal minimum requirements. Thus, in these versions, there will be no energy consumption attribute. This solution unfortunately abstracts from the rich environment surrounding appliance consumption, but is necessary to create the distinction between a labeling program with purely public attributes and one with public and private attributes.

The structure of the surveys will also enable us to investigate a number of other issues and test a number of other hypotheses. Some of these other issues are:

- The salience of the different environmental labels relative to price and non-environmental attributes;
- Relationship between consumer response to the environmental label and the attitudinal and demographic variables;
- Effect of the two different levels of private incentive with the ENERGY STAR label (ES_H and ES_L);

- Whether respondents receiving the survey versions with the public-reward-only label (GPP and ESM), and thus those who have not had their intrinsic motivation reduced, will be more likely than those receiving the survey versions with the public/private label (ES_H and ES_L), to state a willingness to engage in pro-environmental actions in the future;
- Whether there is an interaction effect between the environmental labels and price of the product, with the public-reward-only labels (ESM and GPP) showing less sensitivity to changes in price than the public-private labels (ES_H and ES_L);
- Discount rate necessary to justify willingness to pay for product varieties with the ENERGY STAR label; and
- Whether consumers exhibit differences in preferences over the manner in which the emissions reductions are achieved, as indicated by differences in willingness-to-pay between for product varieties with the GPP and ESM labels.

Econometric Analysis

The econometric analysis will consist of three parts. First, utility functions will be estimated based on responses to the CA questions. Second, willingness to pay measures for the environmental attributes will be calculated. Third, comparisons of these willingness to pay measures and/or characteristics of the utility functions across instrument formulations and respondent characteristics will be carried out in order to test the hypotheses proposed above.

The estimation of the utility functions typically involves likelihood maximization with a likelihood function constructed using response probabilities derived from an underlying economic model of random utility maximization (RUM), based on the approach originally outlined by McFadden (1974). In this general formulation, a respondent's utility associated with the *ith* alternative, u_i , consists of a deterministic component, v_i , and a stochastic component, ε_i:

$$u_i = v_i + \varepsilon_i \qquad i = 1,...,N \tag{1}$$

The deterministic component will be some function of attributes of the alternative (denoted X_i) and of the individual (denoted Z)

$$v_i = f(X_i , Z; \beta) \tag{2}$$

where β is a vector of parameters to be estimated. The stochastic component reflects unobserved attributes of either the individual or the alternative and/or random variation in preferences among individuals. The ε_i's are assumed to have a zero mean, and are conventionally taken to be independently and identically distributed (IID) and to be homoscedastic, with a constant variance. Because of its tractability, the model usually employed is a multinominal logit (MNL) model in which the ε_i's are assumed to be IID extreme value with a common scale parameter μ; in this case the probability of selecting the *ith* alternative in a CA experiment is given by

$$Prob(i\ chosen) = exp\ (\mu\, v_i\ ) / \textstyle\sum_j\ exp\ (\mu\, v_j\ ). \tag{3}$$

In this framework, the parameters to be estimated are β and μ. With most formulations of (2), one of these parameters will not be identified; this is generally handled by normalizing $\mu = 1$. Given estimates of β (and μ), one can define compensating variation (WTP) or equivalent variation (WTA) welfare measures for items or for attributes of items featured in the CA experiments. Given the RUM formulation, WTP and WTA are random variables from the point of view of the researcher, with probability distributions induced by those of the ε_i's. For a point estimate, it would be natural to employ the mean or median of this distribution. Hanemann (1999) shows some theoretical properties of these welfare measures, and Herriges and Kling

(1999) examine their empirical properties based on a Monte Carlo markov chain simulator developed by McFadden (1995).

To analyze our survey data, we expect to employ more complex RUM models than the MNL model in (3), for three important reasons. First, the MNL model does not allow adequately for heterogeneity in preferences among respondents – the systematic heterogeneity is reflected in the set of variables included in *Z*, and all the residual heterogeneity must be captured in the ε_i's. Second, the MNL model implies an assumption of independence of irrelevant alternatives (IIA) that experience has shown is often violated. Third, the MNL model implies that, in evaluating alternatives, the individual exhibits variances of the ε_i's that are constant irrespective of the alternative and the preference elicitation task and setting – assumptions that experience has shown are also often violated. Therefore, richer models will be needed for our data analysis.

The key to obtaining a model that avoids these restrictions is to employ a different and more general stochastic specification of the ε_i's. There is now a substantial literature on how to do this, which is summarized by several of the contributors to a special issue of the *Journal of Econometrics* (Vol. 89, 1999), as well as in the recent textbook by Louviere, *et al* (2000). Most of these involve variants of the extreme value distribution, including the following: (1) Nested logit, based on the generalized extreme value distribution; this relaxes the IIA assumption, but it requires that the all of the ε_i's within any given cluster have the same variance. (2) Random effects heteroscedastic logit model (Bhat, 1995; Hensher, 1998), allows the ε_i's to be independently, but not identically, distributed as extreme value variates, each with a separate variance. This formulation has been used extensively for the purpose of combining choice data from different sources – e.g. from different surveys or different elicitation formats (Louviere, *et al*, 2000, Chap 8). (3) Covariance heterogeneity fixed effects model, in which the variances of the ε_i's is explicitly parametrized as a function of covariates. This has been used by Swait and Adamowicz (1999) to model the effect of the complexity of the choice task (represented through some appropriate metric) on the variability of CA responses; it could similarly be used to capture effects such as learning or fatigue that might influence responses as the survey progresses; or respondent uncertainty, where the variance is a function of respondent characteristics (e.g. level of education) or characteristics of the specific choice (e.g., degree of similarity among the alternatives in the choice experiment). (4) Mixed logit, where a part of the ε_i vector is assumed to have an error-components structure that can induce both heteroscedasticity and correlation over alternatives (Brownstone and Train, 1999); McFadden and Train (1997) prove that *any* RUM model can be approximated arbitrarily closely by an appropriate mixed logit model. (5) Random parameter logit, where (a subset of) the coefficients β in (2) are taken to be random with some mean and some covariance matrix (Revelt and Train, 1998); while the motivation is different, this model may be formally indistinguishable from the mixed logit model. If the coefficient associated with an attribute of the individual (*Z*) is random, this allows for correlation of the random component across responses from the same respondent. (6) Models where ε_i consists of two components, one being extreme value and the other normal, yielding what Ben-Akiva and Bolduc (1996) call "probit with a logit kernel;" an example is a random parameters model where β is normally distributed (Allenby, *et al*, 1998). (7) Hierarchical Bayes models (Lenk *et al*, 1996), which employ a probit model with a logit kernel embedded in a Bayesian setting where the researcher has a prior distribution for β and uses the CA data to obtain an updated posterior distribution for β. (8) Latent class heteroscedastic MNL models where, instead of the random parameter formulation (5) with the parameters drawn from some continuous distribution, the parameters are assumed to have a discrete joint distribution with a discrete number (say *S*) of support points – it is assumed that there are *S* types of consumers, each with its own parameter vector β_s; in addition to the S parameter vectors, one estimates a class inclusion probability π_s giving for each individual the probability that he is of type *s*. An early application of a latent class model in marketing is Swait (1994); a more recent application to CA is Peter Boxall's Ph.D dissertation (Boxall, 1999).

Of these alternatives, only nested logit yields a simple, closed-form expression for the choice probabilities in (3); the other approaches involve conditional choice probabilities integrated over the distribution of the random components which do not yield closed-form expressions and require some form of numerical integration instead. While numerical approximation was used previously, Monte Carlo simulation is now widely employed as the method of integration, and software to do this is available from David Hensher and Kenneth Train which can be adapted to deal with the various approaches associated with (2) through (6). The Bayesian approach in (7) requires more complex simulation of probability integrals, but this is available in a canned routine from Sawtooth Software. The latent class models (8) are implemented through standard maximization software. While we are prepared to investigate a variety of models if the data appear to require this, at this point we expect to focus most of our attention on random effects logit (2), the covariance heterogeneity fixed-effects model (3), mixed logit (4) and possibly latent class models (8).

Conclusion

This project will provide information relevant to both consumer labeling and information disclosure generally and will help in the design of these programs. It will produce evidence of a preliminary but helpful sort about:

- How labels that provide information that is predominantly, if not solely, of a public good nature are likely to fare relative to labels that combine the public reward with a private reward, especially those that provide what might be considered a "token" private reward;
- What consumer characteristics are likely to be associated with willingness to consider an environmental attribute in consumption decisions;
- How useful CA is for assessing labeling proposals; and
- How seriously to take the wealth of marketing surveys in which respondents appear responsive to environmental labels.

In broader terms, this research has important implications for the use of information disclosure, if not market mechanisms in general, in all areas of environmental regulation. Intrinsic motivation, on some level, is almost certain to be lurking in the basis for all environmental information disclosure programs because of the public good qualities of improvements in environmental performance. Thus, while information from the Toxics Release Inventory may prompt an investor to shy away from or gravitate toward a particular firm or industry because of what the information indicates about likely needs for future capital or equipment costs associated with emissions abatement, it is perhaps equally likely that the investor's concern for the future profitability of the firm or industry involves intrinsic motivation. Either the investor herself might hold preferences over a firm or industry's environmental profile, or the investor may be concerned about the likelihood that other consumers may now or in the future hold, and be willing to act upon, such preferences.

At an even broader level, economists have long argued for the adoption of market mechanisms as instruments of environmental regulation. However, the pace of adoption has been slowed by a number of different objections to these types of instruments. One of the most commonly expressed, but least tested, objections concerns what might be called their amorality - i.e., that, by “legalizing pollution,” these policies will engender “moral ambiguity” and ultimately increase the difficulty of the regulator’s task. An expansive view of this research is as an attempt to use the distinction between intrinsic and extrinsic motivation to test this objection. After all, what are market mechanisms, but appeals to extrinsic motivation? And, what reasonable definition of moral ambiguity would not encompass a process by which intrinsic motivation to protect the environment is crowded out by extrinsic motivation to benefit oneself? Thus, MCO and, more generally, the distinction between intrinsic and extrinsic motivation provide the means to state this general objection to market mechanisms in an empirically testable form.

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Voluntary Information Programs and Environmental Regulation: Evidence from 'Spare the Air'[1]

W. Bowman Cutter
UC Riverside

and

Matthew Neidell
Columbia University

[1] Corresponding author: Matthew Neidell. E-mail: mn2191@columbia.edu. Address: Department of Health Policy & Management, Columbia University, 600 W. 168th St., 6th floor, New York, NY 10032. Telephone: 212-342-4522, facsimile: 212-305-3405. The authors thank Joshua Graff Zivin, Lucas Davis, Matthew White, and seminar participants at the Santa Barbara occasional environmental workshop, Environmental and Resource Economics 3rd World Congress in Kyoto, and the Center for Globalization and Sustainable Development Seminar Series at Columbia University for useful comments, Mark Coryell at the EPA for helpful discussions, and Nicholas Crain and Katie Hamic for excellent research assistance. Funding from the EPA STAR grant number RD-83284801-0 is gratefully acknowledged.

Voluntary Information Programs and Environmental Regulation: Evidence from 'Spare the Air'

Abstract: This paper assesses whether individuals change their transportation choices in response to "Spare the Air" (STA) advisories, a public voluntary information program in the San Francisco Bay Area that elicits reductions in ozone producing activities. Since STAs are issued when ozone levels are predicted to exceed a particular threshold, we use a regression discontinuity design to identify the effect of STAs. We also use traffic conditions in Southern California, an area without STAs, to estimate difference-in-differences models. The results suggest that STAs reduce traffic volume and slightly increase the use of public transit, with some intriguing patterns of responses within the day, but do not have a statistically significant effect on ozone levels.

JEL codes: Q52, Q53, Q58, L91

Keywords: voluntary programs; air quality; traffic; public transit; ozone

Environmental policy makers around the world increasingly rely on voluntary programs to improve environmental quality. The 'Community Right-to-Know Act' that led to the development of the toxic release inventory (TRI) and 'Climate Wise' are examples of landmark efforts to reduce toxic and carbon dioxide emissions, respectively (Morgenstern and Pizer (2007)). Most voluntary programs target firms who, despite the notion of altruism, may respond because it affects profits through changes in consumer demand.[2] Therefore, such programs ultimately hinge on consumers, who indirectly improve environmental quality through purchase decisions although there are no direct economic incentives to do so.

The main focus of this paper is to assess whether individuals respond to information programs targeted directly at them by voluntarily forgoing consumption of a commodity that may increase pollution.[3] We examine the "Spare the Air" (STA) program, offered in the San Francisco Bay Area, which is designed to elicit voluntary reductions in automobile trips on days when ground-level ozone is predicted to exceed Air Quality Standards (AQS). STAs encourage the public to reduce driving through ride-sharing or use of public transit. Since some of the emissions from automobiles are a direct precursor to ozone formation, this program intends to lower ozone levels and improve the chances of attaining AQS in order to avoid costly regulations.

A secondary focus of this paper is to assess whether STAs impact ozone levels, which speaks to highly-contested ozone regulation policy.[4] The increased marginal abatement cost associated with lowering ozone from the current, historically low levels suggests that traditional

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[2] See, e.g., Hamilton (1995), Khanna et al. (1998), Konar and Cohen (1997) for evidence of the effect of TRI on stock prices and Bui and Mayer (2003) for evidence of the effect of TRI on housing prices.

[3] An exception is Reiss and White (2003), who found that households in San Diego voluntarily decreased electricity consumption in response to media campaigns during the 2000-1 electricity crisis. However, this was a one-time program that arose from a unique situation, so it is not clear how it relates to regularly maintained information programs used for regulatory purposes.

[4] This debate is recently demonstrated by the lengthy legal battle over the proposed 8-hour ozone standard, which as issued by the EPA in 1997 and finally upheld by the Supreme Court in 2002 (Bergman (2004)).

regulation methods may be particularly costly for local governments and private firms (Lieu et al. (2003)). Lowering ozone is further complicated by the variability in the underlying natural conditions that lead to ozone formation. For example, even if ozone-causing emissions are constant throughout the year, unusually hot and sunny weather leads to high levels of ozone, partially explaining the pervasive ozone levels in California.[5] Furthermore, because global climate change is predicted to increase temperatures, this may increase ozone levels for any given level of ozone-causing emissions (Racherla and Adams (2006)), so episodic high ozone levels may be a more important public health problem in the coming decades. Traditional regulations that lower emissions by power plants or public vehicle fleets reduce emissions on all days, regardless of meteorological conditions. It may only be necessary to reduce emissions for the limited number of times per year when natural conditions might lead to exceptionally high ozone levels. Therefore, ozone outreach action programs, such as STA, may be more efficient than traditional regulations by allowing policymakers to focus regulatory effort only on those days when the effort is needed to avoid exceeding ozone standards. Given that numerous areas throughout the country have since implemented similar voluntary programs, such as Sacramento, CA, Atlanta, GA, Charlotte, NC, Houston, TX, and Pittsburgh, PA, to name a few, evaluating their impact is necessary to determine how these programs can best be incorporated into state and local efforts to meet air quality standards.

To assess if people are responding to STAs, we use administrative data on highway traffic volumes and public transit ridership in the Bay Area. If people respond to STAs by substituting away from higher ozone-producing activities towards lower ones, we expect to see a decline in traffic volume coupled with an increase in public transit use. Whether people respond to this particular program, however, is complicated by counteracting incentives. If STAs result

[5] The majority of California does not meet national ambient air quality standards for either 1-hour and 8-hour ozone.

in a reduction in trips by some individuals, then other individuals may respond to the reduction in expected traffic (and hence reduced travel time) by undertaking more trips, resulting in a free-rider problem. In addition, evidence indicates that individuals in Southern California reduce time spent outside in response to “smog alerts”, which are also based on ozone forecasts, though issued at a higher threshold (Neidell (2007)). Therefore, it is plausible that STAs signal information about risk so that individuals susceptible to ozone may decrease the use of public transit because it increases time outdoors and thus exposure to ozone. These incentives create an ambiguous prediction of the effect of STAs on transportation choices depending on the nature of the trip.

In addition, STA alerts may have a differential effect depending on the purpose of the trip and availability of alternative options. Discretionary (i.e., leisure) trips may be easier to change than work-related commuting trips because discretionary trips can be cancelled or rescheduled, as they are flexible by definition. On the other hand, most workers have little flexibility in missing a work day, especially if labor supply is fixed in the short run and telecommuting alternatives are unavailable, so commuting trips have a significantly higher cost of cancellation. Since discretionary trips are taken throughout the day, while commuting trips are concentrated in the peak rush hour periods, we examine the STA effect for each hour during the day in order to allow the response to vary throughout the day.

We use a regression discontinuity (RD) design to identify the effect of STA on transportation choices. Since STAs are issued when ozone levels are predicted to exceed a particular threshold, we compare outcomes on days just above the threshold to outcomes on days just below the threshold. If other factors affecting transportation choices are similar around the threshold, as evidence supports, this design controls for all confounding factors. Therefore, any difference in transit outcomes can be directly attributed to the STA advisory. Furthermore, the threshold used for issuing STAs is not publicized[6] and exogenously changed over the time period we study because of changes in federal air quality standards for ozone, so it is unlikely individuals respond to the underlying index that determines STA status.

In addition, we extend our RD design for the traffic regressions by estimating difference-in-difference models that include a control group that does not have a voluntary alert program. For the control group, we use traffic volumes in the metropolitan Los Angeles area. This area has many similar behavioral and environmental factors as the Bay Area, but does not have a voluntary traffic reduction program, so controlling for changes in traffic conditions in Los Angeles captures unobserved factors common across the two areas.

Our findings indicate people respond to STAs, but this is only detected when we employ the regression discontinuity model. STAs reduce total daily traffic by 2.5 to 3.5 percent, with the largest effect during and just after the morning commuting periods. STAs have no statistically significant effect on total daily public transit use, but borderline statistically significant effects during peak commuting periods. Our results are robust to alternative specifications of the RD and the inclusion of traffic monitor or BART station fixed effects. Given the robustness of our results, the plausible time of day patterns, and evidence of substitution from driving to public transit, it seems unlikely our results are driven by unobserved heterogeneity.

Given that we find evidence of a reduction in ozone-producing activities, we also assess whether these programs impact ozone levels using the same regression discontinuity design. Although the ozone formation process is far more complicated than the reduced form model we estimate, the model we estimate directly addresses the policy relationship of interest: do STAs

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[6] For example, we contacted the Bay Area AQMD several times until we could locate the correct employee who knew the STA threshold.

lower ozone levels? Naïve estimates indicate that STAs *increase* both 1-hour and 8-hour ozone levels, confirming that STAs are more likely to be issued on days that would have higher ozone levels anyway. In our regression discontinuity models our estimates, though statistically insignificant, indicate a decrease in ozone levels, which highlights the importance of accounting for the factors leading to ozone formation.

Our results cast doubt on the effectiveness of the STA program and, since the program has the best chance of working in an environmentally friendly area with several public transit alternatives, we suspect comparable traffic programs elsewhere in the U.S. are unlikely to significantly improve air quality. That individuals respond to STAs suggest such voluntary information programs have a potential role in regulatory policy, but such programs alone do not appear sufficient for detecting improvements in air quality; additional incentives appear necessary.

1. Background on Ozone and STAs

Ozone (*oz)* is not directly emitted into the atmosphere, but is formed from interactions of nitrogen oxides (*NOx*) and volatile organic compounds (*VOCs*) in the presence of heat, sunlight, and solar radiation (*solrad*):

(1) $oz = f\,(NOx, VOC, weather, solrad).$

Because of this process, ozone levels vary considerably both across and within days – it tends to peak in the summer and middle of the day when heat, sunlight, and/or solar radiation are at their maximum (U.S. EPA (2003)). Ozone levels are particularly high in California because of greater amounts of heat and sunlight that lead to ozone formation, the mountains that help to “trap” pollutants, and the temperature inversion layers that enhance ozone production.

NOx and VOCs, the two primary precursors to ozone, are directly emitted. Both stationary and mobile sources, primarily automobiles, contribute considerably to NOx and VOC emissions. For example, 49 percent of NOx emissions in the San Francisco Bay Area, Sacramento Valley, and San Joaquin Valley are due to on-road mobile sources, with 55 percent of that coming from gasoline vehicles (Air Resources Board (2003)).

Although there are no direct air quality standards (AQS) for NOx and VOC, AQS for ozone are based on measures taken on a daily basis. For example, in order for an area to attain AQS for 8-hour ozone, "the 3-year average of the fourth-highest daily maximum measured at each monitor within an area over each year must not exceed 0.08 ppm" (40 CFR 50.9; see Federal Register of April 30, 2004 (69 FR 23996)). Because this is based on a peak observation and not the mean over a period of time, despite extensive efforts to reduce ozone levels, unexpected weather can lead to air quality violations.

Policy makers consider various approaches to achieving AQS. One approach is to shift the distribution of NOx and VOC to the point that the maximum amount of emissions will not result in an ozone violation. Given the inherent fluctuations in weather, ensuring that violations no longer occur even on hot, sunny days can impose extensive costs to firms and individuals, especially if there are increasing marginal abatement costs to reducing ozone levels.

An alternative approach to avoiding AQS violations is to respond to forecasted weather conditions by limiting sources of pollution only on days when violations may occur. This can be accomplished by targeting the sources with the lowest cost of shifting pollution generating activities to other days. Since factories face considerable costs to alter their production on a temporary basis, one potential avenue is to target individuals. In particular, individuals who commute by automobile may find it less costly to switch transportation behaviors temporarily, making this a potentially more efficient policy.

The Bay Area Air Quality Management District (BAAQMD), which encompasses all of seven counties - Alameda, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara and Napa - and portions of two others - Solano and Sonoma, has issued STAs since 1991. In order to provide ample notification for people to alter their behavior, STAs are issued in advance based on air quality forecasts[7], and are widely publicized on the television, radio, and newspaper.

Air quality forecasts are provided for five regions (*r*) within the BAAQMD. An STA, which is disseminated the day before and day of the expected high ozone conditions, is issued based on the maximum ozone forecast across regions according to:

(2) $$STA_t = 1\{oz^f_t = \max_t (oz_{rt})\};\ oz_{rt} = f\,(oz_{rt-1}, weather^f_{rt}, solrad_t) \geq trg\}$$

where oz^f is forecasted ozone and *trg* is the trigger rule for issuing STAs. Note that traffic conditions are not used in the ozone forecast. According to equation (1), however, automobiles contribute to observed ozone levels through NOx and VOC. Therefore, temporarily reduced use of automobiles will lower NOx and VOC levels, which lower expected ozone levels, and increase the probability of attaining AQS.

2. Theory

To determine the conditions under which individuals respond to STAs, we develop a model where individuals receive value from contributions toward environmental goods even if they do not directly benefit from these goods. This is akin to ‘existence value’ -- individuals value the existence of goods they do not use in any way, such as the preservation of land -- in the environmental economics literature and to the ‘warm glow’ individuals get from giving to public

[7] All major cities in the U.S. are required to provide air quality forecasts to inform the public of local air quality and provide ample notification to react, though the main purpose is to protect public health (U.S. EPA (1999)). As mentioned in the introduction, several areas also offer programs to reduce ozone levels.

charities.[8] We generally follow the warm-glow model except we assume individuals receive greater altruism benefits from their actions as pollution problems worsen. That is, the benefits individuals receive when switching from driving to public transit are greater as ozone increases.

To formalize our model, utility is affected by a composite good (z), time spent traveling, health effects from exposure during transit (h), and environmental altruism (s), which involves their contribution to ozone levels. People do not enjoy traveling, so utility is decreasing in travel time. Health costs are weakly increasing in ozone level, $h[oz] \geq 0$, but for the vast majority of the population, their health is unaffected by ozone at these levels. Health costs are only incurred by those who use mass transit because it involves spending more time outdoors, which increases exposure to ozone.[9] Individuals spend their exogenously determined earnings[10] (w) less the monetary cost of commuting (c_j) on consumption of z. Since each person's polluting activities make a minimal contribution to overall pollution levels, we consider each person a price-taker in the ozone production market. That is, one individual's mode of transportation has no effect on ozone levels to a first approximation.

Individuals have three main choices (indexed by j) for each possible trip they might take during a day: drive alone (d), use public transit (p), or not take a trip (0). We eliminate a fourth choice of carpooling because we do not observe carpool trips in our data, but this does not impact the hypotheses we test. The associated travel time for each mode j (t_d,t_p,t_0) may be a function of STA because driving time is affected by the number of drivers on the road ($D=\Sigma d$), which is the total number of commuters minus the total number of public transit riders. If some

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[8] See Freeman (2003) for a review of the concept and Clarke (2003) for a recent example of existence valuation, and Andreoni (1995) for evidence of warm-glow.

[9] Ozone rapidly breaks down when it interacts with colder air (Chang et al. (2000)), so we assume driving involves no exposure to ozone, which is likely because drivers can use air conditioning on these unusually hot days.

[10] We assume labor supply is fixed in the short-run, but could alternatively let travel time affect time available for work. This does not affect the insights from our model.

drivers switch from driving alone to public transit, then the equilibrium driving time decreases because there are fewer cars on the road.[11] We assume public transit time is not affected by an STA because fixed time schedules allow increased ridership without delays (as long as there is spare capacity).

Each transportation mode then gives the following utility for individual *i*:

(3a) $y_{i,0} = \beta_0 X + u[(w)] - t_{i,0} + s_i[oz]$

(3b) $y_{i,d} = \beta_d X + u[(w-c_d)] - t_{i,d}[D[STA]]$

(3c) $y_{i,p} = \beta_p X + u[(w-c_p)] - t_{i,p} + s_i[oz] - h_i[oz]$

where consumption of the composite good is given by $z_j=(w - c_j)$ and X is a vector of transportation mode characteristics that affect the utility from transportation mode *j* but do not vary with the expected ozone level. We allow health costs (*h*), travel time (*t*), and warm-glow (*s*) to differ by individuals. For instance, individuals who live farther from BART stations or are more susceptible to the effects of ozone may incur greater health costs from using public transit. Individuals choose the mode y_j such that $y_j = y_{max} = max[y_0, y_d, y_p]$.

To assess how STAs affect travel modes, we assume an STA functions as a signal of higher ozone levels (i.e., $\delta STA=\delta oz$) for those utility components that are a function of ozone levels. This is a reasonable assumption because an STA is the most easily accessible signal of higher ozone levels in the Bay Area. With this setup, the effect of an STA on the change in utility for each travel mode is given by equations 4a-4c:

(4a) $\delta y_o/\delta STA = \delta s_i/\delta oz \geq 0$

(4b) $\delta y_d/\delta STA = -\delta t_{i,d}/\delta oz \geq 0$

(4c) $\delta y_p/\delta STA = -\delta h_i/\delta oz + \delta s_i/\delta oz$

[11] This is only true when highway delays exist, which is common in the Bay Area.

Equation (4a) indicates that forgoing a trip in response to the STA provides a warm-glow, which increases utility from that choice. Equation (4b) indicates that an STA alert provides no warm-glow for the driving alone alternative but reduces travel time, which also increases utility from that choice. Equation (4c) indicates that an STA alert provides a warm-glow for the public transit mode but also increases potential health costs, so the net effect on utility is ambiguous. These derivatives alone do not imply that individuals choose a particular travel mode, but instead reflect the change in utility from choosing a particular travel mode when an STA is issued.

We assess the effect of STAs on two distinct transportation trips: commuting trips and discretionary trips. We draw this distinction because labor supply is typically fixed in the short run, so canceling a trip is not an option for commuting trips for the vast majority of individuals. Evidence from Schreffler (2003), which is based on a small telephone survey that requested daily travel activities, found that for people who identify as reducing trips due to an STA, only 14.8% of trips were work related and the rest were not. Moreover, these trips tend to occur throughout the day, so there is a greater chance that these trips occur during the middle of the day when ozone levels peak.

2.A. Commuting trips

For commuting trips, we rule out the option of canceling a trip because of fixed labor supply and only compare (4b) to (4c). Since ozone levels peak during the middle of the day, they are much lower during typical commuting periods, so any health effects from ozone exposure are minimal. These derivatives imply individuals decrease the probability of driving (increase the probability of using public transit) if the environmental warm-glow outweighs the reduced travel time from emptier highways. Therefore, although STAs are designed to lower traffic volumes, they also have the perverse effect of providing an incentive to increase driving and reduce public transit use. This perverse incentive only kicks in if people respond to STAs in sufficient volume to improve traffic speeds, so it is unlikely to increase driving, but instead attenuates the effect of STAs on commuting trips. The Schreffler (2003) study finds that divers who were not aware or did not respond to STA alerts actually increased their number of trips on STA alert days; decreased highway congestion could be one reason for this observed increase.

2.B. Discretionary trips

For discretionary trips, we separately compare each of the 3 options (cancel trip, drive, public transit) to assess driving and public transit choices. Individuals decrease the likelihood of driving relative to canceling their trip if the warm glow exceeds their benefit from reduced travel time. This is the same prediction as above for commuting trips. Alternatively, individuals decrease the likelihood of driving relative to using public transit if the net effect of their warm glow less the expected health costs from public transit exceeds the reduced travel time benefit. Whether traffic decreases on net depends on the alternative mode people consider.

The model suggests that switching to public transit has low potential utility gain for discretionary trips. Canceling a trip weakly dominates public transit since it also entails receiving the warm-glow but has no negative health effects, so the probability of canceling increases relative to public transit. And, as just described, individuals increase the probability of public transit relative to driving only if the warm glow net of increased health costs exceeds the reduced travel time. Taken together, STAs have an ambiguous effect on discretionary public transit use, with the greatest likelihood of a decrease in public transit during peak ozone periods.

3. Empirical Methodology

Our goal is to estimate the demand for driving and public transit. Estimation of this equation may be hampered because STA days are not exogenously assigned. The factors that determine when an STA is issued, such as weather conditions, may also affect individual behavior, and it may be difficult to observe all of these factors. For example, STAs are more likely to be issued during particularly hot days when weather conditions are more favorable to ozone production. People may be likely to avoid the heat by staying in air-conditioned cars during these same conditions, leading to an increase in traffic. If we are unable to completely account for weather conditions or other unobservable factors correlated with STA days, then a naïve regression analysis could yield a spurious relationship or fail to find a significant relationship between STAs and transportation choices.

To account for such confounding, we use a regression discontinuity design to identify the effect of STAs (Cook and Campbell (1979)). This design assumes that all unobservable factors either do not vary around the STA trigger rule, or they evolve smoothly around the trigger rule in the same manner as the observed covariates. If days just below the STA trigger rule are identical to days just above the trigger rule, then the discontinuity in transportation choices that occurs at the trigger rule represents the causal effect of STA advisories.

To formalize this method, we estimate the following equation for both total daily volume and separately for each hour of the day:

(5) $$y_{kt} = \beta * STA_t + g(oz_t^f) + \delta_1 * W_t + \delta_2 * y_{kt-1} + \delta_3 * STA_{t-1} + \theta_k + \mu_t + \varepsilon_{kt}$$

where y is traffic or BART volume, the subscript k represents the traffic monitor or BART station, and the subscript t represents the date. We specify y in levels rather than logs because in the hourly regressions the reduced total daily volume is the relevant factor for STAs. For example, a 5% reduction at 2 a.m., when traffic volumes are low, should not have the same impact on air quality as a 5% reduction at 9 a.m., when traffic volumes are high. However, we report the percentage change in traffic from an STA for total daily volume for ease of interpretation. g is a function that relates the air quality forecast for ozone (oz^f) to transportation choices. W are other factors correlated with transportation choices, including contemporaneous and lagged observed and forecasted weather and separate dummy variables for day of week, month, and year. We include 1 lag of the dependent variable to account for any transitory shocks specific to a monitor or station, such as a highway construction project that lasts several days or longer, and lagged STA to account for any serial correlation.[12] In models using hourly measures of traffic, we include lags from the same hour on previous days rather than previous hours on the same day. θ_k is a monitor/station random effect to account for common shocks to each monitor/station. As a specification check, we also specify θ_k as a fixed effect, which captures all observed and unobserved factors constant at a given monitor or station over time. μ_t is a date specific random effect to account for the fact that STAs are issued at a daily level but we observe multiple monitors/stations per day.[13] ε is an idiosyncratic error term. Our hypothesis to test is $\beta=0$, that STAs have no effect on transportation choices.

We also extend our model for traffic conditions by including traffic monitors in Los Angeles as a control and estimating difference-in-difference models. Since the Los Angeles area is geographically close, it shares similar air quality and meteorological conditions as the Bay Area. Furthermore, the South Coast Air Quality Management District (SCAQMD), which consists of most of Los Angeles, Orange, Riverside, and San Bernardino counties, provides air quality forecasts but does not provide an STA program.[14] Therefore, we estimate a difference-

[12] Excluding both of these lags had a minimal impact on our estimates.
[13] When we include monitor or station random effect in addition to date random effects, we estimate two-way mixed effects models (Baltagi (2005)).
[14] Other metropolitan areas closer to the Bay Area, such as Sacramento, have STA programs so they cannot be used as controls. The Los Angeles area is therefore the area most similar to the Bay Area with traffic detectors and air quality forecasts but without an STA program.

in-differences model by including traffic from various monitors in Los Angeles in our main regression:

(6) $y_{kta} = \beta_1 * STA_t + \beta_2 * a + \beta_3 * STA_t * a + g(oz_{ta}^f) + \delta_1 * W_{ta} + \delta_2 * y_{kt\text{-}1a} + \theta_k + \mu_t + \varepsilon_{kta}$

where $a=1$ if the air quality district is the Bay Area and $a=0$ if South Coast. β_3 now represents the effect of STAs on traffic conditions.[15]

Using BART is only one of several options for people to alter their commuting behavior and reduce their contribution to pollution. They may carpool, work at home, ride their bicycle or walk to work, or take other forms of public transportation. All of these behaviors can lead to a reduction in traffic volume, but have no effect on BART use. Therefore, we expect a smaller effect on BART than on traffic volume.

To allow for a flexible specification of g, we estimate models restricting the sample to observations centered near the trigger rule. To understand how this strategy works, imagine restricting the sample to days with ozone forecast of .083 and .084 parts per million (ppm), where the trigger rule for issuing an STA is .084. We argue that any difference between the days other than the STA is random, as evidence below in Table 2 supports, so $\beta = E[y|STA=1] - E[y|STA=0]$ is the causal effect of STA on transportation choices. Since there are few observations with ozone forecasts of exactly .083 or .084, we instead restrict our sample to days centered on the trigger rule and also include the above mentioned covariates and the ozone forecast to account for any potential differences across the days above and below the trigger. We present estimates from two sample restrictions – within .02 and .01 ppm of the trigger rule – to assess the sensitivity of our estimates to the choice of g. Restricting the sample limits the generalizability of our results but is more likely to yield unbiased estimates for the existing

[15] Using Los Angeles as a control group minimally impacted our point estimates, though it improved precision considerably.

policy (Dinardo and Lee (2004)). Since STAs do not need to be issued for ozone levels very different from the current trigger levels for attaining AQS, the treatment effect near the ozone levels where STAs are currently issued is most relevant for ozone regulation policy.

4. Data

Data on STAs and ozone forecasts come directly from BAAQMD. Ozone STAs are only issued during the ozone season, which is from June 1 to October 15, when solar radiation, sunlight, and heat are at their peak.[16] STA alerts are issued when the ozone forecast was predicted to exceed .081 ppm in 2003 and 2004 and .084 ppm in 2001 and 2002.[17] This change in the trigger rule is due to changes in federal air quality standard for ozone, and not an endogenous policy change to influence responses to STAs. Because we observe the ozone forecast for each region within BAAQMD, we follow the decision rule in equation (2) and use the maximum forecast across the regions for each day. Table 1 shows the number of STAs issued by year in the full and RD sample. There are a total of 23 STAs issued over the 4 years and, in our most restrictive RD sample, there are 44 days when the air quality forecast is within .010 ppm of the trigger rule.

We are unaware of individual level data on transportation choices observed on a daily basis, so instead use daily aggregate measures. For one measure, we use traffic data from the Freeway Performance Measurement System, which is a joint project of the University of California at Berkeley and various California state agencies. This system collects real-time traffic flow and speed from freeways sensors throughout the State of California to generate various performance measures. The traffic monitors measure the number of vehicles passing

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[16] During the winter season, 'Spare the Air Tonight' may be issued to reduce particulate matter from wood burning stoves and fireplaces and motor vehicles.
[17] .081 ppm corresponds to 92 on the air quality index, an alternative scale frequently used for conveying air quality forecasts, and .084 corresponds to 100.

through a roadway and the speed of each vehicle in five minute intervals. We use data from 92 traffic monitors available in the BAAQMD and 50 monitors available in SCAQMD. We choose Bay Area Monitors so that there is a monitor on every freeway in the San Jose, Oakland, and San Francisco area. Given the large amount of monitors available, we use data from randomly selected monitors within these freeway segments. In SCAQMD we select 50 monitors at random from Los Angeles County.

While several performance measures are available from the traffic data, we use "traffic flow" as the dependent variable, which is the number of vehicles passing a detector during a given time period. This variable, aggregated appropriately, measures the total number of vehicles on that segment of the road. Although measures are available at 5 minute intervals, we must be cautious in not defining too narrow of a window that reflects traffic conditions in addition to traffic volume. For example, if heavy traffic congestion from 8:00 a.m. to 8:05 a.m. leads to slower driving speeds for the entire 5 minutes, then flow will indicate fewer vehicles on the road. Therefore, we compute all day traffic (6 a.m. – 12 p.m.) so that all vehicles clear the road and separate hourly measures within that time period.[18]

Although traffic flows are not necessarily an indication of trip reductions (it could reflect automobile accidents, road construction, etc.), our econometric analysis will not be affected as long as these other factors vary smoothly around the discontinuity. That is, if construction delays are similar both above and below the STA trigger level, then changes in traffic volume attributed to the STA will reflect changes in transportation choices.

For another measure of transportation, we use ridership on the Bay Area Rapid Transit (BART), the major commuting rail system in the region. This data, obtained from the San Francisco Metropolitan Transit Authority, consists of hourly station entrances and exits at each

[18] We omit volumes before 5 a.m. because they are considerably smaller than volumes throughout the day.

of the 43 stations. BART stations are mainly located in the San Francisco and Oakland areas. We compute comparable measures of the dependent variable to the traffic data. To increase responses to STAs, BAAQMD began offering free rides on BART in 2004 to all passengers when an STA is issued. In that year, fare collection gates remained opened on STA days, so entrances and exits were not counted. Therefore we omit this year from the BART analysis[19], though any effect on ozone levels will be capture in our ozone model.

Table 1 also shows summary statistics for the traffic and BART measures. Monitors in the Bay Area average flows of over 65,000 vehicles per day. BART stations average roughly 6,000 passengers per day. In terms of distribution throughout the day, traffic volumes in the Bay Area are widely dispersed between the hours of 7 a.m. and 7 p.m., while BART volume shows stronger commuting rush hour patterns. These patterns suggest that BART use is more heavily concentrated among regular commuters than road traffic and that discretionary trips are a lower proportion of BART ridership than road traffic.

For the other covariates included in our model, daily pollution data are readily available from the California Air Resources Board. There are 31 ozone monitors in the BAAQMD, and we use measures of both 1-hour and 8-hour maximum, both of which are regulated by AQS during the time period we study. We obtain daily data on weather from the Surface Summary of the Day (TD3200) from the National Climatic Data Center (NCDC). Using the numerous weather stations available in the Bay Area, we assign temperature and precipitation at the county level.[20] Since weather forecasts are an important component of ozone forecasts, we also add data on weather forecasts at the county level, obtained from coded city forecast (FPUS46)

[19] It is also unclear whether we should include these days because BART use may change because of price changes in addition to warm-glow.

[20] Data from weather stations from some entire counties were missing for several months in 2003. These values were replaced with measures from the nearest county.

provided by the Monterrey station (KMTR), available from the NCDC. The weather forecasts include the predicted high and low temperatures and cloud cover, which we capture by using a set of dummy variables. Given the different sources of data used, we limit the analysis to the years where all data exists, which consists of 2001 through 2004 for traffic and 2001-2003 for BART.

In Table 2, we present evidence to support the quasi-experimental random assignment the regression discontinuity design affords. In this Table we assess whether the covariates given in *W* in equation (5) are correlated with STA status. To do this, we present the difference in means on STA versus non-STA days, with the overall means of each variable in column 1.[21] We present this for the entire sample, shown in column 2, and for our RD samples after adjusted for the ozone forecast, shown in columns 3 and 4. For example, on STA days the maximum temperature is 14 degrees higher on average than non-STA days using all observations, but is less than 1 degree higher in the sample within .02 ppm of the STA trigger. The covariates do not balance when using the entire sample: differences for 5 of the 8 variables are statistically significant, raising potential confounding concerns. When we employ the regression discontinuity design, however, all of the covariates are balanced. This supports the notion that STAs can be treated as exogenous when exploiting the RD design so that any difference in transportation choices can be causally attributed to STAs.

5. Results for Transportation Choices

The first set of results, shown in Table 3, presents estimates of the effect of STA on total daily traffic volume in Panel A and BART ridership in Panel B. For comparison purposes, column 1 presents results using the entire sample and ignoring the ozone forecast. The results

[21] Although there are multiple stations per date, we use only 1 observation per date in this Table to properly account for the Moulton effect.

indicate a drop in traffic from STAs of approximately 1100 vehicles per monitor, but this is not statistically significant. When we estimate our preferred RD design, the effect doubles in size to over 2300 vehicles and becomes statistically significant. Moving to the more restrictive RD sample reveals a comparable estimate of 2000 vehicles, implying our estimates are not particularly sensitive to the functional form of the RD. These estimates suggest total daily traffic volumes decrease by 3-3.5% when an STA is issued and also indicate that naïve regressions that do not properly account for how STA days differ from non-STA days are biased.

Immediately below these results, we also present results using traffic monitor fixed effects. Thus far, we have used a traffic monitor random effect, which assumes that any monitor specific factors are uncorrelated with STAs. The fixed effect accounts for all observed and unobserved time-invariant factors specific to each monitor, so it offers one robustness check for our model. Our estimates are virtually unaffected by including the fixed effect, suggesting total daily traffic decreases in response to STAs.

For the BART results, in Panel B, we find that STAs are associated with an increase in total daily use of about 35 riders per station, which is less than a one percent change in total daily volume, but this estimate is not statistically significant. This estimate is comparable across all specifications, suggesting STAs are not associated with total daily use of public transit as measured by BART volume.

As previously mentioned, responses to STAs may vary by time of day depending on the nature of one's trip. In Figures 1 and 2 we plot the separate estimates of the STA coefficients with confidence intervals for each hour of traffic and BART volumes, respectively. We include estimates from only the RD samples within .02 ppm of the trigger and with monitor/station random effects, though estimates using fixed effects and a narrower window yielded comparable results.

Examining the response to STAs by hour of day reveals several interesting patterns. For traffic, we find large, statistically significant decreases in traffic during and immediately after morning hours, no evidence of a response throughout the middle of the day and into the evening rush hour, and decreases after 8 p.m., though smaller than morning decreases. The responses outside of rush hour are consistent with discretionary trips responding (Schreffler (2003)). The decrease in morning but not evening rush hour further suggests responses come from discretionary trips since commuting involves round trip travel. Given that ozone concentrations typically peak in the late afternoon and responses later in the day are unlikely to impact ozone levels, it is somewhat surprising to see traffic decreases after 8 pm. We offer two possible explanations for the unwarranted night response: 1) the evening commuting trip for those individuals who reduce the morning rush hour trip is either later than typical commuters or is pushed back later than normal, possibly to reduce exposure to ozone; 2) people may not be aware of the ozone formation process and peak pollution periods, so they obtain their warm glow when shifting activities is easiest. In support of this, STAs do not specify when people should alter their behavior. Furthermore, the Bay Areas also offers the STA tonight program during the winter, which encourages people to reduce PM 2.5 concentrations via reduced driving (and reduced use of fireplaces and woodstoves), so individuals may confuse the two. Overall, these patterns tend to support the change in traffic volume is come from discretionary trips, though we can not rule out other explanations.

Turning to the hourly BART results, we find evidence of varying responses throughout the day consistent with model predictions, though they are generally imprecise. The two largest increases in BART use occur at 9 a.m. and 6 p.m., with both estimates borderline statistically significant.[22] Both occur during rush hour, in the hour immediately after peak hourly entrances occur. Given that we estimate an effect for those who do not typically use BART, this just off-peak response could represent the increased marginal time associated with switching to public transit. These results are consistent with our prediction that the largest response for BART occurs during commuting hours.

We also find instances of decreases in BART use from 2-4 p.m., with the 3 p.m. estimate statistically significance in certain specifications. Since STAs provide information about expected air quality at a level where health concerns may arise, people may respond to STAs by reducing public transit trips in order to lower their exposure to pollution . Ozone levels peak around 3 p.m., so the decrease in BART during these hours coupled with no change in traffic volumes suggests the cancellation of public transit trips is consistent with evidence of avoidance behavior. The potential health benefits from the information contained in STAs are important to consider, but from a regulatory perspective, the goal of STAs is to reduce ozone concentrations.[23]

To further gauge the sensibility of our estimates, we compare them to estimates from other studies (Cummings and Walker (2000), Welch et al. (2005)), though we recognize ours may differ because of two important methodological differences: 1) other studies do not account for ozone forecasts, so the results are most comparable to our estimates without controlling for ozone forecasts and 2) other studies include traffic lags from the previous hour, rather than the previous day (as we do), to estimate whether traffic patterns changed within a day. For determining whether these programs have an effect on transportation choices, it is appropriate to

[22] The effect at 9 am is statistically significant with a window of +/- .01 ppm of the STA trigger, though the point estimate is comparable to the .02 ppm window.

[23] See Neidell (2007) for a more complete analysis of the effect of air quality information on avoidance behavior.

examine how transportation patterns change when an STA is issued vs. when an STA is not issued, i.e. across days. Cummings and Walker (2000) examine a similar voluntary program in the Atlanta, GA area on hourly traffic volumes and found statistically insignificant effects, just as we do in estimates that do not employ the RD design. Welch et al. (2005) examined the impact of ozone advisories on hourly public transit in Chicago, IL, and found considerably smaller impacts, though a similar pattern of increases during peak commuting periods and decreases during non-peak hours.[24] Given that these findings are comparable to results from our regressions that ignore ozone forecasts, we contend that the insignificant effects found elsewhere may be due to confounding.

6. Results for Ozone Concentrations

Given that we find evidence that STAs affect transportation choices, we now focus on whether such changes affect ozone levels. A structural model of ozone formation that accounts for ozone-related emissions and environmental conditions, such as the Community Multi-Scale Air Quality modeling system, is beyond the scope of this paper. Instead, we estimate a reduced form equation that relates ozone levels to STAs. This model provides estimates of the precise policy effect we seek to understand: do STAs affect ozone levels? Although we estimate models using the individual hourly ozone concentrations (results available from authors upon request),[25] we only provide estimates using daily ozone as defined by AQS because it is the policy variable of interest.

We estimate the same model as in equation (5) except we use the maximum 8-hour and 1-hour ozone level at each monitor and include a monitor random or fixed effect. Shown in

[24] Although estimates from Welch et al. (2005) are reported as statistically significant, standard errors were not adjusted to account for observing multiple stations within a day, so the estimates may not be statistically significant if valid standard errors are reported.

[25] Similar to results using daily ozone, we find no statistically significant estimates of the effect of STAs on hourly ozone levels using the same hours as in Figures 1 and 2.

Table 4, we find STAs have a statistically significant effect on 8-hour or 1-hour ozone levels in our model that uses all observations and does not employ the RD design. These estimates suggest that ozone levels *increase* by roughly .003 ppm when STAs are issued, the opposite effect of the intended policy. Finding a spurious correlation between STA and observed ozone levels is not surprising because STAs are issued when ozone is expected to be high, so there is a strong possibility for omitted variable bias.

When we use our RD design, however, this perverse effect goes away. Estimates are now in the expected direction, indicating decreases in ozone from STAs, but are not statistically significant. The standard errors are fairly wide, though, so it is not possible to rule out considerable effects. For example, based on the upper limit of the 95% confidence interval in the more restrictive RD sample, 1-hour ozone levels may decrease by as much as .001 ppm. Given air quality standards of .012 ppm for 1-hour ozone, a decrease of .001 could be meaningful for obtaining AQS if ozone forecasts are accurate. This extreme case aside, these results suggest the decrease in traffic from issuing STAs does not appear sufficient for delivering a significant impact on ozone levels.

One caveat to this analysis is that the estimation approach used to estimate the STA effect on ozone levels simplifies the process by which ozone precursors react with natural conditions to form ozone. It is likely that there is considerable geographic heterogeneity in the effect of STAs on monitors because landscape features and the distribution of vehicle emissions may concentrate ozone effects in certain areas. Also, temporal difference in the STA effect on ozone levels may arise because wind direction varies by day. Although we claim our estimate is the policy effect of interest, a more advanced model of air shed processes that better accounts for this process may be better suited for this analysis, but this is beyond the scope of an economics paper.

Although we do not find a statistically significant effect of STAs on ozone levels, benefits to the policy may accrue in neighboring air quality districts. Ozone and its precursors, such as NOx, can be transported hundreds of miles, leading to intra-regional environmental impacts (U.S. EPA (1998)). Therefore, STAs issued in the Bay Area may affect ozone levels in the Central Valley and Sacramento, a topic that needs to be explored in more detail.

These results are consistent with those of Davis (2006), who found no statistically significant effect on ozone levels from a driving restriction program in Mexico City that bans all vehicles from driving one day per week based on the last digit of the license plate. Although it is possible the effects of STAs on air quality differ because of the different context of the policy – a voluntary program in a developed country as opposed to a mandated program in a developing country – these studies together suggest that such driving reduction programs may not be achieving the desired results.

7. Conclusion

As policy makers discuss ways to improve environmental quality, the adoption of voluntary programs is a potentially efficient mechanism. ‘Spare the Air’ is one such program targeted at individuals, but it is unknown whether the program is achieving the desired results. This paper seeks to inform agencies in deciding whether or not to adopt such a program, and to address more generally the role of voluntary information programs, though we recognize several peculiarities of STAs that may preclude extending our findings to other programs.

We find that individuals respond to STAs by reducing ozone-causing activities, but not in sufficient volume to have a significant effect on ozone in the Bay Area. Since the Bay Area has the advantages of well-developed alternative transportation modes and an environmentally aware population, our evidence casts doubt on whether metropolitan areas without these advantages can enjoy even limited success with Spare the Air type programs. Although further outreach efforts to encourage more drivers to change behavior appear necessary for the STA program to be effective, the counteracting free-rider problem of improved speed from lower traffic volumes may limit the ultimate effectiveness of this program and should not be ignored. Therefore, our analysis casts doubt on whether this particular voluntary program can improve environmental quality, and suggests alternative programs without counteracting incentives may be more effective.

The results are also relevant to whether the recent decision to offer free fares to BART passengers on STA alert days is a cost-effective way to increase the effect of STAs. Clearly, the answer hinges on how many extra people switch from driving to BART on STA days as a result of the fare elimination, something we can not answer because the free fare policy has only been implemented for a few days and entrances were not recorded on these days.[26] Since the free fare applies to all passengers, regardless of their usual transportation choice, the program costs the city at least $365,000 in lost revenue each day an STA is issued.[27] Switching would have to be very elastic for the program to justify its costs, so our analysis casts some doubt on whether offering free fares to all passengers on STA days is worth the benefit.

A necessary component of this analysis that policymakers must also consider is the costs to individuals from changing behavior. Carpooling, delayed or cancelled trips, and taking public transit impose time costs to consumers that policy makers must acknowledge. Although these

[26] Furthermore, the free fare policy was associated with numerous complaints about overcrowding (Matier and Ross (2006).

[27] Table 1 indicates approximately 260,000 riders on the BART per day during smog season. Valuing the trips at the minimum fare of $1.40 yields $364,659.

costs are voluntarily absorbed by consumers, the STA responses are based on a government signal that altruism is particularly valuable on certain dates. Therefore, policymakers need to know these costs and weigh them in its decisions, making this a priority for future research.

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Figure 1. Effect of STA on Traffic by Hour
+/- .02 ppm of trigger

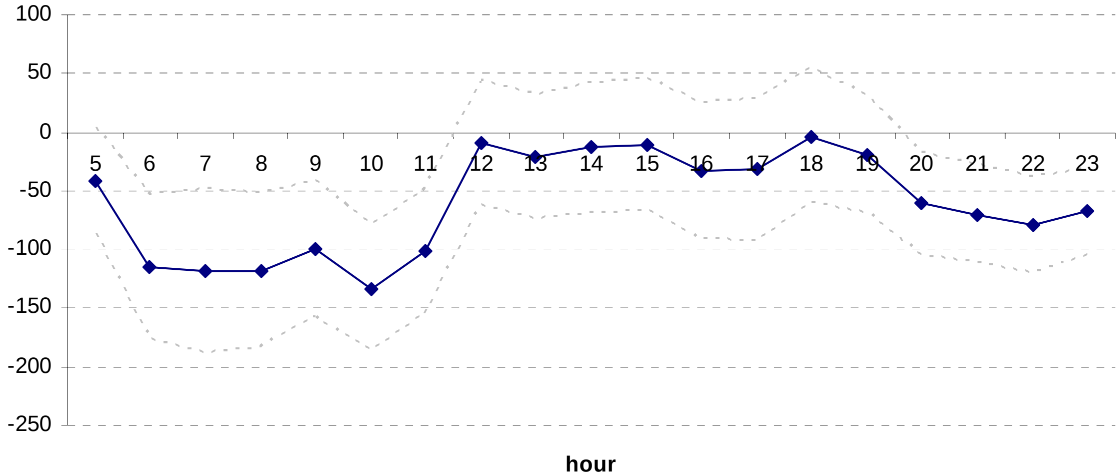

Figure 2. Effect of STA on BART by Hour
+/- .02 ppm of trigger

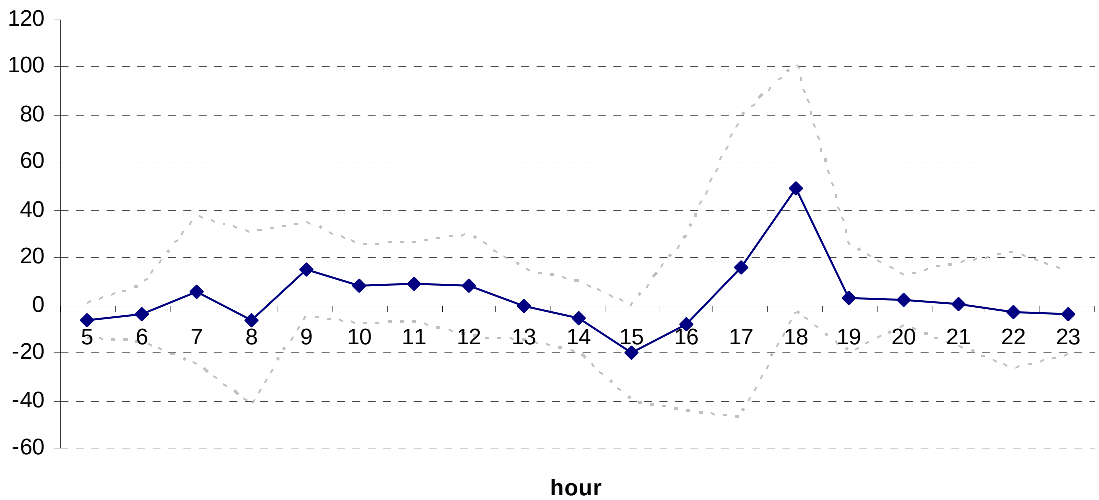

Table 1. Summary Statistics

A. Number of STAs by Year

year	STA=1	All observations STA=0	+/- 20 ppb of trigger STA=0	+/- 10 ppb of trigger STA=0
2001	4	130	23	7
2002	7	127	32	8
2003	9	125	63	21
2004	3	131	38	8
Total	23	513	156	44

B. Means of Dependent Variables

	Bay Area Traffic		BART	
Hourly values	mean	std. dev.	mean	std. dev.
5	1,664	989	70	69
6	2,792	1,608	216	194
7	3,760	2,016	518	445
8	3,896	1,824	631	477
9	3,870	1,570	375	246
10	3,803	1,423	250	141
11	3,903	1,433	237	146
12	4,013	1,457	256	193
13	4,074	1,473	257	229
14	4,298	1,542	271	296
15	4,423	1,606	333	445
16	4,520	1,660	476	754
17	4,604	1,706	696	1,310
18	4,277	1,611	582	1,108
19	3,684	1,395	313	533
20	3,058	1,222	177	286
21	2,780	1,167	144	241
22	2,351	1,116	137	299
23	1,715	952	102	238
all day	65,856	23,755	6,057	5,912

	ozone 1-hour		ozone 8-hour	
	mean	std. dev.	mean	std. dev.
all day (ppm)	0.0532	0.0208	0.0426	0.0149

Table 2. Difference in means of covariates across STA status

	1	2	3	4
	mean	All observations	+/- .02 ppm of trigger	+/- .01 ppm of trigger
precipitation	0.184	-0.079	0.027	0.026
		[0.75]	[0.61]	[0.78]
max. temperature	81.92	14.198	0.994	-1.713
		[0.00]	[0.60]	[0.52]
precipitation (in.) (lag)	0.184	-0.109	-0.011	-0.007
		[0.65]	[0.83]	[0.94]
max. temperature (lag)	82.015	11.657	0.871	-0.554
		[0.00]	[0.68]	[0.86]
forecast max. temperature	81.524	12.401	1.707	1.562
		[0.00]	[0.29]	[0.54]
forecasted sunny outlook	0.637	0.337	-0.014	-0.100
		[0.00]	[0.90]	[0.44]
forecasted partly cloudy outlook	0.326	-0.299	0.014	0.100
		[0.00]	[0.90]	[0.44]
holiday (lag)	0.024	0.020	0.034	-0.014
		[0.54]	[0.61]	[0.87]

Note: Value in each cell is the difference in means across STA status. Columns 3 and 4 adjust for ozone forecast. p-value that variable equal across STA status in brackets.

Table 3. Effect of STA on all day traffic and BART

	1	2	3
	all observations	+/- .02 ppm of trigger	+/- .01 ppm of trigger
A. Traffic			
monitor random effect	-1105.965	-2332.260**	-2009.982*
	[823.082]	[857.489]	[1010.082]
	-{0.017}	-{0.035}	-{0.031}
monitor fixed effect	-995.185	-2111.731*	-1683.411
	[822.683]	[856.634]	[1008.854]
	-{0.015}	-{0.032}	-{0.026}
Observations	70805	24073	8768
# of days	536	179	67
# of monitors	142	142	142
B. BART			
station random effect	34.584	40.273	29.448
	[86.777]	[114.965]	[173.317]
	{0.006}	{0.007}	{0.005}
station fixed effect	32.496	41.398	39.162
	[86.697]	[114.636]	[171.911]
	{0.005}	{0.007}	{0.006}
Observations	21391	7160	2520
# of days	536	179	67
# of stations	43	43	43

* significant at 10%; ** significant at 5%; *** significant at 1%. Value in each cell represent the STA coefficient from a separate regression. Standard errors in brackets. All regression include dummy variables for lagged holiday, lagged STA, month, year, and day of week, controls for contemporaneous and once lagged precipitation, contemporaneous and once lagged quadratic in temperature, forecasted maximum temperature, and dummy variables for forecasted outlook. Numbers in braces represent the percent change in traffic from STA, obtained by dividing the estimated coefficient by the corresponding mean from Table 1.

Table 4. Effect of STA on 1-hour and 8-hour ozone

	1	2	3
	all observations	+/- .02 ppm of trigger	+/- .01 ppm of trigger
A. 1-hour ozone			
monitor random effect	0.0030*	-0.0012	-0.0014
	[0.0018]	[0.0031]	[0.0049]
	{0.056}	-{0.022}	-{0.026}
monitor fixed effect	0.0029*	-0.0012	-0.0016
	[0.0017]	[0.0030]	[0.0048]
	{0.054}	-{0.023}	-{0.030}
Observations	6406	2139	777
# of days	536	179	65
# of monitors	12	12	12
B. 8-hour ozone			
monitor random effect	0.0027*	-0.0009	-0.0017
	[0.0014]	[0.0026]	[0.0040]
	{0.063}	-{0.020}	-{0.040}
monitor fixed effect	0.0026*	-0.0009	-0.0019
	[0.0014]	[0.0024]	[0.0038]
	{0.061}	-{0.021}	-{0.045}
Observations	6406	2139	777
# of days	536	179	67
# of monitors	12	12	12

* significant at 10%; ** significant at 5%; *** significant at 1%. Value in each cell represent the STA coefficient from a separate regression. Standard errors in brackets. All regression include dummy variables for lagged holiday, lagged STA, month, year, and day of week, controls for contemporaneous and once lagged precipitation, contemporaneous and once lagged quadratic in temperature, forecasted maximum temperature, and dummy variables for forecasted outlook. Numbers in braces represent the percent change in traffic from STA, obtained by dividing the estimated coefficient by the corresponding mean from Table 1.

Executive Summary

Environmental Behavior and Decision-Making: Corporate Environmental Behavior and Benefits of Environmental Information Disclosure

U.S. Environmental Protection Agency (EPA)
Region 2 Offices
27th Floor, Conference Room A
290 Broadway
New York, NY
January 14–15, 2008

EXECUTIVE SUMMARY

INTRODUCTION AND OVERVIEW

The U.S. Environmental Protection Agency's (EPA) National Center for Environmental Research (NCER) meeting on Environmental Behavior and Decision-Making: Corporate Environmental Behavior and Benefits of Environmental Information Disclosure was held January 14–15, 2008, at EPA Region 2 offices in New York City. NCER sponsored this meeting to discuss research being conducted on firms' compliance behavior with environmental regulations. Voluntary efforts beyond compliance, including environmental management systems (EMS), also were discussed. Research presentations covered behavioral changes in response to environmental information disclosures such as the toxic release inventory (TRI), eco-labeling program, and air quality warnings. The meeting consisted of a series of presentations by researchers from the NCER Science To Achieve Results (STAR) grant program, other EPA offices, industry, and universities. Approximately 75 people attended the meeting.

DAY 1: JANUARY 14, 2008

Introductory Remarks
Kathy Callahan, Deputy Regional Administrator, EPA Region 2
Chris Saint, NCER, Office of Research and Development (ORD), EPA

Ms. Callahan thanked participants for attending the meeting and explained the STAR program's importance to EPA. She is pleased that the EPA regional offices have a growing relationship with STAR because it allows them access to very high-quality research without the need to sort through ORD and catalogs to find it. In the area of economics and decision-making, STAR brings EPA into an understanding of how the economic behavior of companies and individuals influences their response to regulations and environmental programs and policies, and helps the Agency to understand how they make environmental decisions. STAR researchers conduct research that builds on strands of existing work (such as corporate compliance), as well as new areas (such as eco-labeling and air quality information). This knowledge is critical to refine programs for maximum effectiveness in terms of enforcement, but also to have the ability to influence, on a day-to-day basis, the environmental choices that companies and individuals make. Research can provide direct feedback on regional activities. The Agency also is interested in how voluntary programs and behaviors are affected by economics because EPA engages in voluntary programs to a substantial degree as an adjunct to a good enforcement framework.

Dr. Saint presented information on EPA's interest in STAR Economics and Decision Sciences (EDS). EPA is interested in learning what motivates behavior change in response to environmental issues to optimize the effectiveness of Agency actions. Specifically, EPA would like to learn methods for valuation of ecological and health benefits, the factors that influence corporate environmental behavior as they relate to the effectiveness of government interventions, methods for use of market mechanisms and incentives in environmental programs, and the value and use of environmental information. Previously funded research and additional information is available on the NCER Web Site at http://www.epa.gov/ncer.

SESSION I: FACTORS INFLUENCING CORPORATE COMPLIANCE BEHAVIOR
Moderator: Joseph Siegel, U.S. EPA Region 2

Mr. Siegel noted that having worked in regulatory enforcement and policy for many years, he understood that businesses consider their financial circumstances when deciding how to comply with the law, and that individual states often do not show concern for neighboring states when regulating environmental issues. These facts provide much to discuss in terms of compliance behavior.

Regulatory Regime Changes Under Federalism: Do States Matter More?
Wayne B. Gray, Clark University

Dr. Gray explained that EPA was created to ensure that states pay some attention to environmental issues, but they have a fair amount of discretion in devising regulations. His research examined the extent to which differences across states and political environments influence regulatory stringency, how this translates into the amount of pollution emitted by businesses, and how both of these factors are affected by a change in federal regulatory pressures.

The pros of state discretion are that states have flexibility in regulating innovative policies, and different regulations in different states allow comparison of policies to determine which are most effective. The cons include the fact that effects on neighboring states often are discounted, and that state regulations may be more lenient to boost economic well-being at the expense of environmental protection.

The main question Dr. Gray sought to answer is whether stricter federal regulations reduce state differences in regulatory stringency by forcing more lenient states to become more stringent, or increase state differences by enabling strict states to increase stringency. Dr. Gray used the Cluster Rule, a federal regulation enacted in 2001 that targeted reductions in toxic air and water releases from pulp and paper mills, as a case study to examine this scenario. The results found some Cluster Rule effects, specifically: reductions in air toxics around 2001; very large reductions in chloroform starting earlier; weakly reduced water toxics in effective-BAT (best available technology) plants; and slightly less PM_{10} and volatile organic compounds (VOC) emitted from effective-MACT (maximum achievable control technology) plants. However, overall, there were increases in water toxics, and MACT plants increased air toxics around the effective date. The Cluster Rule, therefore, was not strongly associated with reductions.

When these data were examined state by state, plants in states with *stringent* state regulations showed smaller reductions due to the Cluster Rule, while those with *lenient* state regulations showed larger reductions. As a result the differences between the states decreased. This would indicate that state differences matter less even when federal rules are stricter. In this case, federal enforcement was more effective in places that did not have much state enforcement prior to the rule. However, plants in states that had stricter regulations prior to the Cluster Rule already had lower emissions than those in more lenient states prior to the rule's enactment. Dr. Gray noted these caveats to his findings: these data were from a single industry, and negative publicity was not considered, but it is an additional factor beyond regulation that can increase an industry's incentive to reduce emissions.

The Persistence of Economic Factors in Shaping Regulation and Environmental Performance: The Limits of Regulation and Social License Pressures
Robert A. Kagan, University of California–Berkeley

Dr. Kagan's research examined the interplay of regulatory pressures, social license pressures, and economic factors in determining the environmental performance of firms in terms of heavy-duty diesel truck emissions. The factors that determine the differences among individual firms should drive the design of regulatory programs.

The economic model of firm behavior assumes that compliance is driven entirely by the risk of violation detection and punishment, which implies that firms do not go beyond compliance. The socio-legal view of firm behavior takes compliance as the norm even when enforcement risk is relatively remote, and assumes many firms go beyond compliance due to social norms and pressures.

Social license governs the extent to which a corporation is constrained to meet societal expectations and avoid activities that societies (or influential elements within them) deem unacceptable, whether or not those expectations are embodied in law. Dr. Kagan's research sought to determine if social license pressures are meaningful with many small firms with fewer economic resources.

Trucks were chosen as the subject of study because they have a large environmental impact in the aggregate, and because the bulk of the industry consists of a large number of small firms, which provides a regulatory challenge. This research project studied the evolution of federal and state regulatory programs, focusing on California and Texas.

There is no direct federal regulation of trucks and truck owners. There are no requirements for owners to buy new, lower polluting models or to get older, dirtier trucks off the road. Instead, the federal approach has been to require engine manufacturers to meet current emissions standards.

The economic problem with regulation in the trucking industry occurs because it is a case of perfect competition due to the great number of small, precariously capitalized companies. Therefore, the traditional "polluter pays" theory, which assumes regulatory compliance costs will be passed on to product users, does not apply. In addition, a political problem exists: creating regulations that would drive many thousands of small firms out of business and drive up costs of all goods and services is politically risky. Therefore, the federal choice was to push states to get old trucks off the roads.

Research results showed that of the three pressures for environmental change (regulatory, social license, and economic), it was economic pressures that drove environmental performance. In fact, better environmental performance is an unintended consequence of economically motivated behavior. Company level variation flows mainly from economic variables, including market conditions, firm profitability, and the firm's economic niche. Additionally, social license has no direct impact on small companies unless communities can exert economic pressures that result in regulatory action. Regulatory policies must take these realities into account.

Discussant: Walter Mugdan, U.S. EPA Region 2

Mr. Mugdan explained that since 2002, he has been leading a program division that has little to do with enforcement, but handles most of the region's voluntary programs. Because of the amount of effort EPA has put into these programs, it is extremely important to hear information from these presentations to determine if voluntary programs are working. For example, in terms of climate change, the United States has conducted little regulatory activity to decrease CO_2 greenhouse gas (GHG) emissions. At the federal level, this effort has had an almost entirely voluntary focus. In the past few years, there has been burgeoning activity at the state level. For example, the Regional Greenhouse Gas Initiative (RGGI) consists of eight northeastern states committed to regulatory measures to reduce GHGs. California has similar requirements.

Performance Track is EPA's flagship voluntary program. Companies that join this program commit to going beyond compliance with regulations and taking further measures to reduce emissions. If they succeed, they get a seal of approval from EPA, but very little else. They are choosing to join for reasons of their own, whether right thinking or good publicity. In addition, there is a voluntary diesel emissions program that was established, because there is a legal requirement that EPA not regulate in-use fleets. Since the 1960s, vehicular emissions have been regulated via new car fleets and engines, the benefit of which shows after approximately 5 years. This works better with cars than trucks, because truck engines have much longer lifespans and can be operated for 30 to 40 years. EPA has concentrated heavily on trying to promote voluntary retrofitting and also is promoting a reduction of idling.

Mr. Mugdan noted that the presentations raised some questions and issues for discussion. When states were being inactive in the 1960s, there was a great deal of pressure for the federal government to step in. Then after the 1970s, a decade that saw a tremendous amount of action on the environment, the federal government has stepped back, or at least has not stepped forward to produce climate change regulations. Do states matter more when the federal government is less active?

In terms of the Cluster Rule, Dr. Gray's data showed chloroform reductions before the regulations took effect. Did these occur due to publicity, or did the industry know regulations were coming? In addition, why were there fewer reductions in air toxins than anticipated?

Mr. Mugdan stated that the presentations rang true in terms of companies' motivation to go beyond compliance. It is much more difficult to get small firms to take actions on their own. However, there are some exceptions with slightly larger, privately held firms, which can be driven to take further environmental protection measures by a committed manager or owner.

Regarding diesel emissions, when trucking firms are given money to retrofit, they will do so, but not if they are asked to use their own money. What would it be like if states and cities forced retrofitting? If states moved their attention to developers, authorities, and public governments, asking them to force retrofitting in the companies they did business with, social pressures might work. All post-September 11 construction work performed in New York City is mandated by the Port Authority to be retrofitted with cleaner engines, for example.

Questions and Discussion

Dr. Nancy Anderson, The Sallan Foundation, noted that New York City Mayor Michael Bloomberg reported that 79 percent of the city's carbon footprint comes directly or indirectly from buildings due to heating, cooling, maintenance, and so on. Because buildings have a lifespan of 60 to 80 years, based on Dr. Kagan's explanation of the motivating factors for trucks to go greener, what did he advise that could be done to make buildings greener? Dr. Kagan responded that with big buildings it is often difficult even to determine who owns them, so it would be difficult to pressure them without direct regulation. It would take clear government rules in this area.

Mr. Joseph Malki, U.S. EPA Region 2, asked for elaboration on the ultra-low sulfur diesel fuel rule. Mr. Michael Moltzen, U.S. EPA Region 2, responded that there is a requirement for sulfur levels to be reduced in fuel, but no requirement for new engines or equipment to be added on. This will result in some emissions reductions. Mr. Mugdan added that this is a regulatory requirement, not a voluntary measure.

Mr. Moltzen asked if in conducting research on replacing older trucks, Dr. Kagan examined the workability of retrofits for this purpose as well as replacements. Dr. Kagan responded that retrofits made a big difference in California buses, but it would take a larger study to look at the difference in effects between replacement and retrofitting.

Mr. Moltzen added that EPA's SmartWay Transfer Partnership is innovative in that it provides an incentive for small companies to purchase newer trucks. Customers in the area expressed a preference for green trucking firms, and are willing to be more flexible with delivery schedules if the trucking firm is green. SmartWay also provides information on several lenders that offer loans to owner/operators of small trucking companies to help pay for technologies that will save fuel while reducing pollution. Dr. Kagan asked, in terms of financing, if there was any discussion about pressuring states to impose licensing fees graduated by the age of the truck, which could generate more funds for retrofitting subsidies. Mr. Moltzen responded that the Port of Long Beach clean air plan incorporates elements like this, but in New York, scrappage programs forcing older vehicles to be retired sooner were seen as inequitable because they targeted owners of older vehicles who might not be able to afford to replace them.

Ms. Lingard Knutson, U.S. EPA Region 2, formerly worked for the Port Authority of New York and stated that with trucks, the changes were initiated due to the General Conformity Rule, not a voluntary program.

Mr. Mugdan noted that Dr. Gray's findings that federal regulations were more useful in states where there had been no previous regulations seemed to show that enforcement works. Dr. Gray responded that comparing the impact of inspection activity versus enforcement activity, plants owned by smaller firms responded more to regular enforcement. At larger firms the impact of negative publicity is greater than that of regulation, since these firms are much bigger targets for negative publicity surrounding violations found through inspection.. Repeated inspections of the same places showed the largest drop in the level of violations, or measures of worker exposure, after the first inspection, with smaller decreases after the second and third inspections. There is a fair amount of calibrated evidence that returning to the same facility repeatedly is less effective than more inspections of different facilities.

Ms. Nora Lopez, U.S. EPA Region 2, said there had been a trend with industry leaving New York and New Jersey and moving to the southern states. Is this due to less regulatory pressure from southern states? Dr. Gray agreed that new plants have tended to be located in places that have less stringent regulations, but it is a combination of efficiency of the permitting process and regulatory strictness that draws businesses. Companies prefer more predictable processes. Locations with less stringent rules but uncertain permitting are less desirable.

SESSION II: ENVIRONMENTAL MANAGEMENT SYSTEMS (EMS)
Moderator: Nicoletta DiForte, U.S. EPA Region 2

Ms. DiForte agreed with the way Dr. Saint characterized some of the STAR grants research, specifically relating to the role of government intervention in corporate decision-making. The choice of the word intervention versus regulation better matches how EPA has been adapting its approaches. The discussion of whether voluntary approaches or regulation had more impact underscores the need for research in this area. Ms. DiForte announced that Dr. Madhu Khanna was unable to attend the meeting, and that Dr. David Ervin would give her presentation.

Oregon Business Decisions for Environmental Management
David E. Ervin, Portland State University

Dr. Ervin's research goals were to test the influences of market, regulatory, and other factors on the adoption of environmental management programs (EMPs), voluntary environmental programs (VEPs), pollution prevention (P2), and environmental performance (EP) for Oregon businesses, and infer the market and policy conditions that promote effective voluntary environmental management programs through analysis of primary data. A survey was sent to 1,964 facilities in Oregon in 2005, and there was a 35 percent response rate.

The study found that VEP participation is more costly for firms, but provides a visible signal that enables a firm to differentiate its products. EMP participation, on the other hand, is more affordable but requires more managerial creativity. Managerial attitudes, regulatory pressures, and investor pressures were all determinants of the extent to which a firm would implement EMPs. These same factors (particularly managerial attitudes and regulatory pressures) in addition to EMP adoption determined the likelihood of P2 adoption. Managerial attitudes and values on environmental stewardship have the largest positive effect on EMPs. Competitiveness, regulatory pressures, and investor pressures have positive effects on EMPs, while barriers to adoption have a negative effect. Therefore, the regulatory system is an essential complement to voluntary business environmental management. Consumer pressures and pressures by interest groups were not found to be significant. These findings have implications for how economists should approach the problem. To explain EMP adoption, a utility maximization model is required, as there is a diverse array of motivational pressures in addition to profits that influence adoption decisions.

Future work will be required to improve environmental performance measures and data. If regulators can get the attention of upper management, they will have greater leverage in creating change; the question is how to do this cost effectively. Accomplishing this will require research into the origins of upper management attitudes on the environment.

Certified Environmental Management Standards: An Institution for Removing Information Asymmetries in the Market for Corporate Environmental Performance
Ann Terlaak, University of Wisconsin–Madison

Dr. Terlaak's research focused on exploring environmental certified management standards (CMS), for example, the Eco-Management and Audit Scheme (EMAS) with certification that was integrated with ISO 14001. Prior research found that certified firms do not have better performance than non-certified firms. However, certified firms have environmental performance that systematically varies across industries, which made the effects of CMS difficult to study.

The first research effort was a conceptual study on the power and limitations of CMS to guide environmentally responsible firm behaviors. When compared to norms, two elements, codification and certification of practices, enable and constrain CMS in guiding desirable firm behaviors. These factors enable CMS when 1) general consensus about environmental activities is incomplete, 2) in emerging management areas and crosscultural transactions, and 3) when behaviors are difficult to observe because they are not manifested in products. The same factors limit the effectiveness of CMS, because codification of practices attracts poor performers, while certification of practices attracts good performers who may already be engaging in certifiable activities. Thus, codification does not provide enough differentiation for the effect of certification, as both poor and good performers adopt codified practices. This causes inconsistencies and weakens the decentralized enforcement processes from which CMS derive their power.

The second research effort was an empirical study that examined how corporate social strategy shapes adoption patterns and the use of CMS. Dr. Terlaak found that facilities that perform poorly relative to industry peers tend to certify to ISO 14001, but these facilities tend to be better than others within the firm, operate in cleaner industries, and have prior experience with CMS. For the firm, the returns on the cost of adopting and certifying social CMS practices are debatable, but stakeholders may exert pressure on firms with poorly performing facilities to certify. Therefore, firm management will tend to choose better performing facilities to be certified in an effort to lower adoption costs.

Dr. Terlaak then considered ISO 9000, which produces more of a private good than ISO 14001. Findings were tested by comparing inter-firm adoption patterns of ISO 14001 with adoption patterns of ISO 9000. Better firm performers tend to adopt ISO 9000, but these are still poorer performers than those who adopt ISO 14001.

The research concludes that CMS is not a reliable signal of superior environmental performance, and is an ineffective improvement tool if it is not adopted by those facilities that most urgently need to improve. It is therefore not suitable as a stand-alone regulatory instrument. Because the codification of best practices seems essential to CMS, certification may be meaningless, or even confusing, because the magnitude of improvements varies widely. Regulators could examine removing the certification element to focus CMS on potential operational benefits, or retaining the certification element while subsidizing a market premium proportional to improvements. Additionally, other firms can learn by observing the behavior of firms that adopt CMS. Beyond the flagship adopters, smaller firms and average and below-average performers should be targeted so there will be broader uptake of new programs.

Pollution Prevention Practices: Determinants of Adoption and Effectiveness in Reducing Toxic Releases
Madhu Khanna, University of Illinois at Urbana–Champaign
(Presented by David E. Ervin, Portland State University)

Dr. Khanna's research examined four aspects of the adoption and effectiveness of pollution prevention (P2) and total quality environmental management (TQEM) practices, and made recommendations for the most effective policy approaches based on the results.

The factors that motivate firms to voluntarily adopt TQEM were found to be internal benefits and capabilities rather than concerns about external stakeholders. These included use of a large number of chemicals, strong research and development activities, and both small previous toxic releases and higher toxicity weighted past releases at adopting firms.

TQEM does lead to the adoption of pollution prevention practices, but its impact on different P2 activities is not uniform. TQEM is more likely to lead to adoption of non-generic firm-specific P2 practices. Key determinants are previous years' toxic releases. For example, firms and facilities within firms with high toxic releases face higher costs of P2, and therefore are less likely to adopt P2 practices. Regulatory pressures, and regulation of hazardous air pollutants in particular, motivate P2 adoption, as does high technical capability within the facility.

In terms of the types of P2 practices responsive to TQEM, the most common are customized attributes and procedural modifications, especially those that are evident to consumers and those that enhance efficiency rather than off-the-shelf modifications in materials and equipment. TQEM tends to enhance P2 in industries with operations that are more dependent on customized practices.

This research assumes that the environmental goal of P2 adoption is reduction of toxic releases. The previous year's count of new P2 practices adopted does show a reduction of toxic releases, but the impact is stronger for onsite discharges than offsite disposal. P2 practices have both a direct and declining indirect impact on future toxic releases. Facilities located in high income areas show greater toxic release reductions from P2, perhaps due to green voting.

This analysis indicates that voluntary environmental management efforts by firms do lead to environmentally friendly P2 innovations. Therefore, public policy efforts should be targeted to promote TQEM, particularly by offering technical assistance to lower adoption costs for firms in certain industries (e.g., chemicals and petroleum) and smaller, less technically innovative firms. Concerns with the toxicity of pollutants should be emphasized to stimulate public and regulatory pressure for reduction. However, regulatory stimulus is needed to supplement voluntary incentives for P2 and toxic release reduction.

Discussant: Kathleen Malone, U.S. EPA Region 2

Ms. Malone expressed her interest in the presentations, specifically because EPA has gone through many changes in its enforcement program. In 1992, it was very much about facility-by-facility enforcement versus industry-wide efforts. Now, the Agency uses integrated strategies to encourage change in the culture of the industry as a whole, and has changed its mechanisms to include compliance assistance and promoting environmental audits. The studies on what encourages people to adopt EMS are timely, though the fact that regulatory actions are necessary to maintain functioning voluntary programs is not a surprise. However, if regulatory pressure was the only necessary factor, all firms would have an EMS; therefore, other factors are in play. Management's perception of environmental issues seems to be key. EPA will look forward to further research on what encourages change in the attitudes of upper management.

Another issue is involvement of small- and medium-size firms in voluntary programs. EPA gets the big firms in voluntary programs, but most of the environmental problems are being caused by smaller firms. Dr. Terlaak's presentation raises the problem of looking at EMS not as distinguishing good environmental performers, but as an improvement tool. Ms. Malone noted that she had dealt with several facilities, and though most were improving, certification did not mean they were the best in the area. The firms that are certified are considered low priority in terms of inspection, but this may not be a useful benefit of certification. Dr. Terlaak's presentation created more questions than answers. Dr. Terlaak responded that the market does not know what certification means. Ms. Malone explained, speaking as a regulator, that whether certified facilities should be viewed as good performers or improving performers will make a difference in enforcement efforts.

Discussant: David Gunnarson, Lockheed Martin

Mr. Gunnarson explained that though Lockheed Martin is a large corporation, he would only speak about his experience at his own facility because nothing is mandated on a company-wide basis. His facility got involved with the Performance Track program because his plant manager wants the facility to be the best in everything it does. Most of the work that the facility does is for governments. The facility holds 20 to 30 different certifications; the environmental piece is just one. Performance Track by itself does not mean that much, but the facility seeks certification that will help identify good business practices. Lockheed Martin produces products such as sonar systems and avionics, not consumer products, so there is no motivation due to the fact that consumers will see the certification stamp. There are different reasons firms will be involved in these programs.

Mr. Gunnarson's facility participates in ISO 14001, which allowed a good demonstration of the excellent programs Lockheed Martin already had in place. This was simple because Lockheed Martin was already in ISO 9001, and also participates in the Virginia Environmental Excellence Program, which allows firms to have facilities with different levels of compliance to deal with a staggered maturity of environmental programs.

Regulations are a critical foundation for compliance. To earn a profit, firms need a certainty about the rules, and regulations set a floor for performance excellence. However, the current regulatory scheme does not solve all problems, and regulations may not be able to address global warming very well. Firms and regulators will have to look toward other solutions. Facilities will run into hurdles, for instance, when approaching the procurement department and asking to change the way the facility buys paper, or approaching the trucking department to say that the facility wants only green trucking.

The inclusion of low-priority inspections as a firm benefit in the certification programs is problematic and not a good example of the program's intent. Mr. Gunnarson welcomes inspection of his facility. EPA should be inspecting facilities; this is how certified firms should be rewarded. However, relief on some issues that do not make sense would be helpful. For example, at one time, the facility had to dispose of some waste within 90 days. Disposing of barrels that were not full added to costs. Now waste can be stored for 270 days. The facility does not want to avoid compliance with regulations, but wants requirements to be smarter. A caution about the toxic release inventory (TRI) program is that some increases may be due to normal production practices. His facility got out of the TRI, but are now back in because of lead used in soldering. Only 100 pounds per year are allowed, and this is not much when production is done on a large scale. Mr. Gunnarson does not know what metric to propose as an alternative, but the TRI is very skewed by production and other variables.

Questions and Discussion

Mr. Chuck Kent, U.S. EPA Office of Policy, Economics and Innovation, noted that EPA relies heavily on research, and that it appreciates this work. Dr. Ervin's paper resonated strongly with EPA's experience that managerial attitudes are important in the Performance Track program. He shares the skepticism about EMS and its relationship to performance, but it is a useful tool. Performance Track is awarding performance, not awarding firms for having an EMS. In EPA's view, the effect of voluntary programs cannot be achieved without regulation.

Mr. John Cusack, Gifford Park Associates, added that EMS correlates not with performance but with particular industries. In certain industries, customers require ISO 14001. It is important to ask how to integrate EMS with regular management systems. A stand-alone EMS and a stand-alone management system that do not communicate with each other produce a big problem. Another question is how to change managements' attitudes about the environment. Dr. Ervin responded that he did not realize that the research would uncover such a strong impact from this variable, and that what really informs management needs to be discovered. Mr. Cusack stated that he believes some managers have an influence because they are good managers, not because they are environmentalists. Dr. Ervin agreed.

Dr. Peter Meyer, University of Louisville, asked that when considering the role of regulations regarding the adoption of EMS, regulation of financial markets as well as environmental regulations should be considered. Dr. Ervin replied that in two analyses, investor pressure was a significant factor in variations in EM behaviors among firms, but more research needs to be conducted in this area.

Mr. Charles Hernick, The Cadmus Group, explained that he works with public water systems, and EPA has been promoting EMS for these systems, which is a challenge to implement. In terms of inputs and production for drinking water, decisions on processes are made 10 to 15 years out. How might an industry that makes big decisions on an infrequent basis benefit from EMS? Dr. Terlaak replied that there are multiple issues in this case, but there is some evidence that those who adopt EMS later could be observing what other industries are doing and learning from mistakes that others make.

Mr. Gunnarson responded that he worked with a water plant and a wastewater plant to get them ready for ISO 14001, and they have made improvements to facilities based on management process decisions. Previously, they were not looking at the total energy usage. In that industry, change does not happen often, but there is room for improvement in small, incremental steps. Setting up a management system helps municipalities run their businesses better. Mr. Gunnarson noted that he also worked with garage operations in Manassas, Virginia, in managing waste oil, and with a school. EMS can be applied anywhere to make improvements. Ms. Malone added that EPA would like to encourage EMS in organizations with big turnovers in employees, such as the Department of Defense, because there will be a system in place that does not depend on institutional knowledge. This also is true of facilities that have separate shifts, and organizations without large environmental programs can use EMS as a system to ensure compliance.

SESSION III: VOLUNTARY CLIMATE CHANGE PROGRAMS
Moderator: Irene Boland, U.S. EPA Region 2

Evaluating Voluntary Climate Programs in the United States
William A. Pizer, Resources for the Future

Noting that there has been explosive growth in these programs since the early 1990s in the United States, Europe, and Japan, Dr. Pizer's research objective was to determine whether voluntary programs reduced pollution. In evaluations of voluntary programs, agencies often claim large benefits, usually on the basis of gross changes over time. However, even trying to control for baseline trends, most analyses ignore the possibility that participants are inherently different from non-participants.

EPA has 87 voluntary programs, so it is crucial to understand if voluntary programs change environmental behavior and, if so, the size of the environmental gains from these programs. Businesses are motivated to use voluntary programs to enhance their reputation with customers, government, investors, and communities; gain technical assistance; and help shape future requirements. Government is motivated because voluntary programs can offer a more holistic approach to environmental problems than traditional regulation, and can build public support for future regulatory action. Environmental groups have a mixed reaction to these programs; they are in favor of any environmental gains, but some fear that the focus will move from the worst polluters to more progressive firms.

One example of a success is the voluntary 33/50 Program on toxics, started in 1991, which focused on measurable reductions (33% or 50%) for 17 TRI chemicals in major industries. The actual reductions from this program exceeded the program goals. This may have been in part attributable to fear of regulations, and some evidence suggests negative gains or a lack of them beyond Montreal Protocol substances.

ClimateWise was an EPA program, in effect from 1993-2000, that focused on non-utility industrial sectors. It required a baseline emission estimate from firms, but not an inventory. Firms were offered technical assistance and an annual workshop. This research used comparisons with a matched set of non-participants to determine what would have happened without participation. The study found modest differences in consumption of fuel (participants used less) and electricity (participants used more) in the early years, but no significant differences in later years.

The research results showed that there is a 5 percent reduction for energy programs, which is consistent across programs and countries. Thus, there is evidence that voluntary programs do change behavior, but are not suitable for major reductions. Incentives have a modest impact on reductions achieved among participants, but a potentially larger impact on the level of participation. Efforts to increase the number of participants in programs may yield greater environmental gain than efforts to increase the reductions from individual firms. More attention is needed on the baseline determination for evaluation, including both forecasts and control group approaches. Additionally, subtle changes in social attitudes and corporate practices may be significant, but are difficult to measure. This study measured environmental outcomes, but does not capture whether the existence of a voluntary program makes firms more prepared for regulations.

Voluntary Agreements To Improve Environmental Quality: Are Late Joiners the Free Riders?
Magali Delmas, University of California–Santa Barbara

Dr. Delmas' research focused on the fact that with voluntary agreements (VAs), benefits are available to all participants regardless of their personal contributions. This creates the ability for some firms to be "free riders," especially because most VAs lack explicit penalties to sanction free riders. Incentives and private benefits of participation vary over time and are shaped by the institutional environment. This research project found that there is a difference in cooperative behavior between early and late entrants within the VA, because private incentives vary with the timing of participation in collective action.

The study used data from the Climate Challenge Program, a Department of Energy voluntary program for the electric utility industry, and offered four hypotheses. The first is that early participants in the Climate Challenge Program are subjected to higher political pressure than late joiners and non-participants. They have more incentives to enroll in a VA and they do it early if the individual benefits outweigh the costs of organizing the collective effort. Early participants also are more likely to be members of the industry trade association, and experience both normative pressure and support in facilitating participation. Conversely, late joiners are less likely to have undertaken efforts to reduce their emissions prior to the start of the program. Finally, late joiners are more likely to cooperate symbolically while early joiners are more likely to cooperate substantively because of the different incentives and pressures.

The research results supported these hypotheses. Additionally, it found that non-participants were significantly different from symbolic participants, and that the quality of early adopters does not guarantee the quality of late joiners, which contradicts some earlier research. These findings indicate that VAs might not be effective tools if they are associated with no sanctions for free riders, and that political pressure is very important in the push for reductions. However, there is a question whether VAs with sanctions would attract firms. Perhaps regulators could consider VAs with various incentives according to various levels of performance.

Discussant: Joseph Siegel, U.S. EPA Region 2

Mr. Siegel thanked the presenters and offered comments based both on EPA's general position on voluntary programs and his own opinion. Dr. Pizer's paper concluded that participation in ClimateWise is not likely to be associated with significant emissions reductions and therefore not necessarily effective. However, larger programs like EPA's ENERGY STAR may be more effective. In recent remarks, Dr. Kathleen Hogan, Director of EPA's Climate Protection and Partnership Division, stated that ENERGY STAR helped save $14 billion in energy bills in 2005, and avoided GHG emissions equal to those of 25 million cars. All of EPA's climate partnership programs in 2006 reduced emissions by 70 million metric tons of carbon, equal to that produced by 45 million vehicles. These programs appear to be generating significant reductions, though there is not a control group to evaluate these results more thoroughly. EPA has gotten better at program design since ClimateWise. Dr. Hogan stated that further study needs to be conducted because: (1) a longer timeframe for data sets is needed; (2) there is a spillover effect from voluntary programs in that companies not registered may be using program protocols and tools; and (3) there is a need to develop better baselines. Voluntary programs (VPs) can prepare industry for regulations, help lower costs in the future, give companies and regulators experience with baseline formulation, and provide innovative methods of emission reduction techniques. VPs also can address hard-to-measure GHG emissions and can work synergistically with other programs.

The success of VPs must be considered in the context of the particular environmental harm that they seek to address: that is, what is the goal of any program on climate change? The United Nations Framework Convention on Climate Change and other policy decision makers agree that stabilization of GHGs in the atmosphere has to be on a level that will prevent dangerous anthropogenic interference with the climate system. In the face of uncertainty regarding these reductions, how should EPA make decisions when the outcome of policy choices is unknown? In a well-known legal case, Ethyl Corporation versus EPA, the court found that public health may be endangered both by a lesser risk of greater harm or a greater risk of lesser harm. That is, the greater the harm, the less risk necessary for EPA to take action. Climate change presents the potential for enormous harm, and the risk of harm also is great.

Mr. Siegel's comments touched on how policy choices on climate change VPs might be influenced by the two findings: (1) late joiners are free riders in the Climate Challenge Program; and (2) emission reductions from ClimateWise were not significant.

Climate Leaders, one of EPA's newer programs started in 2002, relies on a protocol similar to the World Resources Institute's and the World Business Council for Sustainable Development's method of measuring emissions, which is the gold standard throughout the world. This program provides excellent technical support and help with inventory management plans. The first joiners are not required to reach their goals until 5 to 10 years later (2007-2010), and each year there are new joiners. Do we have time to wait and see if late joiners do better than the research today predicts in light of the enormous harm that we see from climate change?

The Lieberman-Warner proposal that was voted out of committee looks to stabilize GHGs in a manner that is consistent with scientific data. Senator Lieberman said the goal of his portion of the proposal is to ensure that GHGs do not exceed 500 parts per million (ppm) in the atmosphere. The European Union has a standard of 450 ppm, and James Hansen of the National Aeronautics and Space Administration said 350 ppm should be the limit, and it has already been exceeded. These numbers cannot be achieved without very aggressive targets; EPA must determine if voluntary programs will be more effective than mandatory programs. The Lieberman-Warner proposal seeks a 15 percent reduction in GHGs by the year 2010.

EPA's Climate Protection Partnership 2006 Annual Report stated that a reduction of 70 million to 118 million metric tons can be achieved by 2015. This does not come close to the reduction that the legislation will require. A mandatory program may be required. Other factors suggest that VPs may not be the best: (1) There is a proliferation of litigation against corporations and government, which shows a lack of confidence in voluntary programs; (2) Companies must comply with a patchwork of different state regulations; and (3) Most firms expect mandatory requirements at some point, but they are unsure of what the requirements will be. Therefore, they are having difficulty planning for them. EPA should be generating mandatory programs at this point while continuing the more successful VPs.

Discussant: John Cusack, Gifford Park Associates

Mr. Cusack noted that there is confusion about the purpose of VAs, but this varies. The purpose can be to reduce emissions, prepare for eventual regulations, or give the political appearance of action, which applies to businesses as well as the government, and also to people and environmental groups. It is beneficial that management issues were recognized as important, because in the long run, businesses will have to make changes. General Electric announced that it doubled its commitment to renewable energy to $6 billion, which is more than the U.S. Government spent on climate change this year.

One disappointment with the presentations is that when trying to determine what drives voluntary reductions, instead of correlating actions with emissions, research should correlate actions with profits, sales, revenues, and stock prices, because that is what will inspire businesses to take action. Another point of concern is the concept of being a free rider on a program that does not appear to have worked. It has not been taken into account that it takes time to plan and implement these programs, and success or failure cannot be expected to be measured in 2 to 3 years or even 5 years. No late-joining firm is getting something for free if competitors, from being in the program, gained an advantage they did not have.

Regarding Dr. Pizer's paper, it is hard to measure environmental factors; there is no time to analyze 50 or 60 factors on climate change for every company. Firms need to know three or four important things that they can do about this issue. Mr. Cusack noted that there is no silver bullet, but "silver buckshot" is needed, which could include voluntary programs. Change will not happen through purely technical solutions. Policymakers must fundamentally change how management does business. For example, Wal-Mart announced it would ask its suppliers to reduce energy use by 5 percent per year over the next 5 years to reduce Wal-Mart's carbon footprint. This will reduce its indirect emissions, which will have a big impact. Another example is the Chicago Climate Exchange, which is a voluntary organization to join, but requires participants to meet emissions standards or pay a penalty. Mr. Cusack predicts that this is the direction voluntary programs will take in the future.

One system that has hope of working is the American College and University Presidents' Climate Commitment, which began approximately 1 year ago. Its goal is to make campuses climate neutral over a number of years, and the program hoped to get 100 members enrolled by the end of last year. Instead, 460 members signed up. Government programs need to get results like this. Research needs to broaden its horizons instead of just digging deeper into individual factors. Research on voluntary programs must involve financial interests; otherwise, it will not work. There must be a business case for why management should care about these issues, whether it is fear of regulations or a fear of competitors, because that is what will make them tick in the long run. More research must be done on how to communicate this to businesses, and research on the results of the carbon disclosure project also is needed. In this project, 1,000 companies reported climate emissions; in the first year, 75 percent said climate change is a material business issue, but only 25 percent were taking any action. How can research reverse these numbers? These research projects are a good start, but research must be used for predictive purposes rather than just looking at what has happened in the past. A criticism is that no one understands the structure of utilities after deregulation. How can this best be learned? How can research deal with the dynamic environment and aim for a moving target to show improvement? More than a 5 percent reduction is needed to achieve success.

Questions and Discussion

Dr. Delmas commented that it is helpful to look back at previous data. Change can occur very rapidly, and it is necessary to examine the context in which this is happening, and the context of effective programs. Mr. Cusack said that he thought looking forward was important as well as looking backward.

Dr. Pizer agreed that there must be a business case for these types of programs for them to be successful. When talking about performance for climate change voluntary programs, with a few notable exceptions, it is about energy use. Most people will not switch their boiler, but will decrease how much fuel they use. Only a very few manufacturing companies spend more than 3 percent of their costs on energy, so this is a very small piece of a company's cost structure. Therefore, it will be hard to get voluntary action in this area. When starting his study, Dr. Pizer thought there might be no effect shown, so a 5 percent reduction appeared important. All of these programs show small effects, but large effects are sought. It is important to realize, for a business case, that markets are pricing changes needed for energy efficiency, and they would not price this unless they were expecting regulation.

Ms. Boland commented that EPA's Climate Leaders program purposely targeted the biggest firms in GHG-intensive sectors, which might have a negative effect on small businesses in terms of setting an example that small businesses can use. How could EPA shape a voluntary program more widely to achieve better results from some of the smaller businesses and industrial groups?

Dr. Pizer responded that it was his intuition that the biggest gains from voluntary programs involved getting people to think about things they had not thought about before. The most energy-intensive industries already have spent a lot of time thinking about energy, so there may be a gain to get small businesses to think about their energy costs. The other option is to focus on non-CO_2 gases.

Mr. Cusack noted that it was a problem that companies join programs to lower the impact of their emissions, but they do not look at the impact of their products. A good example was the diesel trucks that take 40 years to get off the road. Research has to look at products and their impacts, which makes it harder to measure emissions. Perhaps emissions are increasing, but the products still are becoming much better.

Dr. Pizer stated that firms would not voluntarily retire trucks early, so those efforts have to be regulatory. In the Wal-Mart example, if the suppliers said they would raise costs by 5 percent, would Wal-Mart really enforce its carbon reduction plan?

Mr. Siegel explained that 50 percent of Climate Leaders partners are in the Fortune 500, and the other 50 percent also are large companies. There may be a need for greater outreach and more intensive work with the smaller companies to ensure success.

Mr. Stephan Sylvan, U.S. EPA Office of Policy, Economics and Innovation, noted that EPA partnership programs involve time teaching firms how to design a good program. With this research showing that these programs are thought to be highly flawed, what can EPA tell firms when they want to hear about successful programs? What about the organic labeling program, smoke-free workplaces, dolphin-safe labeling, recycling, and so on, as effective examples?

Dr. Pizer explained that to learn about how and why programs succeed or fail, the programs must have built-in evaluation mechanisms. It takes time to evaluate programs, and evaluation mechanisms are needed to try to control for selection to the program, and to establish baselines to gauge performance in those programs over time relative to that baseline. If researchers must wait for census data for outcome measures, there is a 5-year lag. Mr. Cusack added, regarding the data, that in New Jersey there are 58 colleges, and in 2001, all of the college presidents voluntarily agreed to reduce their emissions by 10 percent between 1990 and 2005. In 2005, only 10 schools were monitoring their GHG emissions, and only 30 schools were keeping track of how much energy they used. If this happens in higher education, a relatively sophisticated market, what is happening in smaller markets? EPA is on track to solve some of the problems with large firms, but still does not know where to go in solving problems with smaller companies, and needs more research conducted in this area.

Mr. Siegel said that some universities join a project to reduce emissions by a certain date, and non-participants become the control group. The non-participating group then learns that they can derive energy savings by some of the techniques that are being used by the participating universities. Does it bias what the control group levels are if there is an influence on the non-participants by the participants? Dr. Pizer responded that many of the studies evaluating programs are based on the assumption that the program is rather small in comparison to the universe of potential controls. Once a program includes everyone, this assumption does not apply. Counter factuals can be constructed based on historical trends or other modeling exercises, but that will result in a much more dubious study.

Ms. Boland mentioned California demand-side management results showing a 2 to 4 percent reduction of electricity usage, while it was her impression that California reduced their energy use more than this over the past 15 years. What were the roles of these programs, and how can EPA account for the benefits of voluntary programs that create a foundation of knowledge that later spurs action? Currently, EPA faces this problem with green buildings. The environmental footprint of a building is enormous, but rarely will developers say "EPA is the reason we built green." How can EPA quantify the information fertilization role that it plays in the success of its programs? Dr. Pizer noted he was trying to think of what control group to use to measure what is happening now against what would have happened if the program had not existed. The California study is a narrowly defined household study, so a lot is not included. One of the interesting things in that study is the finding that the provision of information from someone the household trusted mattered more than information from an unknown entity.

Regarding the suggestion that more firms be incorporated into these programs, Dr. Timothy Smith, University of Minnesota, commented that because there are laggard effects, safeguards are in place to keep too many people from joining. How do we rectify this? Dr. Delmas responded that there is a question on bringing in more people who are doing less, or fewer people who are doing more. Different models can coexist, but it is difficult to use them in a single program.

Dr. Pizer added that the key is to target firms that may not have been thinking about the program's focus. Programs on toxics and non-CO_2 gases are likely to get more results. Mr. Cusack added that the financial community must be convinced that incorporating these programs will affect their success. Dr. Pizer cautioned that the financial sector should be involved, but because this sector is interested in making money based on what the rules will be in the future, their advice on public policy may be biased. Mr. Cusack added that if EPA did not listen to the financial sector, it may not create useful programs. Long-term investors have to look at risk and return, and will accept a lower return if they have more certainty of what the rules will be.

Ms. Janice Whitney, U.S. EPA Region 2, asked if research should stop studying voluntary programs and look at what level of regulatory enforcement is needed, along with voluntary programs, to reach environmental goals. Rather than having government regulating on its own, what if the public added pressure on firms? How can EPA bring all of the interests together and get everyone involved in the discussion?

Dr. Delmas agreed with the limitation of some of these voluntary practices. Regulatory tools could be more market oriented, but with regulation, everyone must participate.

Mr. Cusack cautioned that if either the government or business is left out of this process, there will be no progress. Mr. Siegel added that there has been a lack of consensus building and collaboration. The local level is one place to start. Dr. Pizer noted that leadership also has been lacking.

Dr. Dinah Koehler, U.S. EPA ORD, noted that the thread of this avenue of research is the tension between voluntary and mandatory programs. The next presentations will focus on how information disclosure with the TRI influences corporate behavior.

DAY 2: JANUARY 15, 2008

SESSION IV: HAZARDOUS WASTE MANAGEMENT
Moderator: Barry Tornick, U.S. EPA Region 2

Mr. Tornick noted that voluntary cleanup programs have become increasingly important. However, though more sites get cleaned up with these programs, corrective action cannot be taken through them. States also may find that they have to revoke these Memoranda of Agreement and issue a report to allow enforcement.

Mr. Tornick added that in the 1970s and 1980s, EPA had an adversarial relationship with companies. This is not the case today. Companies are the real experts on their processes, and know when they have a violation. The goal is to build trust between the agencies and the companies.

What Drives Participation in State Voluntary Cleanup Programs? Evidence From Oregon
Allen Blackman, Resources for the Future, and Kris Wernstedt, Virginia Tech

The broad problem addressed in this research is the difficulty of remediating sites contaminated with hazardous waste. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, inadvertently created incentives for site managers and developers to shun contaminated sites for fear of having to pay for cleanup. State "mini-superfund" laws created in the image of CERCLA have similar liability features, and may have compounded the problem. To address these concerns, all but a handful of states have created voluntary cleanup programs (VCPs) that create incentives for site managers to clean up contaminated properties.

This research project sought to determine what drives participation in VCPs using data from Oregon's Department of Environmental Quality (DEQ). Data reveals that the probability of joining the VCP is significantly greater for sites that are both on the Confirmed Release List (CRL) and in census block groups with higher than average housing values. This may be because these site owners have more to gain financially from getting a No Further Action (NFA) letter and selling or developing their property. Also, it may be that sites in neighborhoods where property values are higher are subjected to stronger pressure to remediate. Another finding is that sites with permits are more likely to participate in the VCP. These sites face lower costs of participating because DEQ already is aware of the contamination, and because they are already familiar with DEQ programs.

This model, however, does not explain participation in the Independent Cleanup Program (ICP). CRL listing does not drive participation in the ICP. The hypothesis states that listing enhances regulatory and non-regulatory pressures for remediation. However, the ICP attracts sites with relatively minor contamination, and regulatory and non-regulatory pressures for remediation on such sites are likely to be low.

These results have notable policy implications: Oregon's VCPs are attracting sites with significant contamination, and listing relatively high-value sites increases the probability of joining. It does this by increasing regulatory and non-regulatory pressure for remediation and including a financial incentive for remediation. Together, these findings imply that the DEQ is able to spur voluntary remediation via public disclosure (CRL). This is a mechanism for encouraging voluntary remediation that has received little attention, and may be relatively inexpensive compared to forcing firms into mandatory programs.

The Consequences of Self-Policing
Sarah L. Stafford, College of William and Mary

Self-policing occurs when a regulated entity voluntarily notifies authorities that it has violated a regulation or law. EPA encourages self-policing through its Audit Policy to minimize formal investigations and enforcement actions. There are no “gravity-based” penalties for disclosed violations that meet the policy’s conditions. EPA also will not recommend criminal prosecution for such violations.

In Dr. Stafford’s research model, facilities can choose whether to deliberately violate the regulations, and whether to perform an audit to discover inadvertent violations. The optimal strategy depends on the facility’s cost of compliance, cost of auditing, the probability of an inspection, the fine for a violation, the fine for a disclosure, and the transition probabilities (the probability of moving from the targeted to non-targeted group). Decreasing the fine for a disclosure leads to more disclosures, and potentially more audits, at facilities in the target group. However, if facilities that disclose are rewarded with a lower probability of future inspections, they may decrease the level of deliberate compliance. The leverage of the targeted enforcement regime is thus reduced. There also is the possibility that a facility might disclose a “red herring,” or a minor violation, to receive reduced enforcement later to hide a major violation.

The research results show that disclosures affect the probability of inspection. The magnitude of the effect depends on compliance history, but the effect is always a reduction in the probability of inspection. Facilities with a high probability of inspection are more likely to disclose. Facilities currently targeted by regulators are more likely to self-police than those not targeted. On the other hand facilities with very low probabilities of inspection do not disclose. These facilities have the lowest level of contact with regulators and thus are more likely to inadvertently violate. Regulators might want to focus outreach efforts on such facilities or consider methods for increasing the incentives for them. Additionally, decreased future enforcement may be important to encourage self-policing.

Currently, disclosure rates in the regulated community are low, but they are likely to increase. Current low levels of participation could be due in part to the fact that the community is not aware of the benefits of self-disclosure. EPA might want to draw attention to the fact that future enforcement will not increase. However, regulators need to weigh the benefits of increased self-policing against the potential that facilities may strategically disclose, particularly when disclosures affect future enforcement.

Green Production Through Competitive Testing
Terry Taylor, University of California–Berkeley

In the European Union, China, and California, it is illegal to sell electronics containing lead, mercury, cadmium, and brominated flame retardants, but enforcement would require laboratory tests beyond the regulator’s ability. However, third parties, including competitors, will often follow-up on reports of violations. When Dutch authorities, acting on a tip from a competitor about cadmium in a cable, halted the sale of Sony Playstations, Sony lost $110 million in revenue.

Dr. Taylor’s research examines whether regulators should rely on manufacturers for testing, and the impact of competitive testing on industry structure, output, profitability, and the environment. What does it cost when firms produce non-compliant units and when does it make sense for a regulator to allow the firms to police themselves?

Relying on competitive testing is attractive when the number of firms is small, testing is effective, the compliance cost is low, and the regulator is highly uncertain of compliance cost, and less effective in detecting noncompliance. This mechanism is ineffective when there are many firms operating at lower profit margins, because competition will not be significantly affected. When asymmetric firms (those with weak brand value) are knocked out of the market, the results are not significant. Therefore, it is unlikely a competitor will test their products. This creates incentive for entry by environmentally damaging "white box" manufacturers.

There are caveats, including the possibility of collusion, and if there are only two manufacturers in the market, one will know that the other turned them in. For competitive testing to work, plausible deniability and anonymous reporting are needed. Therefore, relying on competitive testing to enforce regulations will tend to be effective when: (1) the industry is dominated by a small number of players, but enough to discourage collusion; (2) Firms have strong brands to protect and pricing power; (3) The market in which the firms compete is attractive and profitable; (4) Firms are better informed about the costs and means of compliance, know how to detect violations by other firms, and the social cost of noncompliance is moderate. If the latter is too high, regulators will have to step in; and (5) Barriers prevent entry by small firms that could produce in an environmentally damaging way.

Discussant: Carl Plossl, U.S. EPA Region 2

Mr. Plossl commented that EPA's Hazardous Waste Compliance Branch has tried to promote green production through changing production techniques, the only regulatory option the Agency currently has, but without success. In trying to push cleaner production, most enforcement is directed at universities and government entities and looks at what everyone considers hazardous (such as hazardous wastes in computer monitors). EPA has not seen any changes in purchasing behavior, just in disposal methods. The policy toolbox needs to change.

EPA needs to make a strong effort to change historic enforcement patterns with universities and the health care industry. There have been limited inspections and a low enforcement track record. The perception of the likelihood of inspection must change. EPA's method is to provide outreach to a problematic sector first; followed by strong, publicized enforcement; and then to enter a third period where audits and self-disclosures are encouraged. This changes the perception of the likelihood of enforcement even if it does not change the likelihood itself. As a result EPA can focus resources elsewhere.

Region 2 has a strong self-disclosure and self-audit effort targeted in part at universities and the health care industry. The region has tried many different techniques to reach those sectors. A factor that was not discussed in the presentations is negotiated icebreakers. Programs need to bring a few firms in to begin the process through careful negotiations when trying to bring in a whole industry, especially in an industry that lacks a history of enforcement. This can encourage self-disclosure. Others in the industry will see the results, and this tends to lead to a cascade of new self-disclosures.

In terms of red herrings and strategic self-disclosures, these often are driven by uncorrectable violations. Because EPA had a history of not inspecting facilities that self-disclose, after an enforcement action, a facility may offer a disclosure that covers a lot of different violations, none of which were part of the original enforcement action. This prevents enforcement of these additional violations.

There is limited ability to analyze Agency efforts because implications of the Paperwork Reduction Act have made it hard to survey the industry to determine their effectiveness. Additionally, the limited inspection policy means a random inspection of facilities that have disclosed is not possible, so it is uncertain whether self-disclosures have changed compliance levels.

Discussant: Larry Schnapf, Schulte Roth and Zabel, LLP

Mr. Schnapf explained that with the example of China and toys, the pressure points for demanding green production are retailers and distributors, because there are too many small manufacturers to reach. Market pressure is more dominant in this case than with voluntary cleanups.

Additionally, there are fundamental problems with the way hazardous waste cleanups are conducted. Reporting obligations are archaic, with no requirement to report historical contamination above cleanup levels. It has been 28 years since the passage of CERCLA, and there are still mothballed sites. If property owners were required to report historical contamination above cleanup levels, these sites would not be hidden. The primary motivators for VCP on properties are the lenders. If a buyer asks “should I investigate and do I have to report?”, it depends on the lender, who is the surrogate regulator. If lenders are given secured creditor exemption, they have the incentive to decrease stringency. EPA created a moral hazard by allowing liability defenses without determining what is in the ground. EPA should investigate and have industry groups form minimum standards. There is an epidemic of unreported self-directed cleanups across the country. States are not equipped to examine these sites. If the reporting obligations are changed and perhaps if secured creditor exemptions are limited to those who hold loans and do not sell them more properties will be disclosed.

Questions and Discussion

Mr. Tornick asked if EPA should send letters to all facilities asking for disclosure. Mr. Schnapf responded that there has to be greater enforcement, because the perception is that the states will not have enough enforcement money and most property owners and facilities take the chance that they will not be caught. Mr. Tornick replied that perhaps it would make sense to send letters to every facility and use the responses to determine subsequent actions.

Dr. Yehuda Klein, City University of New York, noted that based upon the presentations he inferred that an industry with several large firms in the competitive fringe such as pharmaceuticals would not be an appropriate place for competitive testing. Dr. Taylor responded that there is a mix of fringe players. Big players will have an incentive to test one another and no incentive to comply. Small fringe players will have an incentive to do neither, so if fringe players are a small portion of market, competitive testing can make sense. Ms. Rabi Kieber, U.S. EPA Region 2, asked if Dr. Taylor had examined the interplay between self-audit policy and competitive testing. Dr. Taylor responded that he had not, but that there were ways to expand the work by examining the interaction of firms turning in a competitor or themselves, and the interaction between stopping the hazardous material production and disposal issues. Those ideas should be considered together.

Dr. Mary Evans, University of Tennessee–Knoxville, asked why a firm would choose VCP and not ICP? Mr. Blackman responded that ICP is designed for highly contaminated sites.

A participant noted that firms should have the incentive to test the firm above them and the one below them when there is vertical differentiation in the market. Dr. Taylor commented that this depended on the incentive to knock other firms out of the market. With vertical differentiation, firms on top have more incentive to stay in the market, and competitive testing works well for firms that have high perceived brand values, but not on the bottom of that vertical market.

Mr. Cusack asked about the relationship between disclosure to EPA and to the Securities and Exchange Commission (SEC). Do firms assume that because they will have to disclose to the SEC, they may as well join a voluntary program? Mr. Schnapf explained that there has been little movement by the SEC, so there is not sufficient shareholder interest. There will not be much action from the SEC for the next year or so.

Dr. Koehler asked how to create a competitive testing environment for mothballed sites in terms of one firm turning in another firm. Dr. Taylor replied that there must be some kind of competitive interaction between mothballed sites to make this work, but that is not likely. Mr. Schnapf agreed and noted that he could not imagine that a mothballed site would be of a significant impact to a competitor. It is in all of the firms' best interest to keep these sites mothballed unless the SEC changes its regulations and enhances disclosure. There is a legislative proposal to put mothballed sites into a private trust for remediation. Many mothballed sites are in a fringe real estate area, so there is little competitive advantage for another firm to force the owner to clean it up.

Dr. Kagan mentioned a finding that companies are pleased to learn about EPA or other government sanctions against competitors regardless of whether the target had any competitive advantage. Firms spending money to comply like to know that their competitors are penalized for violating the law. There may be motives to engage in complaints against violators, even when there is no competitive advantage if the cost of doing so is small. Mr. Tornick added that facilities in some industries ask whether competitors are being regulated in the same manner. Dr. Taylor said that firms will be happy to turn one another in, even though the penalty may be small. This does not happen if all manufacturers in an industry are noncompliant because they do not want to draw attention to that fact.

Dr. Ervin added that competitive testing may be driving people toward environmental performance in terms of collaborative outcome. Dr. Taylor said that with the cooperative versus the competitive approach, there also is a question on how EP is enforced. There is no conclusive analysis that EP is worth more than competitive testing.

SESSION V: INFORMATION DISCLOSURE: THE TRI
Moderator: Nora Lopez, U.S. EPA Region 2

Ms. Lopez noted that the TRI program celebrated its 20th anniversary 2 months ago. It is a unique program managed by a very small group of people with limited resources, but it is very effective in using those resources. Industry groups used to hate the program, but now they are using it to measure their efficiency.

Regulation With Competing Objectives, Self-Reporting, and Imperfect Monitoring
Scott Gilpatric, University of Tennessee–Knoxville

Dr. Gilpatric's research is exploring the optimal regulatory response with self-disclosure programs such as TRI. Environmental information disclosure programs may yield both direct and indirect benefits. An indirect benefit results from increasing firms' private costs of emitting, and thereby reducing emissions, while a direct benefit occurs if disclosure itself reduces the social costs associated with a given level of emissions.

In Dr. Gilpatric's model, there are basic assumptions about a firm's behavior: a firm pays a tax on disclosed emissions, and pays a penalty on revealed undisclosed emissions. An imperfect audit by the regulator may reveal some, but not necessarily all, undisclosed emissions. Given this understanding of firm behavior, the regulator chooses a tax rate and audit probability (i.e., enforcement intensity) to minimize social welfare costs. Here "tax" stands for the cost that a firm incurs due to disclosure, and it is assumed to be uniform per unit. Revelation of undisclosed emissions would cost the firm more than a voluntary disclosure.

What is the optimal response? At first, an audit with greater intensity should be performed so large emissions are disclosed. Once these get larger, reduce the taxes and thereby reduce the enforcement costs. Regulators should consider a disclosure program aimed at emissions for which the social cost becomes negligible if disclosed. The optimal policy is then zero tax, which enables full reporting compliance to be achieved with negligible enforcement costs. It even may be optimal to insulate firms from other sources of disclosure costs, such as liability, to ensure full disclosure, especially if reduction of emissions is more important. Conversely, consider a program aimed at emissions for which disclosure does not significantly reduce social costs. The optimal policy is then to internalize the social cost while minimizing enforcement costs.

Most cases where disclosure programs are employed lie in the middle, where achieving both the direct and indirect benefits is desired. This model illustrates the inherent tension between these objectives, and how the optimal policy balance depends on the relative costs of undisclosed versus disclosed emissions, and the cost of enforcement. The choice to use a disclosure program means regulators want the market to determine the cost to the firm. Emissions decline for real, but also because it becomes beneficial to hide what is done. The more the market responds to disclosure, the more enforcement is needed.

The Effectiveness of Information Disclosure: An Examination of the TRI
Lori Snyder Bennear, Duke University

In thinking about implementing, expanding, or reducing an information disclosure requirement, regulators must consider that benefits are real, but less tangible than costs. With the TRI, one benefit is that public safety officials actually know what is on the site to better respond to it. Information disclosure can be seen both as a policy tool and a pollution control instrument. Information disclosure requirements may lead to reductions in emissions due to public pressure.

Does behavior change for newly reported materials? For new chemicals, do releases of newly reportable chemicals in 1995 differ from trends in chemicals previously reportable? There is limited evidence of this, and it usually is not statistically significant. For a few industries, there is a small negative (improved performance) effect. For lowered thresholds, in the cross-facility comparison, there is no statistically significant effect for mercury, but often a statistically significant but positive (lowered performance) effect for lead, which is the opposite of the hypothesis. In the within-facility comparison, there often is a statistically significant effect, but positive, which again is the opposite of the hypothesis.

Dr. Bennear stated these caveats regarding the findings: these results are preliminary; lack of evidence of causal effect does not mean information disclosure is not worthwhile; these effects cannot be identified from initial reporting, only from changes in reporting requirements; and even if information disclosure does not affect performance, it may still be worthwhile because it facilitates allocation of public and private resources and provides data for analysis.

Disclosure as a Regulatory Instrument for the Environment: A Study of the Toxic Release Inventory in the Printed Circuit Board (PCB) Industry
Linda T.M. Bui, Brandeis University

Dr. Bui's research examined how mandatory disclosure affects firm behavior using the printed circuit board (PCB) industry as a case study. The potential difficulties in using disclosure for pollution abatement are numerous. Consumers may not be aware of, understand, or care about the pollution embodied in a product. Households living near dirty plants do not necessarily value lower toxic releases, and firms may benefit from having lower property values surrounding their facilities. Liability issues are difficult to assess, particularly as many of the effects from toxic exposure are long term and causality is difficult to establish in a court of law.

PCB production is one of the largest contributors to pollution in the micro-electronics industry. Significant changes in market structure over the past 50 years make it less likely for the industry to respond to voluntary pollution abatement programs, but reported releases fell by more than 96 percent between 1988 and 2003. These reductions may have been caused by changes in output, paper reductions, substitution away from listed to unlisted substances, reductions attributable to command and control regulations for other pollutants, and response to mandatory disclosure.

Plants exiting the industry are dirtier than remaining plants, but those plants that do not exit from the sample show a similar pattern in aggregate reductions over time. When restricting data to the plants that are in the sample for the entire period (only 24 of 597 facilities), reductions also are of the same order of magnitude. Facilities located in non-attainment counties have significantly lower levels of releases. There is some evidence that changes in attainment status also are associated with larger reductions in toxic releases. It is estimated that TRI levels would be between 125 percent and 245 percent higher than current levels if no facilities were located in non-attainment counties. Federal regulations for water pollution and for hazardous air pollutants also play an important role in the reduction of toxics. State-level TRI programs make a difference. Facilities located in states with specific reduction targets for TRI substances showed significantly compressed distributions of releases of all types.

State-level policy perceived as being a “threat” of future formal regulation, and may induce firms to abate. Outreach programs that provide information to polluters on pollution prevention or pollution reduction methods also may have a beneficial effect on releases. This may be true especially for industries that are dominated by small- and medium-sized polluters. A better understanding of the mechanism through which public disclosure affects firm behavior is extremely important if policymakers want to rely on it as a regulatory tool.

Discussant: Howard Apsan, The City University of New York

Dr. Apsan noted that this research examines how regulatory efforts change the behavior of both the regulator and regulated entities. Years ago, regulated entities were assiduous in avoiding government intervention in activities. Voluntary disclosure changed the perceptions of the regulated entities. Even though firms make calculations on what the tax will be, and what the likelihood of enforcement might be, they are now much more reluctant to act on calculations alone, because being a good environmental citizen has genuine and proven economic benefits. The overall notion of disclosure as an enforcement tool is a very valuable and fruitful area for research. Research also has to examine different industries that give different insights, such as manufacturers, coal miners, new regulatory reporters versus those who have reported for many years, and organizations that have faced enforcement previously versus those who have not.

Discussant: Dinah Koehler, NCER, ORD, U.S. EPA

Dr. Koehler noted that the purpose of the TRI is to provide citizens with a useful picture of the total disposition of chemicals in their communities and to help focus industry’s attention on pollution prevention and source reduction opportunities. Therefore, the more information citizens have, the greater the pressure on industry to act.

Dr. Koehler commented on Dr. Gilpatric’s study, but used the word “tax” literally, not as social cost as used in the research. The policy dilemma explored in the research is how to induce full disclosure while also creating a mechanism for punishing emissions. In the model the amount a firm decides to disclose depends on a tax on disclosed emissions as punishment for emitting and a penalty on revealed undisclosed emissions. The model shows how the optimal policy balance depends on the relative costs of undisclosed versus disclosed emissions and the cost of enforcement. It would be useful if Dr. Gilpatric could put parameters into his model based on the reality of today. This would give better insights into how high the penalty should be, how the probability of inspection might play out, and how the tax notion might work. Currently, facilities can reduce penalties through supplemental environmental projects. Running a simulation could allow the research to give EPA some real advice. It also would be useful to know how high the penalty should be for major or minor violations.

Dr. Bennear's hypothesis states that information disclosure requirements lead to reductions in emissions from public pressure. However, the results yield a limited negative effect, no effect, or a positive effect. One explanation suggested by Dr. Bennear might be something inherently different in previously reporting industries versus newly reporting industries. Perhaps a better industry effect variable is needed? Are there other omitted variables? The research should break down total releases, toxicity, strategic divestment from dirty facilities, other regulation and enforcement stringency, output size or how much is produced in a year, and estimation method. For example, a facility might not know how to estimate emissions, particularly if they are reporting a chemical for the first time. EPA training and compliance assistance may be needed. This study came up with a puzzling mixed result. There is no effect for mercury, but for lead, there might be various explanations. Maybe lead and mercury are problematic chemicals to analyze. There may be industry-specific issues at work. With mercury, perhaps the industries producing these emissions cannot or will not reduce them under the current regulatory environment. There also might be something inherent to the compound mercury and how it behaves in the environment.

Dr. Bui's research assessed the 96 percent decrease in emissions from the PCB industry from 1988 to 2003. The factors responsible are the voluntary program (33/50), the Clean Air Act, The Clean Water Act, and state-level regulations. There are significant explanatory factors: regulation, state actions, location in non-attainment county, and dirty facility closure.

Dr. Koehler's project at Wharton examined whether students understand the information conveyed by TRI. She hypothesized that people cannot determine the risk from a facility given information conveyed in lbs of emissions. To test this hypothesis, various different information scenarios were constructed, including pounds of emissions, reduction of pounds, cancer cases arising from these emissions, the probability of getting cancer, probability of injury or death, and number of deaths arising from an accident at an emitting facility. For pounds, most people do not understand the data. However, information comparing two facilities based on different levels cancer risk shows that individuals can effectively compare the risks posed by these facilities. Improvements not only in the quality of the data, but also in how the data are presented are much needed. Ms. Lopez noted that the TRI is moving quickly in trying to relate pounds to the health risks for this reason.

Questions and Discussion

Dr. Zachary Pekar, U.S. EPA Office of Air Quality Planning and Standards, asked if EPA provided enhanced risk information that can be understood by the public. Is there information on the public's perception of different chemicals (such as lead paint, mercury in fish)? Is there risk perception misclassification? Perhaps, depending on the mix of chemicals, the public has different responses. Is there a flag chemical to which the public may respond differently that is known to manufacturers? Does that flag chemical change with a significant regulatory event? If regulators tighten nets and conduct lead abatement that gets a lot of media attention, is the public more aware, and is different behavior triggered? Dr. Pekar said there are case studies in which there was a public outcry and in that context, specific chemicals were examined in the TRI. Dr. Bennear responded that there is research on how the public responds to products in private wells, and the reactions to different chemicals are different. Arsenic is seen as important, there is some knowledge of radon, but there are differences in the perception of risk.

Dr. Bui noted that in a study on house prices in Massachusetts, local newspapers revealed everything about polluters, but there was no capitalization in house prices from this information. Only if chemicals smell bad or are visible did households care about such disclosure. People do not recognize most chemical names. There also is a belief that if the site were truly dangerous, the government would step in.

Dr. Koehler added that different ways of presenting the information are needed. It is important to know not just who is receiving the information, but who is providing it and how. The TRI might want to examine different ways of disseminating information. Ms. Lopez responded that the TRI had just received funding for grants to conduct a marketing study on this. In a focus group in New Jersey, people thought if a facility was too dangerous, the government would shut it down. The program is going to find a way to provide more information to the public, and the program can move to address specific health issues and chemicals that are considered high risk. There is an initiative to teach children the concept of right-to-know.

Dr. Klein commented that with exposures in specific areas, and waste transfer stations, it is difficult to make a connection from pounds of release to exposure using the TRI. Is there work in that area? Dr. Koehler explained that studying her research she did a risk assessment on various carcinogenic chemicals using the CalTOX model. Dr. Pekar added that the levels in home-produced items and fresh-caught fish might be high.

Dr. Bui commented that there has been work looking at the TRI in terms of an individual's distance from the site to determine exposures. Dr. Koehler added that inhalation is not the only route of exposure, and that for chemicals which pose a greater risk via ingestion distance from the facility emitting the toxin does not matter as we have a national/international food supply.

Dr. Blackman asked, in terms of the channel through which public disclosure operates, if there is much work with secondary data. Have there been any surveys asking plant managers whether and why public disclosure is effective? Or has there been any release of information about emissions and use of this to rate the facilities? Are there any regulatory or legal barriers to doing that? Dr. Bui responded that petroleum refineries were studied. The uniform answer is that before they had to report, they did not know what the releases looked like. After the reporting, they saw how large the releases were, and realized they must have been inefficient. One facility put covers on vats of sludge after reporting, a trivial fix that had not been considered before. A participant added that it is apparent that there are very low hanging fruit for emissions abatement, but that is different than achieving real significant reductions that would require significant changes in the production process. Ms. Lopez noted that ranking was done from 1987 to 1992, when the Agency used to list the top 10 facilities. There was a change in policy, and now environmental groups do most of the ranking. The problem with that is that EPA still gets the calls on this topic. The Agency is trying to create a platform where anyone can post studies, rankings, and so on.

SESSION VI: INFORMATION DISCLOSURE: ECO-LABELING
Moderator: John Filippelli, U.S. EPA Region 2

Competing Environmental Labels
Carolyn Fischer, Resources for the Future

Dr. Fischer's research examined how the incentives and behavior of industry groups and environmental non-government organizations (NGOs) compare in setting eco-label standards, if society is better off with multiple eco-labels in an industry, and if there is a role for government intervention in third-party voluntary labeling schemes.

Her findings for industry showed that if there is only one label, the NGO adopts a more stringent label than does the industry, and industry further relaxes its label if the two labels coexist. Industry profits increase with multiple labels, and firms will only voluntarily label if it increases profits. Additionally, industry only changes its standard if it increases profits.

The results for NGOs and the environment are a little less clear. An NGO might tighten or loosen its standards in response to an industry label. Environmental damages may be higher or lower with both labels than with the NGO label alone, and specific results depend on the distribution of types of firms in the market and consumer demand for label stringency. NGOs lose substantial participation when an industry label is present. The cost to the NGO also is higher when both labels are in use, because the NGO always tightens the standard in the presence of the industry standard.

In more cases, there are fewer reductions with both labels than with the NGO label alone. Two labels are more likely to be beneficial to the environment if firm types are broadly distributed. In terms of welfare, profits and consumer options increase with more labels, but environmental benefits may decrease. There are incentives for NGOs to work with industry groups to avoid excess competition, and because society tends to want something in the middle of the two. However, consumer willingness to pay for one label may depend on the qualities of the other labels.

Consumer Labeling and Motivation Crowding-Out
Christopher D. Clark, University of Tennessee–Knoxville

The objectives of Dr. Clark's research are to analyze the influence of extrinsic incentives that provide energy cost savings and environmentally beneficial intrinsic incentives on consumers' willingness to pay (WTP) for consumer products. Is there evidence of motivation crowding-out (MCO)? The research also analyzes the influence of program characteristics, demographics, and attitudes and opinions on WTP for environmentally labeled consumer products.

Prior research explored what might motivate people to engage in prosocial behavior. If the label has a cost savings as well as social benefits, this clouds consumers' motivation to feel as if they are acting for the common good, and the reputational payoff is diminished.

This study will use four different survey versions on labeled side-by-side refrigerators to test the MCO hypothesis: WTP for ENERGY STAR with high cost savings, WTP for Green Power Partners or Energy Saver, and WTP for ENERGY STAR with low cost savings.

Policy issues include: the relevance of public and private dimensions of labeling programs; the influence of other program characteristics on consumer response; the influence of demographic, attitudinal, and opinion factors on consumer response; the usefulness of conjoint analysis in evaluating labeling programs and attributes; and an empirical test of the objection that market mechanisms will lead to moral ambiguity.

Discussant: Rabi Kieber, U.S. EPA Region 2

Ms. Kieber explained that she is not an economist, but is working with major developers, owners, and architects to persuade them to examine some green labeling programs. In particular, EPA hopes to get them to look at being Lead Certified. The goal of Region 2 is to bring consumer choice and environmental information to the whole region. People make different decisions for different reasons, and research should delve deeper into demographics such as the gender issue and generational issues.

How should EPA distribute information on what labels mean (e.g., the purpose of green building and building labeling)? If it is difficult for consumers to find labeled products, the labels will not do any good. What is the purpose of the label: to get people to think differently and to make different consumer choices? How can this be marketed? How can EPA take its limited resources and market them? Research has found that it matters to consumers whether they consider the NGO or business doing the labeling a reliable source.

Discussant: Marsha Walton, New York State Energy Research and Development Authority

To identify benefits of single or dual labels, perhaps assuming industry is just maximizing profits proves to be too general. Firms have consciences and environmental goals. Industry would want to make more environmentally sound products because consumers want this. With environmental labels, consumers have informed choice. There is an important role for government here: how do the authors explain the practice of relaxing industry labels when NGO labels exist? It would seem there would be more pressure on industry to make labels more stringent when a second label is present. Are there any plans to do a particular industry case study? Government could reduce the choices consumers are facing by a governmental standard. With so many labels, consumers may want to do the right thing, but become overwhelmed.

In terms of the second paper, how choices are framed and what people will be willing to pay for makes a great difference. When people are presented with an economic rationale, they tend to do a cost-benefit analysis. Dr. Walton is not sure that this research is being approached in the best way. Psychologists have studied brain scans: when the image of a dollar is displayed on a poster in front of people taking a survey, self-interest behavior is triggered. When they are shown a poster of a pristine environment, altruistic behavior is initiated. Different parts of our brains control these behaviors. The private sector knows this. Social affiliations make a big difference, as does the visibility of environmental actions. Side-by-side refrigerators may not be the best example because some of the ENERGY STAR-labeled models consume more energy than smaller non-labeled models. Additionally, only 1 percent of people buy Green Power-labeled refrigerators. People want to know the environmental versus economic effects of product choice.

Questions and Discussion

Mr. Filippelli commented that the crowding out phenomenon is interesting. EPA has 70 to 80 different partnership programs. Some are specific to specific industries, and some are aimed at the public. Is there a limit to the tolerance of the public in terms of understanding this information? Is there a point where the public will be overloaded? Dr. Fischer responded that there are competing motivations. There are possibilities of labels providing broader information, but too many labels create broader credibility issues. Dr. Clark added that ENERGY STAR and Energy Guide labels are what consumers are seeing in the real world.

Mr. Sylvan asked if these labels could be applied to encourage emerging best practices. The assumption that the more stringent the standard, the better the program, is not correct in the eco-labeling world. There is no universal compliance. The best practice would be to set the standard to qualify for the label so that the top 10 in the market would meet it when introduced. When the top 40 or 50 meet it, raise the standard again. Dr. Fischer added that there is a tradeoff between label stringency and participation. Firms can stop labeling if they choose. With multiple labels, firms can choose to use the NGO label, but industry responds with their less stringent label to get more overall participation. Dr. Clark commented that from the consumer side, stringency is not that important. Consumers are looking to contribute to the public good, and the label provides symbolism. As long as consumers believe the standard is real, stringency is not critical. However, a label will not be effective if 90 percent of the firms have it. Varying the standard could work from the consumer side, but it is uncertain in terms of the dynamic aspect. This would be invisible to the consumer. If you raise the standard several times, companies may get frustrated.

Dr. Koehler noted that consumers would understand that the ENERGY STAR label meant $14 in savings per year, but not what a reduction of 195 pounds of carbon emissions meant. They could be given some context, for instance, by the statement that a car releases “x” pounds of CO_2. Dr. Koehler added that the impact must be stated in simple terms. Carbon needs to be just as clear as dollars in terms of consumer understanding. Dr. Clark replied that if consumers knew the impact of their individual choices of ENERGY STAR, they would realize their decision is not going to make a difference. Ms. Kieber responded that EPA is trying to tell consumers their actions do make a difference. If changing the type of light bulb they use matters, changing their refrigerator matters.

Dr. Clark commented that his study would examine two ENERGY STAR labels, keeping energy statements the same, but varying the price. Dr. Steven Wallander, Yale University, expressed interest in learning under what circumstances people will privately provide for the public good. Dr. Clark responded that this study is not looking into deeper public policy questions, because many respondents are completely oblivious to the public benefit. Many models start with the assumption that people are willing to pay more for labeled goods, but it is unknown whether or not this assumption is true. Dr. Fischer agreed that the models assume consumers are willing to pay more. If there is a mandatory policy, this will diminish the benefit that firms get from the eco-labeling. Government regulations on minimum efficiency will lead people to believe that government is taking care of the problem. Dr. Clark would be interested to learn how consumers respond to a minimum standard. Dr. Carol Mansfield, RTI International, stated that if the research wants to examine the market, do not give any additional information to consumers beyond what they would normally get when shopping.

SESSION VII: INFORMATION DISCLOSURE: AIR QUALITY INFORMATION

Moderator: Joann Brennan-McKee, U.S. EPA Region 2

Voluntary Information Programs and Environmental Regulation: Evidence From “Spare the Air”
Matthew Neidell, Columbia University

Most programs target firms and assume consumers will pay a higher price due to the notion of altruism. Dr. Neidell’s research focuses on the actions of individuals. “Spare the Air” is a program in the San Francisco Bay area that focuses on changing driving behavior on days when it will be unusually hot. If the ozone will exceed air quality standards, a “spare the air” (STA) announcement is issued to get people to minimize trips on this day. Free rides on public transportation are offered. The goal of Dr. Neidell’s project is to test STA’s effect on commuting behavior, and whether STA leads to ozone reduction.

STAs are issued during the summer, and there could be a reduction in traffic due to people being on vacation. To account for this, the study examined days on which an STA was issued, and days that were really similar in terms of ozone levels, but when an STA was not issued, any change in commuting behavior can be attributed to the STA. The data showed that most reductions in driving occurred between 6:00 a.m. and 11:00 a.m., but no decrease in the evening commute was seen. A decrease at night will not affect ozone levels. Perhaps people are not getting all of the information that they need. STA’s effect on ozone levels was not statistically significant. Individuals respond, but not in sufficient levels.

National-Scale Activity Survey (N-SAS)
Zachary Pekar, Office of Air Quality Planning and Standards, EPA, and Carol Mansfield, RTI International

Drs. Pekar and Mansfield discussed the design of the survey, which has not yet been conducted. The survey will measure public awareness of and response to information on air pollution conveyed through the Air Quality Index (AQI)**.** Two survey designs will be used: a national cross-sectional survey measuring awareness, knowledge, and stated responses to air quality warnings, and a longitudinal survey in selected cities collecting activity diary data to measure actual behavioral changes on poor air quality days.

The goals of the cross-sectional survey are to collect information on: respondent characteristics, including health status and time spent outdoors; risk perception in terms of the perceived magnitude of the air pollution problem and individual vulnerability; stated averting and mitigating behavior, including possible actions taken, effectiveness of actions, and frequency of actions by individual; knowledge and awareness of AQI; valuation of air quality warnings; and geographic location.

The goals of the longitudinal component of the survey are to collect information on: daily activities up to 7 days; continuous activity data for each diary day with details on type of activity, exertion level, and location, including mode and duration of travel; respondent characteristics, including general health status and status on day of activity; geographic location; stated activity to support comparison against actual activity; and additional questions from the cross-sectional survey.

The possible uses of the research results include: (1) accountability initiatives, such as determining the effectiveness of air pollution warnings at changing public's behavior. Are policies doing what they are supposed to do? (2) enhancements in the design of information outreach programs such as the AQI by improving exposure and risk modeling and improving economic benefits analysis.

Discussant: Bill Baker, U.S. EPA Region 2

Mr. Baker stated that if a VP has any chance of being successful, it must provide each participating individual and firm with the answer to "what's in it for me?" Paying for truck retrofits for diesel control is an example. Or, regulators must convince the regulated entity that they will be more flexible if the firm does what they want them to do on a voluntary basis. A state can get credit for VPs, but must quantify the benefit of the program. The fact that EPA will speak positively about a firm's program in the public arena can be an incentive for adopting a program. "Warm glow" has limits in motivating a firm to enter one of these programs for two reasons: (1) Industries have to look at the bottom line. They are willing to join these programs, but when they lack sufficient funds they tend to leave. (2) Individuals tend to believe it is always the other person causing the problem. Few people are aware of their own impact.

It is difficult to measure the true environmental impact of the VPs. Most effective programs build on existing control efforts, not those that replace controls. They give people credit for being exemplary and doing more than they need to, but there needs to be an underlying requirement. Texas, for example, always wants to do something different than what the Clean Air Act requires. Now, every other state wants to do something different. The best non-regulatory programs fulfill a true need. Programs that have little cost and make people feel good are very effective.

Discussant: Andy Darrell, Environmental Defense

Mr. Darrell explained that with a purely voluntary program, the speed of the feedback that people get in terms of the benefit-feedback loop is very important. If a consumer has a meter in their kitchen that displays electricity usage in the house, the household will reduce its usage. There is an area in between voluntary and mandatory that has to do with price and price signals. Traffic control and STA are examples of this. New York City is struggling with whether to use congestion pricing. In other countries, there is a remarkable response to this, and there is movement into emissions-based tolling that will charge more for higher polluting vehicles. With tolling, drivers are responsive to prices, but they are not responsive to gasoline prices. Part of the reason is that drivers can more easily make a decision to avoid the toll when they see the sign.

There is a need for a mandatory cap on GHG emissions in the United States, and once that is done, a market can be created for businesses to solve problems in the most efficient way possible. The right price signal and the right market are important. Companies care about their stock price, and a big driver of stock price has to do with the way that information is analyzed. Environmental Defense and Ceres asked the SEC to review and improve the way corporations disclose their climate risk in their securities filings. Allstate lost $4 billion due to weather events, but its filing did not contain a single mention of climate change. ExxonMobil mentioned climate change in one perfunctory reference, but offered no analysis. U.S. Cap (uscap.org) is calling on Congress to set a mandatory cap on emissions. Almost 30 percent of CEOs cite environmental concerns as one of the issues that will have the greatest impact on shareholder values in the next 5 years. Getting at the price signals is worthy of much attention and research going forward.

Questions and Discussion

Ms. Brennan-McKee asked if the N-SAS longitudinal survey would allow people to list in what time-frame they did their activities, and whether activities are tightly defined. Dr. Mansfield responded that the Consolidated Human Activity Database has a list of activity codes that the researchers might condense for the survey.

A participant asked if people age 55 years and older might be more health conscious than younger people. Dr. Mansfield responded that age 55 and older was chosen due to a limited budget, and because retired people have a tremendous day-to-day variability in activities.

Mr. Darrell noted that the survey will measure how people change their physical behaviors, but also will raise the awareness of environmental issues. Dr. Mansfield agreed that there is a huge value in just creating awareness.

Dr. Sabine Marx, Columbia University, asked if the survey will ask why people are changing their behavior. Dr. Mansfield responded that they cannot ask unlimited open-ended questions. The survey will ask “why” and ask respondents to choose from a list of responses. Dr. Pekar asked if the survey would ask respondents if they knew anyone who has respiratory problems. Dr. Mansfield replied that there will be many questions in the initial survey that do not give respondents information on the purpose of the study, and the followup in the longitudinal survey would ask questions more closely related to air quality.

Dr. Wernstedt asked if the researchers had thought about different information delivery systems and how people might change their behavior based on the information that they receive. Dr. Pekar responded that the survey will ask how people received the information.

Dr. Mansfield asked Dr. Neidell which alert system worked best, the dichotomous STA or no STA versus the five-color rating smog alert system used in Los Angeles. Dr. Neidell responded that smog alerts had been studied in terms of zoo attendance. If there was a smog alert issued 2 days in a row, there was a much greater effect on zoo attendance on the first day than on the second day. On the first day, perhaps people were more willing to engage in indoor activities. Also, the role of the media is important, and the first smog alert would be a bigger story than the second. It has been found that anything less than a smog alert does not affect behavior.

Final Remarks: Dinah Koehler, NCER, ORD, EPA

Dr. Koehler commented that the past 2 days had been exciting and interesting, and expressed the hope that the meeting would help to create a community or network of scholars, researchers, and implementers to improve policy and research design and implementation. She advised attendees that the proceedings would be posted on the meeting Web site at a later date.

Dr. Koehler thanked the participants for attending and adjourned the meeting at 6:00 p.m.