Monitoring, Enforcement, & Environmental Compliance: Understanding Specific & General Deterrence

Task 4: A Multiple Sector Analysis

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Executive Summary

Significant reductions in non-compliance and emissions are obtainable with traditional monitoring and enforcement. The regulation literature indicates that inspections and enforcement actions produce improved future environmental performance at the evaluated or sanctioned facility. Regulatory activity generates substantial specific deterrence. The literature also shows that inspections and enforcement actions produce significant spillover effects on non-sanctioned facilities. Regulatory activity generates substantial general deterrence.

This report quantitatively measures the specific and general deterrence effects of environmental monitoring and enforcement in the petroleum, paper, steel, inorganic chemicals, organic chemicals, and alumina/aluminum smelting industries. The metrics and statistical techniques were designed to be as technically rigorous as possible yet cost-effective for use by non-statisticians.

The report's immediate goal is model calibration. We identify the strengths and weaknesses of the cost-effective statistical models for quantitatively assessing specific and general deterrence. The report's intermediate goal is to lay the foundation for capacity building. The database preparation and statistical methods discussed highlight the basic sequencing and steps necessary for replication. In the longer run, the study's results and techniques may augment the Environmental Protection Agency's ability to measure and evaluate the effectiveness of its enforcement and monitoring activities. Assessments may aid internal management or may facilitate justifiable statements to external stakeholders about the impacts of monitoring and enforcement on measured environmental outcomes.

Major findings include: (a) Simplified, cost-effective quantitative database methods produce plausible and statistically stable general deterrence effect estimates. (b) Environmental monitoring and enforcement activities generate substantial general deterrence. (c) Environmental monitoring and enforcement activities generate substantial general deterrence, even for sector/contaminant combinations where compliance is typically high. (d) General deterrence effects vary across sectors and pollutants. (e) Simplified, cost-effective quantitative database methods do not generate statistically stable or practically meaningful specific deterrence effect estimates.

Major recommendations include: (a) OECA should consider applying the simplified general deterrence measurement models to additional datasets created from the extensive data available to the EPA. (b) OECA might consider applying the simplified specific deterrence measurement models to additional datasets created from the extensive data available to the EPA. Results, however, should be interpreted cautiously. (c) OECA might consider modest extensions to the simplified models presented and calibrated throughout the Compliance and Deterrence Research Project. (d) OECA might consider modest modifications to the data generating process presented and calibrated throughout the Compliance and Deterrence Research Project.

1. Introduction

Significant reductions in non-compliance and emissions are obtainable with traditional monitoring and enforcement. The regulation literature indicates that inspections and enforcement actions produce improved future environmental performance at the evaluated or sanctioned facility. Regulatory activity generates substantial specific deterrence. The literature also shows that inspections and enforcement actions produce significant spillover effects on non-sanctioned facilities. Regulatory activity generates substantial general deterrence. Results hold both historically and currently.

This report attempts to quantitatively measure the specific and general deterrence effects of monitoring and enforcement in the petroleum, paper, steel, inorganic chemicals, organic chemicals, and alumina/aluminum smelting industries. More precisely, this paper analyzes the deterrence effects of environmental monitoring and enforcement by applying the simplified quantitative measurement frameworks developed and calibrated in Task 3 of the Office of Enforcement and Compliance Assurance (OECA)'s ongoing compliance and deterrence research project. We provide database modeling results for several new sectors and time periods. The metrics were designed to be as technically rigorous as possible, yet cost-effective for future in-house use by Environmental Protection Agency and OECA personnel. In Task 3, the metrics were benchmarked against data analyzed in the pre-existing literature to examine if the estimated deterrence effects from simplified models approximately equal those reported in published studies. Here, we apply the metrics to previously unanalyzed water pollution discharges, water pollution non-compliance, and air pollution compliance.

The immediate goal of this task is further model calibration. We identify the strengths and weaknesses of the simplified models, and we identify which metrics produce the most consistently meaningful results. An intermediate goal of the new sector applications is to lay the foundation for capacity building at OECA and the Agency. The Task 4 database preparation and statistical methods highlight the basic sequencing and steps necessary for Agency personnel to assemble their own datasets and run their own models. The outcomes of this process will be included in the future Task 5 Users Guide.

This paper's results also contribute to the project's longer term goal of improving the Agency's ability to measure and evaluate the effectiveness of its enforcement and monitoring activities. The type of assessments presented here may aid internal management, along with other relevant factors. For example, results may help Agency personnel identify sectors where monitoring and enforcement actions may induce particularly significant changes in environmental performance. The methods may also eventually facilitate justifiable statements to external stakeholders about the impacts of monitoring and enforcement on measured environmental outcomes. Many current methods for evaluating the effectiveness of environmental regulatory activities are incomplete. Outcome measures like pounds of pollution directly reduced through consent decree agreements and court settlements do not typically capture deterrence, and especially general deterrence. For example, if a facility agrees to reduce pollution by

some number of tons in response to a regulator action, this reduction is important but may considerably understate the action's overall impact. Put simply, this direct observation measure fails to capture the impacts of this signal of regulatory 'toughness' on the behavior of other facilities.

2. Scope

As requested in the Statement of Work, this document is limited in scope. It is most effectively considered as part of the Office of Research and Development (ORD) and the Office of Enforcement and Compliance Assurance's (OECA) broader compliance and deterrence research project. Readers of this report are encouraged to familiarize themselves with the associated "Monitoring, Enforcement, and Environmental Compliance: State-of-Science White Paper"[1] and "Monitoring, Enforcement, and Environmental Compliance: Metrics and Model Calibration."[2] The white paper reviews the recent policy-relevant environmental compliance literature. The metrics and models paper presents and calibrates simplified frameworks for database analysis of specific and general deterrence of environmental monitoring and enforcement. Many of the theoretical foundations, statistical concepts, and practical considerations essential to fully understanding this report's methods, findings, and recommendations are discussed in detail in these previous papers and will not be repeated here.

In principle, possible analyses of specific deterrence can take several forms: (a) the change in compliance status due to inspections at the monitored facility, (b) the change in emissions/discharges due to inspections at the monitored facility, (c) the change in compliance status to enforcement actions at the sanctioned facility, and (d) the change in emissions/discharges due to enforcement actions at the sanctioned facility. In principle, possible analyses of general deterrence can take several forms: (e) the change in compliance status due to enforcement actions at other facilities in the same state and sector, (f) the change in emissions/discharges due to enforcement actions at other facilities in the same state and sector, (g) the change in compliance status due to inspections at other facilities in the same state and sector, (h) the change in emissions/discharges due to inspections at other facilities in the same state and sector.

For each of the conventional water pollutants biochemical oxygen demand (BOD) and total suspended solids (TSS), we simultaneously examine metrics (a)-(f). We do not examine metrics (g) and (h), since inspections are so frequent for analyzed plants that there is little practical meaning in the analysis of the impact of an additional inspection in the same state and sector. For air pollution, we analyze specific deterrence metrics (a) and (c). It would be ideal to examine metrics (b), (d), (e), and (f) as well, but unfortunately air emissions data are not consistently measured and reported for comparable cross-sector

[1] White Paper: J. Shimshack, "Monitoring, Enforcement, and Environmental Compliance: Understanding Specific and General Deterrence, State-of-Science White Paper." Paper Prepared for the Environmental Protection Agency's Office of Research and Development and Office of Enforcement and Compliance Assurance. Oct. 2007.

[2] Models and Metrics paper: J. Shimshack, "Monitoring, Enforcement, and Environmental Compliance: Metrics and Model Calibration" Paper Prepared for the Environmental Protection Agency's Office of Research and Development and Office of Enforcement and Compliance Assurance. July 2008.

analyses. The Air Facility System that serves as the basis for this analysis is limited to compliance and permit data. National Emissions Inventory data would seem promising, but it is only available in several year increments and therefore difficult to credibly link to regular monitoring and enforcement activity.

In short, we follow the statement of work exactly and analyze all possible meaningful metrics for water pollution. Air pollution results can be seen as supplemental. Air pollution analyses for metrics (a) and (c), however, provide important supporting evidence for key specific deterrence findings and recommendations.

Several concepts important to the broader compliance and deterrence project are not fully explored here. First, this report is not intended, on its own, to establish the deterrence effects of monitoring and enforcement actions. Results presented here are new, and they contribute to the state of knowledge on general and specific deterrence. Nonetheless, an extensive peer-reviewed literature examines related questions in more comprehensive detail. Second, many replication considerations represent important areas for future research for task 5 and beyond. Subjects for future research include the appropriate replication frequency necessary to characterize a given sector's current deterrence level, the confounding factors that may enhance specific and general deterrence, and the appropriate number of facilities for statistically meaningful quantitative evaluations of deterrence.

3. Empirical Model and Statistical Intuition

This section reviews the key points of the metrics discussion in the Task 3 report. We present the basic model and the statistical intuition underlying those models, but more detailed discussions are left to the earlier document. We provide a more complete discussion of causality and attribution here.

Theoretical foundations

Analyzing the impact of regulatory activity on environmental performance is framed in terms of deterrence. Pollution sources decide how much effort to invest in pollution abatement by comparing the marginal benefits and marginal costs of polluting. Marginal benefits of polluting or violating reflect increased production possibilities and decreased abatement expenditures. Marginal costs of polluting or violating are the expected damages associated with regulatory activity and possible community and customer backlash. Greater regulatory activity, as measured by recent inspections or enforcement actions, is hypothesized to increase a plant's expected compliance, decrease a plant's expected non-compliance, and decrease a plant's expected pollution (on average).

Model Intuition: Specific Deterrence

The basic intuition of the specific deterrence models is quasi-experimental. Essentially, the simplified models compare observations in which there was an agency

action in the recent past to observations in which there was no agency action in the recent past. For example, specific deterrence models may compare:

> facility/time combinations with an inspection/enforcement action at that facility in the past year
>
> -to-
>
> facility/time combinations without an inspection/enforcement action at that facility in the past year.

The difference between these two average levels represents the average specific deterrence effect of an inspection/enforcement action in the recent past. For some of the models, the actual statistical identification of deterrence effects is more subtle, but the basic intuition still holds.

We examine specific deterrence on a sector-by-sector basis. Since a key component of the statistical identification and statistical intuition in the specific deterrence models is a behavioral comparison of facility/time pairs with an inspection or enforcement action to facility/time pairs without an inspection or an enforcement action, specific deterrence models should typically be considered one sector at a time. This restriction ensures that comparison facilities share roughly similar characteristics.

Model Intuition: General Deterrence

The basic intuition of the general deterrence models remains quasi-experimental. Simplified models still compare observations in which there was an agency action in the recent past to observations in which there was no agency action in the recent past. For example, general deterrence models may compare:

> facility/time combinations with an enforcement action at other facilities in the same state and sector in the past year
>
> -to-
>
> facility/time combinations without an enforcement action at other facilities in the same state and sector in the past year.

The difference between these two average levels represents the average general deterrence effect of an enforcement action on neighboring facilities in the recent past. For some of the models, the actual statistical identification of general deterrence effects is more subtle, but the basic intuition still holds.

We examine general deterrence on a sector-by-sector basis. A key component of the statistical identification in the general deterrence models is a behavioral comparison of facility/time pairs with enforcement actions on neighboring facilities to facility/time

pairs without an enforcement action on neighboring facilities. Examining one sector at a time again ensures that comparison observations share roughly similar characteristics.

Basic Regression Model

The overall empirical strategy for measuring specific and general deterrence is to link inspections and enforcement actions to subsequent compliance and pollution behavior. For the more mathematically and statistically inclined reader, the basic regression model is:

$y_{it} = \alpha_i + \gamma_t + D_{it}\delta + \mathbf{X}_{it}\boldsymbol{\beta} + \varepsilon_{it}$, where:

i indexes the unit of observation (a facility)

t indexes time (months or years).

y_{it} represents facility i's compliance status or pollution discharges in period t.

α_i is a facility-specific indicator that may represent unobserved time invariant facility characteristics like size, capacity, industrial sub-category, and profitability.

γ_t is a year-specific indicator that represents unobserved time effects common to all facilities like technological change, sector maturation, and economic fluctuations over time.

D_{it} is the presence or count of lagged EPA/state enforcement or monitoring activities (the key explanatory variable).

X_{it} represents other control variables, possibly including (1) seasonality indicators to control for within-year variation and (2) state-specific indicators to control for average differences in regulatory activity across states. [3]

ε_{it} represents the regression error term addressing the difference between the outcome predictions of the regression line and the actual outcome data.

δ, $\boldsymbol{\beta}$ represent regression coefficients. Notably, δ represents the marginal impact of an additional inspection or enforcement action on subsequent compliance/pollution

[3] As a technical note, in models that actually contain facility specific fixed effects, these state level fixed effects are omitted since they are redundant. Seasonality terms are included when the observation period is one month and omitted when the observation period is one year.

Regression Model: Explanatory Variables

D_{it} is the key explanatory variable. In the specific deterrence model, D_{it} is the presence or count of lagged EPA/state enforcement or monitoring activities directed at facility i in the recent past. In the general deterrence model, D_{it} is the presence or count of lagged EPA/state enforcement activities directed at other plants in plant i's state and sector in the recent past.

Note that detailed explanatory variables representing plant and community characteristics assembled from non-EPA datasets are omitted. State indicator variables, time indicator variables, and panel data statistical techniques (approaches to modeling α_i) account for these omitted factors in our simplified models. State indicator variables capture community and regulatory differences across states. Year indicator variables capture common technological change, sector maturation, and economic fluctuations over time. Panel data statistical techniques (approaches to modeling α_i) capture systematic plant characteristics like age, capacity, industrial sub-category, and profitability. The key assumption underlying this simplification is that facilities are reasonably homogeneous within sectors, technical change is relatively modest, regulations are fairly static, and managerial attitudes are not evolving rapidly for most facilities over the sample period.

Regression Model: Dependent Variables

The dependent variable in our analyses is a 0/1 discrete compliance indicator or a continuous pollution measure for a given plant in a given time period. For example, the 0/1 compliance indicator may signify if a plant is determined to be in violation with its air pollution obligations in a given year. An example of the continuous pollution variable is the percent of permitted total suspended solids (TSS) water contaminants discharged by a given plant in a given month.

When the dependent variable is continuous, like emissions or discharges, we use ordinary linear regression models. The values of the explanatory variables for a given observation predict a corresponding average or expected emissions level. For example, all else equal, we would expect a facility's average emissions to be lower following an enforcement action. When the dependent variable is discrete, however, like a 0/1 compliance status or non-compliance status indicator, we use non-linear models instead of linear regression models. When the dependent variable is limited to take on a value of 0 or 1, ordinary linear regressions are known as linear probability models. The values of the explanatory variables for a given observation predict a corresponding average or expected probability of compliance. For example, all else equal, we would expect a facility's probability of compliance to be higher following an enforcement action. Linear probability models exhibit at least two well-known weaknesses. First, predicted values from a linear regression may lie outside of the 0/1 range. For example, the predicted probability of compliance from a linear probability model may be negative or greater than 1. Second, linear probability models force the impact of an explanatory variable to be the same for all values of the dependent variable. For example, the change in the predicted probability of compliance due to an enforcement action is the same for a

facility with a low probability of compliance and a facility with a high probability of compliance. Non-linear models, like the logit model, overcome these difficulties so we use them when the dependent variable is discrete.

Three Specific Regression Approaches

Technical descriptions of the exact regression approaches are discussed in detail in the Task 3 Metrics and Models report and are summarized in Appendix A of this document.

4. Statistical Issues

Correlation vs. Causality – Potential Concerns

The first lesson of basic statistics is that correlation is not causality. There are two primary reasons for the divergence between statistical relationships (correlation) and causal relationships (causality) in ordinary regressions:

a. Factors not specifically included in the statistical model may simultaneously drive the values of the explanatory variable and the values of the dependent outcome variable. This is often referred to as the omitted variable concern.
b. The causal relationship runs from the dependent variable to the explanatory variable, rather than from the explanatory variable to the dependent variable. This is often referred to as the reverse causality concern.

For an example of the omitted variable concern, suppose a specific deterrence analysis found that facilities with more inspections complied more frequently. This result may represent a causal influence of inspections on compliance. Alternatively, it may simply be that large facilities both receive more inspections and are more likely to comply anyway. In this case, the positive statistical relationship between the number of inspections and compliance may be driven by the omitted facility size consideration and not a causal connection.

For an example of the reverse causality concern, suppose a specific deterrence analysis found that facilities with more inspections complied less frequently. This result may represent a (puzzling) causal influence of inspections on poor compliance. More likely, however, it may simply be that facilities with poor compliance are targeted with more inspections. In this case, the negative statistical relationship between the number of inspections and compliance may be driven by the causal effect of compliance on inspections rather than the desired causal effect of inspections on compliance.

Correlation vs. Causality – Attributing Deterrence to Regulatory Actions

The causality concerns discussed above are important. The regression models used in this report, however, do attempt to isolate causality and attempt to attribute deterrence to regulatory actions as much as possible. The simplified cost-effective techniques may not perfectly isolate causality in all instances, but the techniques do

attempt to minimize attribution problems stemming from both omitted variable and reverse causality concerns.

First, the statistical techniques underlying the specific regression approaches used here and discussed in the technical Appendix A attempt to address the *omitted variable concern*. The basic insight is that more advanced statistical techniques can control for omitted factors that do not vary significantly over the sample period. Omitted factors that are implicitly considered include facility size, industrial sub-category, profitability, managerial attitudes, and others.

Second, the statistical techniques underlying the specific regression approaches used here and discussed in the technical Appendix A attempt to address the *reverse causality concern*. All monitoring and enforcement variables in the analysis are lagged. The basic insight is that it is likely that a current period's pollution or compliance may induce regulator actions in this period, but it is less likely that current pollution or compliance induced regulator actions in the past. Further, two of the three regression models are explicitly designed to provide accurate estimates of deterrence when inspection or enforcement targeting is based upon a plant's overall environmental performance.[4]

Correlation vs. Causality – Remaining Attribution Concerns

Despite the attribution efforts discussed in the preceding sub-section, the methodological simplifications designed for cost-effective analyses imply that the models used in this report may still imperfectly isolate causality. The major concern that the simplified models do not address is that inspections or enforcement actions may be targeted at facilities with *deteriorating* environmental performance relative to peer facilities. Here, targeting is based not just a plant's overall environmental performance, but changes in that plant's environmental performance over time. This particular type of reverse causality may cause problems for attribution, especially for the measurement of specific deterrence in industries with facilities and conditions that are changing rapidly.

Fortunately, this type of reverse causality is typically a more minor concern for the measurement of general deterrence. The key insight is that regulator targeting at any given plant has less to do with emissions or non-compliance at *other* facilities than emissions or non-compliance at the plant in question. Therefore, attribution may be especially credible for the measurement of general deterrence.

It is still possible, although less likely, that reverse causality due regulatory targeting at facilities with deteriorating environmental performance can lead to imperfect attribution in general deterrence models. In the special case where inspections or

[4] A complete proof of this statement is beyond the scope of this report, but most econometrics textbooks provide a more complete discussion of how fixed effects regressions and conditional random effects can provide accurate estimates (on average) of causal effects when the level of the explanatory variable (inspections, fines) is partially caused by the average level of the dependent variable (compliance, pollution).

enforcement actions systematically occur during periods with deteriorating environmental performance across entire states (relative to peer states), reverse causality can significantly impact general deterrence results. Statistical techniques and data augmentation (like data on state-specific economic factors) can minimize this problem, but those techniques and data are beyond the scope of the cost-effective methods used here.

Statistical Significance

We will interpret our regression results using conventional notions of statistical significance. We statistically test hypotheses that examine the relationship between regulatory monitoring and enforcement actions and subsequent pollution and compliance behavior. Our null, or assumed, hypothesis is no relationship. Our alternative hypothesis is that there is a relationship. We will reject the null of no relationship in favor of a statistically significant relationship between monitoring/enforcement actions and compliance/pollution when the probability of incorrect rejection due to randomness in sampling is 10 percent or less. In other words, "statistically significant" in the text refers to statistical significance at the 10 percent level. The 10 percent level, like all possibilities, is arbitrary. We choose 10 percent since it is the largest of the three conventionally analyzed levels. However, more complete statistical significance results are reported in the numerical tables in Appendix B. Regression results with three stars (asterisks) are significant at the 1 percent level, results with two stars (asterisks) are statistically significant at the 5 percent level, and results with one star are statistically significant at the 10 percent level. Other statistical significance levels can be easily approximated using the reported t-statistics in the numerical tables in Appendix B.[5]

Regression to the Mean - Potential Concerns

The modeling approach used here minimizes concerns about regression to the mean. The regression to the mean issue is that periods that triggered regulator actions may reflect abnormally high pollution levels and therefore post-action periods may inherently display lower pollution levels than pre-action periods. However, recall that the statistical intuition subsections above indicate that the relevant comparison is not pre-action vs. post-action performance. The relevant comparison is performance (or changes in performance) for those observations with actions vs. performance (or changes in performance) for those observations without actions, and so the comparison is relative to all non-sanction periods (not just the pre-action period).

Do we need historical baseline data to make statistically sensible inferences?

The intuition of the statistical models used here implies that historically-derived baseline data is not necessary to achieve useful results. Results still show the impact of inspections or enforcement activity on pollution and compliance for a given period of

[5] T-statistics of 1.44 or greater in absolute value are significant at 15 percent. T-statistics of 1.65 or greater in absolute value are significant at 10 percent. T-statistics of 1.96 or greater in absolute value are significant at 5 percent. T-statistics of 2.58 or greater in absolute value are significant at 1 percent level.

time ("aggregate BOD and TSS discharges within a state fall approximately 7 percent in the year following a sanction within that state.") without reference to a historical period or long-term historical trends.

5. Data and Sector Selection

After consulting with OECA personnel, we selected the pulp and paper, petroleum refining, organic chemicals, inorganic chemicals, iron and steel, and alumina/aluminum smelting industries for analysis. The key selection criteria were data availability, model suitability, and aggregate environmental impact. The large industrial sources of our selected sectors have the most complete air and water data. Further, they share salient characteristics with the industries analyzed in the academic literature that serve as the basis for the simplified deterrence measurement metrics. Finally, these sectors have significant environmental impacts, and several were core programs in the completed Sector Facility Indexing Project.

Air Data – Sector Selection

We obtained air data by first retrieving facility identifiers from the Facility Research System (FRS). All facilities that had either a modern North American Industry Classification System (NAICS) code or an older Standard Industrial Classification (SIC) code that was linked to these five sectors were selected. Key 4-digit NAICS codes were 3221 (paper), 3241 (petroleum), 3251 (chemicals), 3311 (iron and steel), and 3313 (alumina and aluminum smelting). Key corresponding 4-digit SIC codes were 2611, 2621, 2812, 2813, 2819, 2861, 2865, 2869, 2895, 2911, 3312, 3331, 3334, and 3339.

We then used the FRS to obtain Air Facility System identifiers for each of the plants corresponding to the selected NAICS and SIC codes. We used the identifiers to select all relevant air facility system compliance data for 1995-2002. We also selected all relevant monitoring data for 1993-2002. The analyzed air dataset contains 451 plants in the paper sector (NAICS 3221), 343 plants in the petroleum sector (NAICS 3241), 1844 plants in the chemicals sector (NAICS 3251), 331 plants in the iron and steel sector (NAICS 3311), and 159 plants in the alumina and aluminum smelting sector (NAICS 3313). All data are observed yearly, so each facility with complete data is associated with 8 observations.

Table 1 summarizes the air data.

Air Data – Compliance, Inspections, and Enforcement Action Definitions

For air pollution data, compliance is indicated if a plant was not determined to be "in violation" at any point over the observation year and was categorized as "in compliance" at least once during the observation year. Non-compliance is indicated if the plant was in violation due to "in violation – no schedule," "in violation – not meeting schedule," "in violation – unknown with regard to schedule," "in violation – with regard

to both emissions and procedural compliance," and "in violation – with regard to procedural compliance."

Air pollution inspections and enforcement actions are identified by action descriptions. Inspections occur if the action description is coded with "inspection (insp)" or "full compliance evaluation (fce)" or "source test conducted or observed (test)" or "visit" or "surveillance (surv)." Air pollution enforcement actions are also identified by action descriptions. Major enforcement actions occur it the action description is coded with "order" or "administrative penalty order" or "letter" or "notice of violation" or "penalty" or "notice."

Water Data – Sector Selection

We obtained water pollution and compliance data by retrieving all data on *major* facilities in the Permit Compliance System with the SIC codes listed above. Only major facilities were selected, since non-majors are not required to track pollution discharges each and every month. Further, majors tend to be more similar to one another than non-majors. We kept all facilities with relatively complete BOD and TSS data for the Jan 1998 to May 2006 sample period. If a facility was the only major of its industrial type in its state, it was omitted. The sample period was chosen due to data availability. In June of 2006, many states stopped inputting PCS data because of pending data migration to a new management system. We keep plants in states with more than one plant of a given industrial type since our goal is to investigate spillover deterrence effects within states.

The final water dataset contains 167 plants in the paper industry (NAICS 3221), 84 plants in the petroleum industry (NAICS 3241), 56 plants in the steel industry (NAICS 3311), 33 plants in the industrial inorganic chemicals industry (SIC2819, NAICS 3251), and 92 plants in the industrial organic chemicals industry (SIC2869, NAICS 3251). No plants satisfied selection criteria for the alumina and aluminum smelting sector (NAICS 3313), as systematic water pollution data for this industry's plants is unavailable. All data are observed monthly, so each facility with complete data is associated with 101 observations.

Table 2 summarizes the water data.

Water Data – Compliance, Inspections, and Enforcement Action Definitions

The dataset contains average monthly quantities and average monthly quantity limits for the conventional water pollutants biochemical oxygen demand (BOD) and total suspended solids (TSS). We chose average quantities of conventional pollutants because they are measured systematically for most majors, and most industrial facilities produce wastewater with significant amounts of both BOD and TSS.

Biochemical oxygen demand (BOD) discharges are measured as the ratio of BOD discharges to permitted BOD levels at a given plant in a given month. Total suspended solids (TSS) discharges are measured as the ratio of TSS discharges to permitted TSS

levels in at a given plant in a given month. BOD compliance occurs if all of the plant's BOD discharges are below permitted levels during the month. BOD non-compliance occurs if any of the plant's BOD discharges are above permitted levels during the month. TSS compliance occurs if all of the plant's TSS discharges are below permitted levels during the month. TSS non-compliance occurs if any of the plant's TSS discharges are above permitted levels during the month.

In principle, non-compliance status could refer to any desired compliance indicator, including Agency determined Significant Non-compliance status or High-Priority Violation status. In the Shimshack and Ward papers that serve as the foundation of the simplified analysis conducted here, compliance status is determined by examining actual discharges relative to permitted standards. While any exceedance of permitted levels is considered non-compliance, a large number of violations correspond to significant non-compliance (greater than 40 percent above permitted limits for water pollutants BOD and TSS).

Water pollution inspections and penalties are identified as in the Permit Compliance System. Inspections occur if the inspection description is coded as any inspection type, including "performance audit" or "compliance evaluation inspection" or "reconnissance" or "compliance sampling" or "compliance bio-monitoring." Financial penalties occur if "penalty amount assessed" in the PCS is non-zero and non-missing. This represents the dollar amount of the assessed administrative penalty as identified in the final order.

6. Specific Deterrence Results

Specific Deterrence of Inspections for Air Pollution Compliance Status

Specific deterrence of inspections for air pollution compliance results are summarized in the first several columns of Table 3. More complete results are presented in Appendix B Tables AI1-AI5 (Air Inspections 1 – Air Inspections 5). The simplified metrics and data build off the seminal work of Gray and Deily (1996), as well as newer papers by Gray and Shadbegian (2005), Gray and Shadbegian (2007), and Deily and Gray (2007). The key metric is the response of a plant's compliance status to lagged EPA/state monitoring activities directed at that facility in the recent past. The unit of observation is a plant/year combination, and each plant is observed over the 8 years spanning 1995-2002.

The specific deterrence of inspections for air pollution compliance results are mixed. The first several columns of Table 3 indicate that many coefficients in the preferred fixed effects specification have the expected positive coefficients. Positive coefficients for these regressions indicate that lagged inspections are associated with improved environmental compliance with air pollution regulations. However, none of the results are statistically significant. Further, coefficients for the chemicals and alumina/aluminum smelting industries have unexpected negative coefficients. Negative coefficients indicate that lagged inspections are associated with deteriorating environmental compliance with air pollution regulations. Most likely, all specific

deterrence of inspection results for air compliance reflect the difficulty of eliminating reverse causality bias in the measurement of specific deterrence with simplified data and metrics.

Specific Deterrence of Enforcement Actions for Air Pollution Compliance Status

Specific deterrence of enforcement actions for air pollution compliance results are summarized in the last few columns of Table 3. More complete results are presented in Appendix B Tables AE1-AE5 (Air Enforcement Actions 1 – Air Enforcement Actions 5). The key metric is the response of a plant's compliance status to lagged EPA/state enforcement activities directed at that facility in the recent past. The unit of observation is a plant/year combination, and each plant is observed over the 8 years spanning 1995-2002.

The specific deterrence of enforcement actions for air pollution compliance results are unforeseen. The last several columns of Table 3 indicate that all coefficients in the preferred fixed effects specification have unexpected negative coefficients. Negative coefficients indicate that lagged enforcement actions are associated with deteriorating environmental compliance with air pollution regulations. Most likely, all specific deterrence of enforcement results for air compliance reflect the difficulty of eliminating reverse causality bias in the measurement of specific deterrence with simplified data and metrics.

Specific Deterrence of Inspections for Water Pollution Discharges

Specific deterrence of inspections for BOD water pollution discharge results are summarized in Table 4a. More complete results are presented in Appendix B Tables W1a-W5a. BOD compliance results are similar in spirit to the BOD discharge results and are not discussed in detail; specifics can be found in Tables W1b-W5b. Specific deterrence of inspections for TSS water pollution discharge results are summarized in Table 4c. More complete results are presented in Appendix B Tables W1c-W5c. TSS compliance results are similar in spirit to the TSS discharge results and are not discussed in detail; specifics can be found in Tables W1d-W5d.

The key metric in the presented specific deterrence of inspections investigations is the response of a plant's conventional water pollution discharges to lagged EPA/state monitoring activities directed at that facility in the recent past. The unit of observation is a plant/month combination, and each plant is observed over the 101 months spanning Jan 1998 – May 2065.

The specific deterrence of inspections for water discharge results are mixed. Many of the coefficients in summary Tables 4a and 4c have the expected negative signs. Negative coefficients for these regressions indicate that lagged inspections are associated with reduced BOD and TSS discharges. However, only TSS discharges from the pulp and paper industry exhibit statistically significant negative relationships between inspections and subsequent compliance. Further, some coefficients in summary Tables 4a and 4c

have unexpected positive signs. Positive coefficients for these regressions indicate that lagged inspections are associated with increased BOD and TSS discharges. Again, these results likely reveal the difficulty of eliminating reverse causality bias in the measurement of specific deterrence with simplified data and metrics.

Specific Deterrence of Penalties for Water Pollution Discharges

Specific deterrence of penalties for BOD water pollution discharge results are summarized in Table 4b. More complete results are presented in Appendix B Tables W1a-W5a. BOD compliance results are similar in spirit to the BOD discharge results and are not discussed in detail; specifics can be found in Tables W1b-W5b. Specific deterrence of penalties for TSS water pollution discharge results are summarized in Table 4d. More complete results are presented in Appendix B Tables W1c-W5c. TSS compliance results are similar in spirit to the TSS discharge results and are not discussed in detail; specifics can be found in Tables W1d-W5d.

The key metric in the presented specific deterrence of penalties investigations is the response of a plant's conventional water pollution discharges to lagged EPA/state penalties directed at that facility in the recent past. The unit of observation is a plant/month combination, and each plant is observed over the 101 months spanning Jan 1998 – May 2065.

The specific deterrence of penalties results for water discharge are mixed, but more plausible than the specific deterrence of inspection results for both air and water. Most of the statistically significant coefficients in summary Tables 4b and 4d have the expected negative signs. Negative coefficients for these regressions indicate that lagged penalties are associated with reduced BOD and TSS discharges. Practical and statistical evidence for specific deterrence of penalties is observed for BOD discharges from the petroleum refining and industrial organic chemicals sectors. Practical and statistical evidence for specific deterrence of penalties is observed for TSS discharges from the iron and steel and industrial organic chemicals sectors. However, a couple of coefficients in summary Tables 4b and 4d have unexpected positive signs. Positive coefficients for these regressions indicate that lagged penalties are associated with increased BOD and TSS discharges. Again, these results likely reveal the difficulty of eliminating reverse causality bias in the measurement of specific deterrence with simplified data and metrics.

Specific Deterrence Discussion

Simplified, cost-effective quantitative database methods do not generate stable specific deterrence effect estimates. Specific deterrence results are unstable, frequently statistically insignificant, and often counter-intuitive. This finding holds for inspections in air compliance, water compliance, and water pollution discharge contexts. This finding also holds for enforcement actions in air compliance and water compliance settings, and may hold in a water pollution discharge context as well. Sensitive results and counterintuitive outcomes are almost certainly driven by difficulties isolating causality in specific deterrence investigations with simplified cost-effective statistical models.

The detailed results in Appendix B tables provide supporting evidence for the reverse causality hypothesis. Fixed effects regression coefficients are universally more positive (less negative) than random effect regressions. As discussed in technical Appendix A, fixed effects remove bias associated with inspection or enforcement targeting based upon the average environmental performance of the monitored firm. The other statistical regression approaches do not remove this bias, and cross-plant differences in overall inspection or enforcement targeting are very likely driving coefficients in a negative direction for the regressions. The true behavioral link may be obscured by the reverse causality bias.

Why is reverse causality important in these models yet not in calibration results for 41 steel plants in the 1980s? First, targeting regimes may have evolved over time and may be more present statistically in these more modern analyses. They may also be more sophisticated. If inspection and enforcement targeting regimes now target firms or sector-state combinations with rapidly deteriorating environmental performance for greater regulatory oversight, the simplified specific deterrence models used here may insufficiently address reverse causality concerns. Second, mean compliance rates in the five modern sectors are significantly higher than the mean compliance rates for the steel industry in the 1980s. High mean compliance rates imply that detecting specific deterrence is more difficult statistically, since there are fewer changes in compliance status. One might also simply expect greater deterrence effects when the typical plant has greater room for improvement. Third, and perhaps most importantly, the sectors and monitoring/enforcement actions requested by the Statement of Work and examined here are extremely heterogeneous. Cross-plant differences in monitoring and enforcement may simply be so large that they drive results. Related academic studies, including the papers that served as the basis for the utilized metrics, typically use significantly narrower industry definitions.

7. General Deterrence Results

General Deterrence of Penalties for Water Pollution Discharges

General deterrence of penalties results for BOD water pollution discharges are summarized in Table 5a. More complete results are presented in Appendix B Tables W1a-W5a. General deterrence of penalties results for TSS water pollution discharges are summarized in Table 5b. More complete results are presented in Appendix B Tables W1c-W5c.

The simplified general deterrence metrics and data build off Shimshack and Ward (2005) and Shimshack and Ward (2008). The key metric is the response of a plant's pollution discharges to lagged EPA/state enforcement activities directed at other facilities in the same state and sector.[6] The unit of observation is a plant/month combination, and each plant is observed over the 101 months spanning 1998:1-2006:5.

[6] Although sector emissions or compliance should be considered on a sector-by-sector basis, it is not strictly necessary to restrict attention to enforcement and monitoring activities directed at other facilities in

The general deterrence of penalties results for water discharges are stable across regression specifications and frequently practically important and statistically significant. Virtually all statistically significant coefficients in Tables 5a and 5b have negative signs. Negative coefficients for these regressions indicate that lagged penalties are associated with reduced BOD and TSS discharges. We find strong evidence for general deterrence from penalties for the BOD discharges of the pulp and paper and industrial inorganic chemicals sectors. We also find strong evidence for general deterrence from penalties for the TSS discharges of the pulp and paper, petroleum refining, industrial inorganic chemicals, and the industrial organic chemicals industries.

We interpret our BOD results in context. The pulp and paper row of Table 5a indicates that the average BOD discharge ratio declines approximately 0.012 in the year following a fine on another pulp and paper plant in the same state. The average BOD discharge ratio declines 0.027 in the second year following a fine on another pulp and paper plant in the same state. Given the overall mean BOD discharge ratios in this industry, this translates (on average) into an approximately 4-10 percent reduction in aggregate BOD discharges. The industrial inorganic chemical row of Table 5a indicates that the average BOD discharge ratio declines approximately 0.046 in the year following a fine on another inorganic chemical facility in the same state. Given the overall mean BOD discharges ratios in this industry, this translates (on average) into an approximately 22 percent reduction in aggregate BOD discharges.

We also interpret our TSS results in context. The petroleum refining row of Table 5b indicates that the average TSS discharge ratio declines approximately 0.050 and 0.031 in the first and second years following a fine on another petroleum plant in the same state. Given the overall mean TSS discharge ratios in this industry, this translates (on average) into an approximately 11-20 percent reduction in aggregate TSS discharges. The inorganic chemicals row of Table 5b indicates that the average TSS discharge ratio declines approximately 0.056 and 0.039 in the first and second years following a fine on another inorganic chemical facility in the same state. Given the overall mean TSS discharge ratios in this industry, this translates (on average) into an approximately 17-24 percent reduction in aggregate TSS discharges. Similarly, industrial organic chemical results translate (on average) into an approximately 1-5 percent reduction in aggregate TSS discharges.

General Deterrence Discussion

The general deterrence of penalties results for BOD and TSS water discharges are stable across regression specifications and frequently practically important and

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the same state and sector. However, Gray and Shadbegian [2005] found that plants seem inclined to respond to general deterrence created by the experiences of facilities in the same state, but not neighboring states. In principle, one might examine the response of pulp and paper compliance to enforcement actions levied in the chemical sector, since these actions may also signal the regulator's reputation for toughness. However, restricting attention to enforcement and monitoring activities directed at other facilities in the same sector seems like the appropriate starting point for analysis.

statistically significant. General deterrence of penalties results for water *compliance* status are also stable across regression specifications and frequently practically important. Compliance/non-compliance specifics can be found in Tables W1b-W5b (BOD compliance) and W1d-W5d (TSS compliance). One interesting note is that the compliance status results are not as consistent across industries as the discharge results. One plausible explanation is that conventional water pollution compliance is generally high in the five analyzed industries, as average conventional water pollutant discharges are 20-30 percent of permitted standards. Effluent violations are infrequent and may be statistically more difficult to detect. Another plausible explanation is that the definition of non-compliance status does not reflect the important behavioral threshold. The investigation of the impacts of enforcement actions on different compliance definitions represents an extremely promising avenue for future research, but is beyond the scope of this document.

For many industries, we find that general deterrence applies to one pollutant but not another. For example, we detect practically important and statistically significant general deterrence for TSS pollutants but not for BOD pollutants in the petroleum and industrial organic chemicals industries. These results, however, are consistent with the combined analyses of Shimshack and Ward (2005) and Shimshack and Ward (2008) published in the literature. Those studies, and especially the later paper, demonstrated that discharge levels and compliance status for one pollutant may be indirectly determined by discharge and compliance decisions for another pollutant. The essential insight is that pollutant quantities are frequently determined jointly since production and abatement decisions simultaneously impact many contaminants at once.

Finally, the general deterrence TSS coefficients for the water pollution discharges and compliance decisions in the steel industry have unexpected signs and are statistically significant. This may reflect the unusual situation when inspections or enforcement actions occur disproportionately during periods of deteriorating environmental performance within a state (relative to peer states). Alternatively, it may simply reflect that steel facilities are not well suited to water pollution analyses. These plants very rarely violate water pollution standards or attract regulatory fines for water effluent violations.

8. Major Findings and Recommendations

Major Findings

- Major Finding: Simplified, cost-effective quantitative database methods produce plausible and statistically stable general deterrence effect estimates.

  All statistically significant general deterrence results for water discharges and compliance from the pulp and paper, petroleum, industrial inorganic chemicals, and industrial organic chemical industries show a negative effect of lagged enforcement actions. For each these four industries, the within-sector results are extremely consistent across statistical specifications.

- Major Finding: Environmental monitoring and enforcement activities generate substantial general deterrence.

  Estimated general deterrence effects for the water discharges of the pulp and paper, petroleum, industrial inorganic chemicals, and industrial organic chemical industries are practically meaningful. Aggregate BOD discharges fall 4 percent and 22 percent in the year following a fine in the paper and inorganic chemicals industries, respectively. Aggregate TSS discharges fall 5, 20, and 24 percent in the year following a fine in the organic chemicals, petroleum refining, and inorganic chemicals industries, respectively.

- Major Finding: Environmental monitoring and enforcement activities generate substantial general deterrence, even for sector/contaminant combinations where compliance is typically high.

  The large general deterrence effects for water discharges from the pulp and paper, petroleum, industrial inorganic chemicals, and industrial organic chemical industries all occurred in sectors with average conventional water pollution discharges between 15 and 30 percent of permitted levels. Conventional water pollution violations are infrequent in these industries, yet regulatory enforcement actions significantly impacted discharges in these sectors.

- Major Finding: Many current methods for evaluating the effectiveness of environmental regulatory activities may be incomplete, and most probably understate true effects.

  Outcome measures like pounds of pollution directly reduced through consent decree agreements and court settlements do not typically capture deterrence, and especially general deterrence. In other words, direct observation measures fail to capture the impacts of a regulator's enhanced reputation for toughness on the behavior of non-sanctioned facilities. This report shows that general deterrence effects of environmental enforcement may be large.

- Major Finding: General deterrence effects vary across sectors and pollutants.

  Although within sector results are stable across statistical specifications, general deterrence coefficient magnitudes vary substantially across sector and pollutant. For example, the BOD general deterrence effects of a fine in the paper industry meaningfully differ from the BOD general deterrence effects of a fine in the industrial inorganic chemicals industry. As another example, the BOD general deterrence effects of a fine in the organic chemicals sector may meaningfully differ from the TSS general deterrence effects of a fine in this same sector. Cross-industry and cross-pollutant differences in deterrence effects are frequently both statistically and practically different from one another.

- Major Finding: The three simplified, cost-effective quantitative database methods developed in Task 3 typically measure general deterrence equally effectively.

  The three regression specifications typically yield statistically similar coefficient estimates for analyzed regressions. As discussed throughout this document and in technical Appendix A, the fixed effects specification is theoretically preferred for linear models. The conditional random effects specification may be preferred for non-linear models, since it mimics the spirit of fixed effects and has other desirable statistical properties.

- Major Finding: Simplified, cost-effective quantitative database methods do not generate statistically stable specific deterrence effect estimates.

  For continuous water discharges, water non-compliance status, and air compliance status, the simplified quantitative database methods generated unstable and frequently statistically insignificant results. Sensitive results and counterintuitive outcomes are almost certainly driven by biases stemming from omitted variables and reverse causality concerns.

Major Recommendations

- Recommendation: OECA should consider applying the simplified general deterrence measurement models to datasets created from the extensive data available to the EPA and facilitated by Task 5 of this project.

  Applying simplified general deterrence models to new sectors, contaminants, and time periods could importantly contribute to the state of knowledge on deterrence. Extensive Permit Compliance System water pollution discharges and violations data, Continuous Emissions Monitoring System air pollution discharges and violations data, Toxic Releases Inventory toxics data, RCRA Biennial Reporting System hazardous waste violations data, and Compliance Data System/IDEA air pollution violations data are available for analysis across a wide range of industries and time periods. In many cases, near-censuses of major facilities can eliminate statistical validity concerns. The water pollution analysis presented here and two academic papers consistently find plausible and statistically detectable general deterrence effects with straight-forward statistical models.

  Sectors for future consideration should be selected on the basis of data availability, environmental impact, and agency priorities. The external validity of the simplified models is also strongest for sectors with salient characteristics similar to the pulp and paper, petroleum refining, and steel sectors used to calibrate the presented models. The common characteristics of these industries are large industrial sources, relatively similar production processes, relatively similar pollution treatment technologies, and geographic diversity. Several core program sectors in the completed Sector Facility Indexing Project are particularly good candidates for replication, since they have significant environmental impacts,

significant data availability, and relatively large and homogeneous industrial facilities.

- Recommendation: OECA might consider applying the simplified specific deterrence measurement models to datasets created from the extensive data available to the EPA and facilitated by Task 5 of this project. Results, however, should be interpreted cautiously.

  Applying simplified specific deterrence models to new sectors, contaminants, and time periods could importantly contribute to the state of knowledge on deterrence. Extensive data are available for analysis across a wide range of industries and time periods. The calibration of the simplified models for the measurement of specific deterrence has yielded mixed results, but future analysis can help determine whether difficulties with specific deterrence measurement are driven by targeting regimes, sector compliance rates, sector heterogeneity, state-level economic conditions, or statistical approaches.

Technical Recommendations

- Technical Recommendation: OECA might consider extensions to the simplified models presented and calibrated in Task 3 of the Compliance and Deterrence Research Project.

  It is possible that modest adjustments to the cost-effective models developed in Task 3 may permit somewhat more consistent and plausible specific deterrence parameters.

- Technical Recommendation: OECA might consider modifications to the data generating process underlying the Task 4 analyses.

  It is possible that modest adjustments to the data generating process underlying the Task 4 analyses may permit somewhat more consistent and plausible specific deterrence parameters. All five air pollution sectors examined were extremely heterogeneous. As analyzed, each industrial sector contains small plants and large plants, facilities with minor environmental impacts and facilities with major environmental impacts, and facilities with highly variable industrial sub-categories and production processes. Cross-plant differences in monitoring and enforcement may simply be so large that they drive results.

- Technical Recommendation: Future work and in-house replications should emphasize fixed effects specifications for linear models and either fixed effects or conditional random effect models for non-linear models.

  As noted, neither fixed effects nor conditional random effects models completely solve the reverse causality problems that arise when estimating specific deterrence, but they minimize those problems relative to other statistical

specifications. Future work should increasingly rely on fixed effects specifications for linear models and fixed effects or conditional random effect models for non-linear models. Alternative conditional random effect techniques might also be used, and these approaches might include additional statistical corrections such as the average emissions of the facility or the average compliance level of the facility. In other words, future research in the compliance and deterrence project should not necessarily be bound to the exact conditional random effect specifications included in the Task 3 report.

9. References

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Table 1 – Air Data

Sector	NAICS Code*	Compliance Data Dates	Monitoring Data Dates	# of Plants	Obs/ Yr./Plt.	Maximum Obs/Plt.
pulp & paper	**3221**	**1995-2002**	**1993-2002**	**451**	**1**	**8**
petroleum refining	**3241**	**1995-2002**	**1993-2002**	**343**	**1**	**8**
chemicals	**3251**	**1995-2002**	**1993-2002**	**1844**	**1**	**8**
iron & steel	**3311**	**1995-2002**	**1993-2002**	**331**	**1**	**8**
alumina & aluminum smelting	**3313**	**1995-2002**	**1993-2002**	**159**	**1**	**8**

NOTES: Key corresponding 4-digit SIC codes were 2611, 2621, 2812, 2813, 2819, 2861, 2865, 2869, 2895, 2911, 3312, 3331, 3334, and 3339. The agreed upon "smelting and minerals processing" sector required interpretation as it is the only industry that crossed 4-digit NAICS lines. 3313 includes Primary Alumina (331311) and Primary Aluminum Smelting (331312). 3313 represents a large portion of all smelting and minerals processing (NAICS 3313 and 3314), so we analyze only NAICS 3313.

Table 2 – Water Data

Sector	NAICS Code*	Pollution or Compliance Data Dates	Monitoring and Penalty Data Dates	# of Plants	Obs/ Yr./Plt.	Maximum Obs/Plt.
pulp & paper	3221	1/98-5/06	1/96-5/06	167	12	101
petroleum refining	3241	1/98-5/06	1/96-5/06	84	12	101
iron & steel	3311	1/98-5/06	1/96-5/06	56	12	101
Chemicals – industrial inorganics	3251 – SIC 2819	1/98-5/06	1/96-5/06	33	12	101
Chemicals – industrial organics	3251 – SIC 2869	1/98-5/06	1/96-5/06	92	12	101
alumina & aluminum smelting	3313	n/a	n/a	0	n/a	n/a

NOTES: We analyze BOD compliance and discharges for the pulp and paper, petroleum refining, industrial inorganic chemicals, and industrial organic chemicals sectors. Only a handful of major steel facilities are required to track and report BOD discharges, so we are unable to conduct a BOD analysis. We analyze TSS compliance and discharges for the pulp and paper, petroleum refining, iron and steel, industrial inorganic chemicals, and industrial organic chemicals sectors. We are unable to conduct any water analyses for the alumina and aluminum smelting sector, since virtually no major facilities in this industry track and report BOD or TSS discharges.

Table 3 – Air Compliance Results Summary: Specific Deterrence of Inspections and Enforcement Actions

Sector	Corresponding Appendix B Tables	FE Inspection Regression Coefficient	FE Insp Result statistically significant at 10, 5, or 1 percent level?	Practical and Statistical Evidence for Specific Deterrence of Inspections?	FE Enforcement Action Regression Coefficient	Enf. Act. Result statistically significant at 10, 5, or 1 percent level?	Practical and Statistical Evidence for Specific Deterrence of Enforcement Actions?
pulp & paper	AI1, AE1	0.254	NONE	NO	-0.576	5%	NO
petroleum refining	AI2, AE2	0.367	NONE	NO	-0.324	NONE	NO
iron & steel	AI3, AE3	0.189	NONE	NO	-0.743	1%	NO
chemicals	AI4, AE4	-0.167	NONE	NO	-0.710	1%	NO
Alumina/AL smelting	AI5, AE5	-0.682	NONE	NO	-0.738	10%	NO

NOTES: The table only reports fixed effect coefficients, since this is our preferred specification and other specifications typically yield practically similar results. The key metrics are the response of a plant's compliance status to lagged EPA/state monitoring and enforcement activities directed at that facility 1-2 years ago. Positive coefficients for these regressions indicate that lagged inspections or enforcement actions are associated with improved environmental compliance with air pollution regulations. Negative coefficients indicate that lagged inspections or enforcement actions are associated with deteriorating environmental compliance with air pollution regulations. Negative coefficients most likely reflect the difficulty of eliminating reverse causality in the measurement of specific deterrence with simplified data and metrics.

Table 4a – BOD Discharges Results Summary: Specific Deterrence of Inspections

Sector	Corresponding Appendix B Tables	FE Inspection Regression Coefficient – Inspections 1-12 months ago	FE Insp Result statistically significant at 10, 5, or 1 percent level?	FE Inspection Regression Coefficient – Inspections 13-24 months ago	FE Insp Result statistically significant at 10, 5, or 1 percent level?	Practical and Statistical Evidence for Specific Deterrence of Inspections?
pulp & paper	W1a	0.000	NONE	0.002	NONE	NO
petroleum refining	W2a	-0.001	NONE	-0.003	NONE	NO
Ind. Inorganic chemicals	W3a	-0.003	NONE	0.006	NONE	NO
Ind. Organic chemicals	W4a	0.012	5%	0.008	10%	NO
Iron and steel	W5a	n/a	n/a	n/a	n/a	n/a
alumina & AL smelting	n/a	n/a	n/a	n/a	n/a	n/a

NOTES: The table only reports fixed effect coefficients, since this is our preferred specification and other specifications typically yield practically similar results. The table only reports discharge results; compliance results are discussed in the text and can be examined directly in the Appendix B tables. Key metrics are the response of a plant's BOD discharges to lagged EPA/state monitoring activities directed at that facility 0-1 years ago and 1-2 years ago. Negative coefficients for these regressions indicate that lagged inspections are associated with reduced BOD discharges. Positive coefficients indicate that lagged inspections are associated with increased BOD discharges. Positive coefficients most likely reflect the difficulty of eliminating reverse causality in the measurement of specific deterrence with simplified data and metrics.

Table 4b – BOD Discharges Results Summary: Specific Deterrence of Penalties

Sector	Corresponding Appendix B Tables	FE Penalty Regression Coefficient – Penalties 1-12 months ago	FE Penalty Result statistically significant at 10, 5, or 1 percent level?	FE Penalty Regression Coefficient – Penalties 13-24 months ago	FE Penalty Result statistically significant at 10, 5, or 1 percent level?	Practical and Statistical Evidence for Specific Deterrence of Penalties?
pulp & paper	W1a	0.030	1%	-0.004	NONE	NO
petroleum refining	W2a	0.001	NONE	-0.029	10%	YES
Ind. Inorganic chemicals	W3a	-0.006	NONE	0.028	NONE	NO
Ind. Organic chemicals	W4a	-0.074	1%	-0.010	NONE	YES
Iron and steel	W5a	n/a	n/a	n/a	n/a	n/a
alumina & AL smelting	n/a	n/a	n/a	n/a	n/a	n/a

NOTES: The table only reports fixed effect coefficients, since this is our preferred specification and other specifications typically yield practically similar results. The table only reports discharge results; compliance results are discussed in the text and can be examined directly in the Appendix B tables. Key metrics are the response of a plant's BOD discharges to lagged EPA/state penalties directed at that facility 0-1 years ago and 1-2 years ago. Negative coefficients for these regressions indicate that lagged penalties are associated with reduced BOD discharges. Positive coefficients indicate that lagged penalties are associated with increased BOD discharges. Positive coefficients most likely reflect the difficulty of eliminating reverse causality in the measurement of specific deterrence with simplified data and metrics.

Table 4c – TSS Discharges Results Summary: Specific Deterrence of Inspections

Sector	Corresponding Appendix B Tables	FE Inspection Regression Coefficient – Inspections 1-12 months ago	FE Insp Result statistically significant at 10, 5, or 1 percent level?	FE Inspection Regression Coefficient – Inspections 13-24 months ago	FE Insp Result statistically significant at 10, 5, or 1 percent level?	Practical and Statistical Evidence for Specific Deterrence of Inspections?
pulp & paper	W1c	-0.002	10%	-0.002	NONE	YES
petroleum refining	W2c	0.010	10%	-0.005	NONE	NO
Ind. Inorganic chemicals	W3c	-0.006	NONE	-0.006	NONE	NO
Ind. Organic chemicals	W4c	0.003	NONE	0.002	NONE	NO
Iron and steel	W5c	0.003	NONE	0.005	10%	NO
alumina & AL smelting	n/a	n/a	n/a	n/a	n/a	n/a

NOTES: The table only reports fixed effect coefficients, since this is our preferred specification and other specifications typically yield practically similar results. The table only reports discharge results; compliance results are discussed in the text and can be examined directly in the Appendix B tables. Key metrics are the response of a plant's TSS discharges to lagged EPA/state monitoring activities directed at that facility 0-1 years ago and 1-2 years ago. Negative coefficients for these regressions indicate that lagged inspections are associated with reduced TSS discharges. Positive coefficients indicate that lagged inspections are associated with increased TSS discharges. Positive coefficients most likely reflect the difficulty of eliminating reverse causality in the measurement of specific deterrence with simplified data and metrics.

Table 4d – TSS Discharges Results Summary: Specific Deterrence of Penalties

Sector	Corresponding Appendix B Tables	FE Penalty Regression Coefficient – Penalties 1-12 months ago	FE Penalty Result statistically significant at 10, 5, or 1 percent level?	FE Penalty Regression Coefficient – Penalties 13-24 months ago	FE Penalty Result statistically significant at 10, 5, or 1 percent level?	Practical and Statistical Evidence for Specific Deterrence of Penalties?
pulp & paper	W1c	0.052	1%	-0.007	NONE	NO
petroleum refining	W2c	-0.018	NONE	-0.012	NONE	NO
Ind. Inorganic chemicals	W3c	-0.058	NONE	0.016	NONE	NO
Ind. Organic chemicals	W4c	-0.092	1%	-0.124	1%	YES
Iron and steel	W5c	-0.045	5%	-0.041	5%	YES
alumina & AL smelting	n/a	n/a	n/a	n/a	n/a	n/a

NOTES: The table only reports fixed effect coefficients, since this is our preferred specification and other specifications typically yield practically similar results. The table only reports discharge results; compliance results are discussed in the text and can be examined directly in the Appendix B tables. Key metrics are the response of a plant's TSS discharges to lagged EPA/state penalties directed at that facility 0-1 years ago and 1-2 years ago. Negative coefficients for these regressions indicate that lagged penalties are associated with reduced TSS discharges. Positive coefficients indicate that lagged penalties are associated with increased TSS discharges. Positive coefficients most likely reflect the difficulty of eliminating reverse causality in the measurement of specific deterrence with simplified data and metrics.

Table 5a – BOD Discharges Results Summary: General Deterrence of Penalties

Sector	Corresponding Appendix B Tables	FE Penalty Regression Coefficient – Inspections 1-12 months ago	FE Penalty Result statistically significant at 10, 5, or 1 percent level?	FE Penalty Regression Coefficient – Inspections 13-24 months ago	FE Penalty Result statistically significant at 10, 5, or 1 percent level?	Practical and Statistical Evidence for General Deterrence of Penalties?
pulp & paper	W1a	-0.012	1%	-0.027	1%	YES
petroleum refining	W2a	-0.007	NONE	-0.009	NONE	NO
Ind. Inorganic chemicals	W3a	-0.046	1%	-0.009	NONE	YES
Ind. Organic chemicals	W4a	0.002	NONE	0.003	NONE	NO
Iron and steel	W5a	n/a	n/a	n/a	n/a	n/a
alumina & AL smelting	n/a	n/a	n/a	n/a	n/a	n/a

NOTES: The table only reports fixed effect coefficients, since this is our preferred specification and other specifications typically yield practically similar results. The table only reports discharge results; compliance results are discussed in the text and can be examined directly in the Appendix B tables. Key metrics are the response of a plant's BOD discharges to lagged EPA/state penalties directed at other facilities in the same state and sector 0-1 years ago and 1-2 years ago. Negative coefficients for these regressions indicate that lagged penalties are associated with reduced BOD discharges. Positive coefficients indicate that lagged penalties are associated with increased BOD discharges.

Table 5b – TSS Discharges Results Summary: General Deterrence of Penalties

Sector	Corresponding Appendix B Tables	FE Penalty Regression Coefficient – Inspections 1-12 months ago	FE Penalty Result statistically significant at 10, 5, or 1 percent level?	FE Penalty Regression Coefficient – Inspections 13-24 months ago	FE Penalty Result statistically significant at 10, 5, or 1 percent level?	Practical and Statistical Evidence for General Deterrence of Penalties?
pulp & paper	W1c	0.003	NONE	-0.011	1%	YES
petroleum refining	W2c	-0.050	1%	-0.031	5%	YES
Ind. Inorganic chemicals	W3c	-0.056	5%	-0.039	NONE	YES
Ind. Organic chemicals	W4c	-0.015	1%	-0.002	NONE	YES
Iron and steel	W5c	0.016	1%	0.007	10%	NO
alumina & AL smelting	n/a	n/a	n/a	n/a	n/a	n/a

NOTES: The table only reports fixed effect coefficients, since this is our preferred specification and other specifications typically yield practically similar results. The table only reports discharge results; compliance results are discussed in the text and can be examined directly in the Appendix B tables. Key metrics are the response of a plant's TSS discharges to lagged EPA/state penalties directed at other facilities in the same state and sector 0-1 years ago and 1-2 years ago. Negative coefficients for these regressions indicate that lagged penalties are associated with reduced TSS discharges. Positive coefficients indicate that lagged penalties are associated with increased TSS discharges.

Appendix A. Technical Details on the Three Regression Approaches

This brief appendix is for the more technically inclined reader, and can be skipped if preferred. Three regression approaches map to basic empirical model of Task 3. The key difference between the three models is their approach to addressing the facility-specific regression parameter α_i. Recall that the key function of this facility-specific regression parameter is to capture the "individuality" of each facility without actually requiring data on all of the differences between facilities. In other words, α_i exploits the panel nature of the data to partially account for facility-specific confounding factors (like size, age, industrial sub-category, and profitability).

The fixed effect empirical model holds the slope coefficient (representing the impact of an additional regulatory action on future pollution or compliance) constant for all facilities, but allows each facility to have its own regression intercept α_i. This approach accounts for the "individuality" of each facility and implicitly controls for all facility-specific confounding factors that are approximately constant across time, like size, profitability, and industrial sub-category. Intuitively, the identification of the fixed effects model can be interpreted as a difference-in-differences estimator. Here, the specific deterrence impact of a marginal (additional) regulator action on compliance or pollution is the difference between (a) the difference between post-action pollution or compliance and the average pollution or compliance levels for all facilities that had received an action in the recent past and (b) the difference between similar time periods and the average pollution or compliance levels for all facilities that did not receive an regulatory action in the recent past. The general deterrence impact of a marginal (additional) regulator action is similar, except that the regulator action is on other facilities in the same state and sector, rather than on plant i itself.

A key advantage of the fixed effects model in linear models is its validity in the presence of certain types of correlation between important explanatory variables and the facility-specific regression parameter α_i. For example, if regulators target facilities for monitoring and enforcement actions that pollute more on average, α_i will be correlated with the enforcement or monitoring explanatory variable. Without fixed effects, this type of targeting might produce a positive correlation between enforcement and emissions simply from cross-plant differences in overall enforcement. With fixed effects, all targeting based upon differences in overall enforcement is swept out of the model.

Random effect models also attempt to capture the "individuality" of facilities while holding the slope coefficient (representing the impact of an additional regulatory action on future pollution or compliance) constant. However, the modeling approach for α_i differs from the fixed effect approach. Instead of allowing each facility its own intercept as in the fixed effects model, the random effects model assumes a statistical distribution for these parameters around a common mean value. Intuitively, the identification of the random effects model can be interpreted like an ordinary least squares regression. Here, the specific deterrence impact of a marginal (additional) regulator action on compliance or pollution is the pollution or compliance difference between observations in which there was an agency action in the recent past to

observations in which there was no agency action in the recent past, after controlling for confounding factors. The general deterrence impact of a marginal (additional) regulator action is the pollution or compliance difference between observations in which there was an agency action in the recent past directed towards others in the same state and sector to observations in which there was no agency action in the recent past directed towards others in the same state and sector.

A key weakness of the random effects model is that it is biased (incorrect, on average) in the presence of correlation between important explanatory variables and the facility-specific regression parameter α_i. If regulators target facilities that pollute more on average that other facilities, random effects models will be biased. Causality running from pollution to enforcement, rather than vice versa, will cause regression coefficients meant to represent the impact of enforcement on pollution to show deterrence effects that are too small or perhaps even the unexpected sign.

Finally, the *conditional* random effects model also attempts to capture the "individuality" of facilities while holding the key slope coefficient constant. The intuition is identical to that of fixed effects, and the aim is still to control for missing variables potentially correlated with the key explanatory variables. Conditional random effects are persistent effects at the plant-level, like fixed effects, but they condition on the sample average of a few observed variables rather than all variables (as in fixed effects). Since the intuition is identical, and fixed effects are more comprehensive, one might wonder why conditional random effect regression specifications are ever preferred to fixed effect regression specifications. For reasons beyond the scope of this report, fixed effects lead to biased (wrong, on average) estimates for the non-linear models necessary when the dependent variable is discrete like a 0/1 compliance indicator.

Conditional random effects models, in principle, lie between fixed effects and random effects models in their ability to minimize bias from correlations between key explanatory variables and facility-specific error terms. When included conditional random effects adequately capture the determinants of regulatory targeting, these models cope with targeting-induced correlations nearly as well as fixed effects. However, if included conditional random effects do not adequately capture the determinants of regulatory targeting, these models may still produce results with significant targeting-induced bias.

Appendix B. Numerical Results

Table AI1. Measuring Specific Deterrence of Inspections: Simplified Quantitative Analyses of Air Pollution Compliance in the Pulp and Paper Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	0.254 (0.88)	-0.315 (-1.19)	-0.146 (-0.54)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 inspection indicator variable. This variable equals 1 if this facility received an inspection 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table AI2. Measuring Specific Deterrence of Inspections: Simplified Quantitative Analyses of Air Pollution Compliance in the Petroleum Refining Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	0.367 (1.21)	-0.187 (-0.66)	0.019 (0.07)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 inspection indicator variable. This variable equals 1 if this facility received an inspection 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table AI3. Measuring Specific Deterrence of Inspections: Simplified Quantitative Analyses of Air Pollution Compliance in the Steel Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	0.189 (0.63)	-0.302 (-1.07)	-0.176 (-0.62)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 inspection indicator variable. This variable equals 1 if this facility received an inspection 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table AI4. Measuring Specific Deterrence of Inspections: Simplified Quantitative Analyses of Air Pollution Compliance in the Chemicals Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	-0.167 (1.05)	-0.656*** (-4.40)	-0.433*** (-2.91)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 inspection indicator variable. This variable equals 1 if this facility received an inspection 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table AI5. Measuring Specific Deterrence of Inspections: Simplified Quantitative Analyses of Air Pollution Compliance in the Alumina / Aluminum Smelting Industries

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	-0.682 (-1.12)	-0.698 (-1.35)	-0.517 (-0.97)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 inspection indicator variable. This variable equals 1 if this facility received an inspection 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table AE1. Measuring Specific Deterrence of Enforcement Actions: Simplified Quantitative Analyses of Air Pollution Compliance in the Pulp and Paper Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	-0.576** (-2.44)	-1.086*** (-4.58)	-0.850*** (-3.52)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 enforcement action indicator variable. This variable equals 1 if this facility received an enforcement action 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table AE2. Measuring Specific Deterrence of Enforcement Actions: Simplified Quantitative Analyses of Air Pollution Compliance in the Petroleum Refining Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	-0.324 (-1.50)	-0.887*** (-3.94)	-0.676*** (-2.99)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 enforcement action indicator variable. This variable equals 1 if this facility received an enforcement action 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table AE3. Measuring Specific Deterrence of Enforcement Actions: Simplified Quantitative Analyses of Air Pollution Compliance in the Steel Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	-0.743*** (-2.89)	-1.255*** (-4.82)	-1.060*** (-4.03)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 enforcement action indicator variable. This variable equals 1 if this facility received an enforcement action 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table AE4. Measuring Specific Deterrence of Enforcement Actions: Simplified Quantitative Analyses of Air Pollution Compliance in the Chemicals Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	-0.710*** (-5.08)	-1.379*** (-9.55)	-1.065*** (-7.32)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 enforcement action indicator variable. This variable equals 1 if this facility received an enforcement action 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table AE5. Measuring Specific Deterrence of Enforcement Actions: Simplified Quantitative Analyses of Air Pollution Compliance in the Alumina / Aluminum Smelting Industries

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Inspections 1-2 years ago on this plant	-0.738* (-1.76)	-1.174*** (-2.71)	-0.996** (-2.26)
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and year. The dependent variable is the 0/1 compliance status with air pollution regulations. Non-compliance ("0") occurs if the facility for one or more quarters during the year. The key explanatory variable is a 0/1 enforcement action indicator variable. This variable equals 1 if this facility received an enforcement action 1-2 years ago. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W1a. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of BOD Water Pollution Discharges in the Pulp and Paper Industry

Variable Description	Linear Regression with Fixed Effects	Linear Regression with Random Effects	Linear Regression with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.012*** (-2.98)	-0.012*** (-2.98)	-0.012*** (-2.98)
Fines 13-24 months ago on another plant in same state	-0.027*** (-6.42)	-0.027*** (-6.41)	-0.027*** (-6.41)
Fines 1-12 months ago on this plant	0.030*** (2.97)	0.030*** (2.96)	0.030*** (2.96)
Fines 13-24 months ago on this plant	-0.004 (-0.40)	-.004 (-0.39)	-.004 (-0.38)
Insps 1-12 months ago on this plant	0.000 (0.02)	0.000 (0.16)	0.000 (0.16)
Insps 13-24 months ago on this plant	0.002 (1.44)	.002 (1.57)	.002 (1.57)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is continuous BOD water pollution discharges as a percent of permitted levels. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W1b. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of BOD Water Pollution Non-Compliance in the Pulp and Paper Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.481 (-1.52)	-0.474 (-1.52)	-0.458 (-1.46)
Fines 13-24 months ago on another plant in same state	-1.40*** (-2.91)	-1.40*** (-2.91)	-1.38*** (-2.88)
Fines 1-12 months ago on this plant	0.774** (2.19)	0.842** (2.44)	0.766** (2.20)
Fines 13-24 months ago on this plant	0.385 (0.44)	0.250 (0.31)	0.085 (0.10)
Insps 1-12 months ago on this plant	0.043 (0.43)	0.042 (0.46)	0.42 (0.45)
Insps 13-24 months ago on this plant	0.151* (1.86)	0.155** (2.03)	0.155** (2.03)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is the 0/1 non-compliance status with BOD limits this month. Non-compliance ("1") occurs if the facility exceeds its BOD average quantity limit this period. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W1c. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Water Pollution Discharges in the Pulp and Paper Industry

Variable Description	Linear Regression with Fixed Effects	Linear Regression with Random Effects	Linear Regression with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	0.003 (0.77)	0.003 (0.75)	0.003 (0.78)
Fines 13-24 months ago on another plant in same state	-0.011*** (-3.13)	-0.011*** (-3.15)	-0.011*** (-3.12)
Fines 1-12 months ago on this plant	0.052*** (5.86)	0.053*** (5.93)	0.052*** (5.86)
Fines 13-24 months ago on this plant	-0.007 (-0.82)	-.006 (-0.72)	-.007 (-0.79)
Insps 1-12 months ago on this plant	-0.002* (-1.75)	-0.002 (-1.63)	-0.002 (-1.63)
Insps 13-24 months ago on this plant	-0.002 (-1.60)	-.002 (-1.49)	-.002 (-1.49)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is continuous TSS water pollution discharges as a percent of permitted levels. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W1d. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Water Pollution Non-Compliance in the Pulp and Paper Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	0.700 (1.53)	0.455 (1.08)	0.474 (1.12)
Fines 13-24 months ago on another plant in same state	0.357 (0.83)	0.176 (0.45)	0.200 (0.51)
Fines 1-12 months ago on this plant	2.52*** (4.11)	2.41*** (4.61)	2.19*** (4.00)
Fines 13-24 months ago on this plant	-0.145 (-0.16)	-0.302 (-0.36)	-0.399 (-0.47)
Insps 1-12 months ago on this plant	-0.538** (2.46)	-0.583*** (-3.11)	-0.587*** (-3.11)
Insps 13-24 months ago on this plant	-0.181 (-0.94)	-.253 (-1.51)	-.260 (-1.54)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is the 0/1 non-compliance status with TSS limits this month. Non-compliance ("1") occurs if the facility exceeds its TSS average quantity limit this period. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W2a. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of BOD Water Pollution Discharges in the Petroleum Refining Industry

Variable Description	Linear Regression with Fixed Effects	Linear Regression with Random Effects	Linear Regression with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.007 (-0.97)	-0.008 (-1.06)	-0.007 (-0.97)
Fines 13-24 months ago on another plant in same state	-0.009 (-1.27)	-0.009 (-1.36)	-0.009 (-1.28)
Fines 1-12 months ago on this plant	0.001 (0.07)	0.007 (0.37)	0.002 (0.12)
Fines 13-24 months ago on this plant	-0.029* (-1.66)	-0.024 (-1.38)	-0.029 (-1.64)
Insps 1-12 months ago on this plant	-0.001 (-0.27)	-0.000 (-0.15)	-0.000 (-0.18)
Insps 13-24 months ago on this plant	-0.003 (-1.29)	-.003 (-1.11)	-.003 (-1.16)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is continuous BOD water pollution discharges as a percent of permitted levels. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W2b. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of BOD Pollution Non-Compliance in the Petroleum Refining Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	0.210 (0.27)	-0.230 (-0.35)	-0.023 (-0.03)
Fines 13-24 months ago on another plant in same state	-0.092 (-0.11)	-0.554 (-0.76)	-0.372 (-0.50)
Fines 1-12 months ago on this plant	-15.31 (-0.01)	-16.13 (-0.00)	-17.23 (-0.00)
Fines 13-24 months ago on this plant	-0.173 (-0.15)	1.07 (0.97)	0.057 (0.05)
Insps 1-12 months ago on this plant	-0.212 (-1.08)	-0.073 (-0.38)	-0.071 (-0.37)
Insps 13-24 months ago on this plant	-0.085 (-0.47)	0.125 (0.72)	0.140 (0.80)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is the 0/1 non-compliance status with BOD limits this month. Non-compliance ("1") occurs if the facility exceeds its BOD average quantity limit this period. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W2c. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Water Pollution Discharges in the Petroleum Refining Industry

Variable Description	Linear Regression with Fixed Effects	Linear Regression with Random Effects	Linear Regression with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.050*** (-3.24)	-0.050*** (-3.28)	-0.050*** (-3.26)
Fines 13-24 months ago on another plant in same state	-0.031** (-2.18)	-0.031** (-2.22)	-0.031** (-2.20)
Fines 1-12 months ago on this plant	-0.018 (-0.48)	-0.016 (-0.43)	-0.018 (-0.47)
Fines 13-24 months ago on this plant	-0.012 (-0.33)	-.010 (-0.28)	-.012 (-0.33)
Insps 1-12 months ago on this plant	0.010* (1.94)	0.010* (1.91)	0.010* (1.91)
Insps 13-24 months ago on this plant	-0.005 (-0.99)	-0.005 (-1.01)	-0.005 (-1.02)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is continuous TSS water pollution discharges as a percent of permitted levels. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W2d. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Pollution Non-Compliance in the Petroleum Refining Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.621 (-1.30)	-0.571 (-1.22)	-0.594 (-1.27)
Fines 13-24 months ago on another plant in same state	-0.710* (-1.68)	-0.663 (-1.60)	-0.681 (-1.64)
Fines 1-12 months ago on this plant	0.607 (0.75)	0.644 (0.82)	0.817 (0.95)
Fines 13-24 months ago on this plant	-13.11 (-0.02)	-19.59 (-0.00)	-19.12 (-0.00)
Insps 1-12 months ago on this plant	0.162 (1.22)	0.200 (1.62)	0.201 (1.62)
Insps 13-24 months ago on this plant	-0.292** (-2.14)	-.237* (-1.81)	-.236** (-1.81)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is the 0/1 non-compliance status with BOD limits this month. Non-compliance ("1") occurs if the facility exceeds its TSS average quantity limit this period. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W3a. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of BOD Discharges in the Industrial Inorganic Chemicals Industry

Variable Description	Linear Regression with Fixed Effects	Linear Regression with Random Effects	Linear Regression with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.046*** (-2.74)	-0.067*** (-2.80)	-0.029 (-1.24)
Fines 13-24 months ago on another plant in same state	-0.009 (-0.55)	-0.010 (-0.40)	0.024 (1.03)
Fines 1-12 months ago on this plant	-0.006 (-0.24)	0.054 (1.60)	-0.044 (-1.25)
Fines 13-24 months ago on this plant	0.028 (1.18)	0.073** (2.31)	-0.025 (-0.76)
Insps 1-12 months ago on this plant	-0.003 (-0.52)	-0.002 (-0.25)	0.001 (0.10)
Insps 13-24 months ago on this plant	0.006 (1.33)	-.019*** (-3.52)	-0.018*** (-3.37)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is continuous BOD water pollution discharges as a percent of permitted levels. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W3b. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of BOD Pollution Non-Compliance in the Inorganic Chemicals Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-1.15 (-0.68)	-1.01 (-0.64)	-0.652 (-0.40)
Fines 13-24 months ago on another plant in same state	-1.26 (-0.83)	-1.08 (-0.73)	-0.658 (-0.43)
Fines 1-12 months ago on this plant	-0.664 (-0.42)	-0.654 (-0.44)	-0.695 (-0.50)
Fines 13-24 months ago on this plant	0.537 (0.39)	0.300 (0.25)	-0.003 (-0.00)
Insps 1-12 months ago on this plant	-0.601 (-1.08)	-0.313 (-0.83)	-0.267 (-0.64)
Insps 13-24 months ago on this plant	-0.088 (-0.16)	0.065 (0.19)	0.060 (0.23)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is the 0/1 non-compliance status with BOD limits this month. Non-compliance ("1") occurs if the facility exceeds its BOD average quantity limit this period. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W3c. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Discharges in the Industrial Inorganic Chemicals Industry

Variable Description	Linear Regression with Fixed Effects	Linear Regression with Random Effects	Linear Regression with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.056** (-1.98)	-0.055** (-1.96)	-0.055* (-1.93)
Fines 13-24 months ago on another plant in same state	-0.039 (-1.39)	-0.038 (-1.35)	-0.037 (-1.33)
Fines 1-12 months ago on this plant	-0.058 (-1.12)	-0.059 (-1.14)	-0.061 (-1.17)
Fines 13-24 months ago on this plant	0.016 (0.30)	.014 (0.26)	.012 (0.23)
Insps 1-12 months ago on this plant	-0.006 (-0.95)	-0.007 (-0.98)	-0.007 (-0.97)
Insps 13-24 months ago on this plant	-0.006 (-0.92)	-.007 (-0.98)	-.007 (-0.97)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is continuous TSS water pollution discharges as a percent of permitted levels. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W3d. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Pollution Non-Compliance in the Inorganic Chemicals Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.281 (-0.34)	-0.245 (-0.30)	-0.033 (-0.04)
Fines 13-24 months ago on another plant in same state	-1.30 (-1.36)	-1.32 (-1.41)	-1.11 (-1.18)
Fines 1-12 months ago on this plant	-1.93 (-1.48)	-1.81 (-1.40)	-2.02 (-1.58)
Fines 13-24 months ago on this plant	0.784 (0.88)	0.868 (0.99)	0.596 (0.68)
Insps 1-12 months ago on this plant	-0.115 (-0.47)	-0.115 (-0.48)	-0.073 (-0.30)
Insps 13-24 months ago on this plant	-0.197 (-0.89)	-0.173 (-0.76)	-0.168 (-0.74)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is the 0/1 non-compliance status with TSS limits this month. Non-compliance ("1") occurs if the facility exceeds its TSS average quantity limit this period. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W4a. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of BOD Pollution Discharges in the Industrial Organic Chemicals Industry

Variable Description	Linear Regression with Fixed Effects	Linear Regression with Random Effects	Linear Regression with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	0.002 (0.33)	0.001 (0.26)	0.002 (0.35)
Fines 13-24 months ago on another plant in same state	0.003 (0.46)	0.002 (0.38)	0.002 (0.47)
Fines 1-12 months ago on this plant	-0.074*** (-4.10)	-0.069*** (-3.84)	-0.075*** (-4.15)
Fines 13-24 months ago on this plant	-0.010 (-0.58)	-0.005 (-0.30)	-0.011 (-0.61)
Insps 1-12 months ago on this plant	0.012** (2.36)	0.012** (2.48)	0.012** (2.46)
Insps 13-24 months ago on this plant	0.008* (1.79)	0.009* (1.92)	.009* (1.87)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is continuous BOD water pollution discharges as a percent of permitted levels. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W4b. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of BOD Pollution Non-Compliance in the Organic Chemicals Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.292 (-1.43)	-0.320 (-1.57)	-0.299 (-1.45)
Fines 13-24 months ago on another plant in same state	0.024 (0.13)	-0.009 (-0.05)	0.016 (0.09)
Fines 1-12 months ago on this plant	-0.308 (-0.88)	-0.254 (-0.74)	-0.359 (-1.03)
Fines 13-24 months ago on this plant	-0.035 (-0.11)	0.057 (0.18)	-0.042 (-0.13)
Insps 1-12 months ago on this plant	0.322*** (2.69)	0.325*** (2.87)	0.325*** (2.87)
Insps 13-24 months ago on this plant	0.154 (1.46)	0.169* (1.69)	0.159 (1.59)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is the 0/1 non-compliance status with BOD limits this month. Non-compliance ("1") occurs if the facility exceeds its BOD average quantity limit this period. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W4c. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Pollution Discharges in the Industrial Organic Chemicals Industry

Variable Description	Linear Regression with Fixed Effects	Linear Regression with Random Effects	Linear Regression with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.015*** (-3.02)	-0.015*** (-3.09)	-0.014*** (-2.98)
Fines 13-24 months ago on another plant in same state	-0.002 (-0.33)	-0.002 (-0.41)	-0.001 (-0.29)
Fines 1-12 months ago on this plant	-0.092*** (-5.41)	-0.086*** (-5.07)	-0.092*** (-5.42)
Fines 13-24 months ago on this plant	-0.124*** (-7.62)	-0.118*** (-7.24)	-0.123*** (-7.58)
Insps 1-12 months ago on this plant	0.003 (0.57)	0.003 (0.74)	0.003 (0.72)
Insps 13-24 months ago on this plant	0.002 (0.51)	0.003 (0.71)	0.003 (0.64)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is continuous TSS water pollution discharges as a percent of permitted levels. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W4d. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Non-Compliance in the Industrial Organic Chemicals Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	-0.507*** (-2.79)	-0.538*** (-3.02)	-0.506*** (-2.82)
Fines 13-24 months ago on another plant in same state	0.237 (1.39)	0.171 (1.05)	0.219 (1.33)
Fines 1-12 months ago on this plant	-0.448 (-1.22)	-0.286 (-0.79)	-0.444 (-1.21)
Fines 13-24 months ago on this plant	-0.857** (-2.39)	-0.708** (-2.00)	-0.828** (-2.30)
Insps 1-12 months ago on this plant	-0.151 (-1.20)	-0.113 (-0.94)	-0.120 (-0.98)
Insps 13-24 months ago on this plant	0.109 (1.01)	0.127 (1.22)	0.113 (1.07)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is the 0/1 non-compliance status with TSS limits this month. Non-compliance ("1") occurs if the facility exceeds its TSS average quantity limit this period. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W5a. Measuring Specific and General Deterrence of Fines: Simplified Quantitative Analyses of BOD Water Pollution Discharges in the Steel Industry

Only a handful of major steel facilities are required to track and report BOD discharges, so we are unable to conduct a BOD analysis.

Table W5b. Measuring Specific and General Deterrence of Fines: Simplified Quantitative Analyses of BOD Water Pollution Non-Compliance in the Steel Industry

Only a handful of major steel facilities are required to track and report BOD discharges, so we are unable to conduct a BOD analysis.

Table W5c. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Water Pollution Discharges in the Steel Industry

Variable Description	Linear Regression with Fixed Effects	Linear Regression with Random Effects	Linear Regression with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	0.016*** (3.34)	0.015*** (3.31)	0.016*** (3.34)
Fines 13-24 months ago on another plant in same state	0.007* (1.71)	0.007* (1.68)	0.007* (1.70)
Fines 1-12 months ago on this plant	-0.045** (-2.21)	-0.038* (-1.88)	-0.043** (-2.16)
Fines 13-24 months ago on this plant	-0.041** (-2.22)	-0.036* (-1.92)	-0.040** (-2.16)
Insps 1-12 months ago on this plant	0.003 (1.09)	0.003 (1.05)	0.003 (1.01)
Insps 13-24 months ago on this plant	0.005* (1.95)	0.005* (1.91)	0.005* (1.88)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is continuous TSS water pollution discharges as a percent of permitted levels. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.

Table W5d. Measuring Specific and General Deterrence of Fines: Quantitative Analyses of TSS Water Pollution Non-Compliance in the Steel Industry

Variable Description	Logit with Fixed Effects	Logit with Random Effects	Logit with Conditional Random Effects
Fines 1-12 months ago on another plant in same state	0.240*	0.229*	0.237*
	(1.90)	(1.82)	(1.88)
Fines 13-24 months ago on another plant in same state	0.098	0.092	0.095
	(0.78)	(0.73)	(0.75)
Fines 1-12 months ago on this plant	-0.399	-0.254	-0.334
	(-0.84)	(-0.54)	(-0.71)
Fines 13-24 months ago on this plant	-1.11*	-1.00*	-1.05*
	(-1.91)	(-1.76)	(-1.85)
Insps 1-12 months ago on this plant	0.057	0.022	0.004
	(0.42)	(0.18)	(0.03)
Insps 13-24 months ago on this plant	0.029	-.024	-.036
	(0.23)	(-0.21)	(-0.31)
Season Indicator Variables	Yes	Yes	Yes
Year Indicator Variables	Yes	Yes	Yes
State Indicator Variables	No	Yes	Yes
Facility-Specific Fixed Effects	Yes	No	No

NOTES: Observations are by plant and month. The dependent variable is the 0/1 non-compliance status with TSS limits this month. Non-compliance ("1") occurs if the facility exceeds its BOD average quantity limit this period. The key explanatory variables are 0/1 fine indicator variables. The specific deterrence explanatory variables equal 1 if this facility received a penalty in the recent past. The general deterrence explanatory variables equal 1 if another facility in this industry in the same state received a fine in the recent past. A superscript * indicates statistical significance at the 10% significance level. ** indicates statistical significance at the 5% significance level. *** indicates statistical significance at the 1% significance level.