Voluntary Information Programs and Environmental Regulation: Evidence from 'Spare the Air'[1]

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Abstract: This paper assesses whether individuals change their transportation choices in response to "Spare the Air" (STA) advisories, a public voluntary information program in the San Francisco Bay Area that elicits reductions in ozone producing activities. Since STAs are issued when ozone levels are predicted to exceed a particular threshold, we use a regression discontinuity design to identify the effect of STAs. We also use traffic conditions in Southern California, an area without STAs, to estimate difference-in-differences models. The results suggest that STAs reduce traffic volume and slightly increase the use of public transit, with some intriguing patterns of responses within the day, but do not have a statistically significant effect on ozone levels.

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Environmental policy makers around the world increasingly rely on voluntary programs to improve environmental quality. The 'Community Right-to-Know Act' that led to the development of the toxic release inventory (TRI) and 'Climate Wise' are examples of landmark efforts to reduce toxic and carbon dioxide emissions, respectively (Morgenstern and Pizer (2007)). Most voluntary programs target firms who, despite the notion of altruism, may respond because it affects profits through changes in consumer demand.[2] Therefore, such programs ultimately hinge on consumers, who indirectly improve environmental quality through purchase decisions although there are no direct economic incentives to do so.

The main focus of this paper is to assess whether individuals respond to information programs targeted directly at them by voluntarily forgoing consumption of a commodity that may increase pollution.[3] We examine the "Spare the Air" (STA) program, offered in the San Francisco Bay Area, which is designed to elicit voluntary reductions in automobile trips on days when ground-level ozone is predicted to exceed Air Quality Standards (AQS). STAs encourage the public to reduce driving through ride-sharing or use of public transit. Since some of the emissions from automobiles are a direct precursor to ozone formation, this program intends to lower ozone levels and improve the chances of attaining AQS in order to avoid costly regulations.

A secondary focus of this paper is to assess whether STAs impact ozone levels, which speaks to highly-contested ozone regulation policy.[4] The increased marginal abatement cost associated with lowering ozone from the current, historically low levels suggests that traditional

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[2] See, e.g., Hamilton (1995), Khanna et al. (1998), Konar and Cohen (1997) for evidence of the effect of TRI on stock prices and Bui and Mayer (2003) for evidence of the effect of TRI on housing prices.

[3] An exception is Reiss and White (2003), who found that households in San Diego voluntarily decreased electricity consumption in response to media campaigns during the 2000-1 electricity crisis. However, this was a one-time program that arose from a unique situation, so it is not clear how it relates to regularly maintained information programs used for regulatory purposes.

[4] This debate is recently demonstrated by the lengthy legal battle over the proposed 8-hour ozone standard, which as issued by the EPA in 1997 and finally upheld by the Supreme Court in 2002 (Bergman (2004)).

regulation methods may be particularly costly for local governments and private firms (Lieu et al. (2003)). Lowering ozone is further complicated by the variability in the underlying natural conditions that lead to ozone formation. For example, even if ozone-causing emissions are constant throughout the year, unusually hot and sunny weather leads to high levels of ozone, partially explaining the pervasive ozone levels in California.[5] Furthermore, because global climate change is predicted to increase temperatures, this may increase ozone levels for any given level of ozone-causing emissions (Racherla and Adams (2006)), so episodic high ozone levels may be a more important public health problem in the coming decades. Traditional regulations that lower emissions by power plants or public vehicle fleets reduce emissions on all days, regardless of meteorological conditions. It may only be necessary to reduce emissions for the limited number of times per year when natural conditions might lead to exceptionally high ozone levels. Therefore, ozone outreach action programs, such as STA, may be more efficient than traditional regulations by allowing policymakers to focus regulatory effort only on those days when the effort is needed to avoid exceeding ozone standards. Given that numerous areas throughout the country have since implemented similar voluntary programs, such as Sacramento, CA, Atlanta, GA, Charlotte, NC, Houston, TX, and Pittsburgh, PA, to name a few, evaluating their impact is necessary to determine how these programs can best be incorporated into state and local efforts to meet air quality standards.

To assess if people are responding to STAs, we use administrative data on highway traffic volumes and public transit ridership in the Bay Area. If people respond to STAs by substituting away from higher ozone-producing activities towards lower ones, we expect to see a decline in traffic volume coupled with an increase in public transit use. Whether people respond to this particular program, however, is complicated by counteracting incentives. If STAs result

[5] The majority of California does not meet national ambient air quality standards for either 1-hour and 8-hour ozone.

in a reduction in trips by some individuals, then other individuals may respond to the reduction in expected traffic (and hence reduced travel time) by undertaking more trips, resulting in a free-rider problem. In addition, evidence indicates that individuals in Southern California reduce time spent outside in response to “smog alerts”, which are also based on ozone forecasts, though issued at a higher threshold (Neidell (2007)). Therefore, it is plausible that STAs signal information about risk so that individuals susceptible to ozone may decrease the use of public transit because it increases time outdoors and thus exposure to ozone. These incentives create an ambiguous prediction of the effect of STAs on transportation choices depending on the nature of the trip.

In addition, STA alerts may have a differential effect depending on the purpose of the trip and availability of alternative options. Discretionary (i.e., leisure) trips may be easier to change than work-related commuting trips because discretionary trips can be cancelled or rescheduled, as they are flexible by definition. On the other hand, most workers have little flexibility in missing a work day, especially if labor supply is fixed in the short run and telecommuting alternatives are unavailable, so commuting trips have a significantly higher cost of cancellation. Since discretionary trips are taken throughout the day, while commuting trips are concentrated in the peak rush hour periods, we examine the STA effect for each hour during the day in order to allow the response to vary throughout the day.

We use a regression discontinuity (RD) design to identify the effect of STA on transportation choices. Since STAs are issued when ozone levels are predicted to exceed a particular threshold, we compare outcomes on days just above the threshold to outcomes on days just below the threshold. If other factors affecting transportation choices are similar around the threshold, as evidence supports, this design controls for all confounding factors. Therefore, any difference in transit outcomes can be directly attributed to the STA advisory. Furthermore, the threshold used for issuing STAs is not publicized[6] and exogenously changed over the time period we study because of changes in federal air quality standards for ozone, so it is unlikely individuals respond to the underlying index that determines STA status.

In addition, we extend our RD design for the traffic regressions by estimating difference-in-difference models that include a control group that does not have a voluntary alert program. For the control group, we use traffic volumes in the metropolitan Los Angeles area. This area has many similar behavioral and environmental factors as the Bay Area, but does not have a voluntary traffic reduction program, so controlling for changes in traffic conditions in Los Angeles captures unobserved factors common across the two areas.

Our findings indicate people respond to STAs, but this is only detected when we employ the regression discontinuity model. STAs reduce total daily traffic by 2.5 to 3.5 percent, with the largest effect during and just after the morning commuting periods. STAs have no statistically significant effect on total daily public transit use, but borderline statistically significant effects during peak commuting periods. Our results are robust to alternative specifications of the RD and the inclusion of traffic monitor or BART station fixed effects. Given the robustness of our results, the plausible time of day patterns, and evidence of substitution from driving to public transit, it seems unlikely our results are driven by unobserved heterogeneity.

Given that we find evidence of a reduction in ozone-producing activities, we also assess whether these programs impact ozone levels using the same regression discontinuity design. Although the ozone formation process is far more complicated than the reduced form model we estimate, the model we estimate directly addresses the policy relationship of interest: do STAs

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[6] For example, we contacted the Bay Area AQMD several times until we could locate the correct employee who knew the STA threshold.

lower ozone levels? Naïve estimates indicate that STAs *increase* both 1-hour and 8-hour ozone levels, confirming that STAs are more likely to be issued on days that would have higher ozone levels anyway. In our regression discontinuity models our estimates, though statistically insignificant, indicate a decrease in ozone levels, which highlights the importance of accounting for the factors leading to ozone formation.

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

1. Background on Ozone and STAs

Ozone (*oz)* is not directly emitted into the atmosphere, but is formed from interactions of nitrogen oxides (*NOx*) and volatile organic compounds (*VOCs*) in the presence of heat, sunlight, and solar radiation (*solrad*):

(1) $oz = f\,(NOx,\ VOC,\ weather,\ solrad).$

Because of this process, ozone levels vary considerably both across and within days – it tends to peak in the summer and middle of the day when heat, sunlight, and/or solar radiation are at their maximum (U.S. EPA (2003)). Ozone levels are particularly high in California because of greater amounts of heat and sunlight that lead to ozone formation, the mountains that help to “trap” pollutants, and the temperature inversion layers that enhance ozone production.

NOx and VOCs, the two primary precursors to ozone, are directly emitted. Both stationary and mobile sources, primarily automobiles, contribute considerably to NOx and VOC emissions. For example, 49 percent of NOx emissions in the San Francisco Bay Area, Sacramento Valley, and San Joaquin Valley are due to on-road mobile sources, with 55 percent of that coming from gasoline vehicles (Air Resources Board (2003)).

Although there are no direct air quality standards (AQS) for NOx and VOC, AQS for ozone are based on measures taken on a daily basis. For example, in order for an area to attain AQS for 8-hour ozone, "the 3-year average of the fourth-highest daily maximum measured at each monitor within an area over each year must not exceed 0.08 ppm" (40 CFR 50.9; see Federal Register of April 30, 2004 (69 FR 23996)). Because this is based on a peak observation and not the mean over a period of time, despite extensive efforts to reduce ozone levels, unexpected weather can lead to air quality violations.

Policy makers consider various approaches to achieving AQS. One approach is to shift the distribution of NOx and VOC to the point that the maximum amount of emissions will not result in an ozone violation. Given the inherent fluctuations in weather, ensuring that violations no longer occur even on hot, sunny days can impose extensive costs to firms and individuals, especially if there are increasing marginal abatement costs to reducing ozone levels.

An alternative approach to avoiding AQS violations is to respond to forecasted weather conditions by limiting sources of pollution only on days when violations may occur. This can be accomplished by targeting the sources with the lowest cost of shifting pollution generating activities to other days. Since factories face considerable costs to alter their production on a temporary basis, one potential avenue is to target individuals. In particular, individuals who commute by automobile may find it less costly to switch transportation behaviors temporarily, making this a potentially more efficient policy.

The Bay Area Air Quality Management District (BAAQMD), which encompasses all of seven counties - Alameda, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara and Napa - and portions of two others - Solano and Sonoma, has issued STAs since 1991. In order to provide ample notification for people to alter their behavior, STAs are issued in advance based on air quality forecasts[7], and are widely publicized on the television, radio, and newspaper.

Air quality forecasts are provided for five regions (*r*) within the BAAQMD. An STA, which is disseminated the day before and day of the expected high ozone conditions, is issued based on the maximum ozone forecast across regions according to:

(2) $$STA_t = 1\{oz^f_t = \max_t (oz_{rt})\};\ oz_{rt} = f\,(oz_{rt-1},\ weather^f_{rt},\ solrad_t) \geq trg\}$$

where oz^f is forecasted ozone and *trg* is the trigger rule for issuing STAs. Note that traffic conditions are not used in the ozone forecast. According to equation (1), however, automobiles contribute to observed ozone levels through NOx and VOC. Therefore, temporarily reduced use of automobiles will lower NOx and VOC levels, which lower expected ozone levels, and increase the probability of attaining AQS.

2. Theory

To determine the conditions under which individuals respond to STAs, we develop a model where individuals receive value from contributions toward environmental goods even if they do not directly benefit from these goods. This is akin to 'existence value' -- individuals value the existence of goods they do not use in any way, such as the preservation of land -- in the environmental economics literature and to the 'warm glow' individuals get from giving to public

[7] All major cities in the U.S. are required to provide air quality forecasts to inform the public of local air quality and provide ample notification to react, though the main purpose is to protect public health (U.S. EPA (1999)). As mentioned in the introduction, several areas also offer programs to reduce ozone levels.

charities.[8] We generally follow the warm-glow model except we assume individuals receive greater altruism benefits from their actions as pollution problems worsen. That is, the benefits individuals receive when switching from driving to public transit are greater as ozone increases.

To formalize our model, utility is affected by a composite good (z), time spent traveling, health effects from exposure during transit (h), and environmental altruism (s), which involves their contribution to ozone levels. People do not enjoy traveling, so utility is decreasing in travel time. Health costs are weakly increasing in ozone level, $h[oz] \geq 0$, but for the vast majority of the population, their health is unaffected by ozone at these levels. Health costs are only incurred by those who use mass transit because it involves spending more time outdoors, which increases exposure to ozone.[9] Individuals spend their exogenously determined earnings[10] (w) less the monetary cost of commuting (c_j) on consumption of z. Since each person's polluting activities make a minimal contribution to overall pollution levels, we consider each person a price-taker in the ozone production market. That is, one individual's mode of transportation has no effect on ozone levels to a first approximation.

Individuals have three main choices (indexed by j) for each possible trip they might take during a day: drive alone (d), use public transit (p), or not take a trip (0). We eliminate a fourth choice of carpooling because we do not observe carpool trips in our data, but this does not impact the hypotheses we test. The associated travel time for each mode j (t_d, t_p, t_0) may be a function of STA because driving time is affected by the number of drivers on the road ($D=\Sigma d$), which is the total number of commuters minus the total number of public transit riders. If some

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[8] See Freeman (2003) for a review of the concept and Clarke (2003) for a recent example of existence valuation, and Andreoni (1995) for evidence of warm-glow.
[9] Ozone rapidly breaks down when it interacts with colder air (Chang et al. (2000)), so we assume driving involves no exposure to ozone, which is likely because drivers can use air conditioning on these unusually hot days.
[10] We assume labor supply is fixed in the short-run, but could alternatively let travel time affect time available for work. This does not affect the insights from our model.

drivers switch from driving alone to public transit, then the equilibrium driving time decreases because there are fewer cars on the road.[11] We assume public transit time is not affected by an STA because fixed time schedules allow increased ridership without delays (as long as there is spare capacity).

Each transportation mode then gives the following utility for individual i:

(3a) $y_{i,0} = \beta_0 X + u[(w)] - t_{i,0} + s_i[oz]$

(3b) $y_{i,d} = \beta_d X + u[(w-c_d)] - t_{i,d}[D[STA]]$

(3c) $y_{i,p} = \beta_p X + u[(w-c_p)] - t_{i,p} + s_i[oz] - h_i[oz]$

where consumption of the composite good is given by $z_j=(w - c_j)$ and X is a vector of transportation mode characteristics that affect the utility from transportation mode j but do not vary with the expected ozone level. We allow health costs (h), travel time (t), and warm-glow (s) to differ by individuals. For instance, individuals who live farther from BART stations or are more susceptible to the effects of ozone may incur greater health costs from using public transit. Individuals choose the mode y_j such that $y_j = y_{max} = max[y_0, y_d, y_p]$.

To assess how STAs affect travel modes, we assume an STA functions as a signal of higher ozone levels (i.e., $\delta STA=\delta oz$) for those utility components that are a function of ozone levels. This is a reasonable assumption because an STA is the most easily accessible signal of higher ozone levels in the Bay Area. With this setup, the effect of an STA on the change in utility for each travel mode is given by equations 4a-4c:

(4a) $\delta y_o/\delta STA = \delta s_i/\delta oz \geq 0$

(4b) $\delta y_d/\delta STA = -\delta t_{i,d}/\delta oz \geq 0$

(4c) $\delta y_p/\delta STA = -\delta h_i/\delta oz + \delta s_i/\delta oz$

[11] This is only true when highway delays exist, which is common in the Bay Area.

Equation (4a) indicates that forgoing a trip in response to the STA provides a warm-glow, which increases utility from that choice. Equation (4b) indicates that an STA alert provides no warm-glow for the driving alone alternative but reduces travel time, which also increases utility from that choice. Equation (4c) indicates that an STA alert provides a warm-glow for the public transit mode but also increases potential health costs, so the net effect on utility is ambiguous. These derivatives alone do not imply that individuals choose a particular travel mode, but instead reflect the change in utility from choosing a particular travel mode when an STA is issued.

We assess the effect of STAs on two distinct transportation trips: commuting trips and discretionary trips. We draw this distinction because labor supply is typically fixed in the short run, so canceling a trip is not an option for commuting trips for the vast majority of individuals. Evidence from Schreffler (2003), which is based on a small telephone survey that requested daily travel activities, found that for people who identify as reducing trips due to an STA, only 14.8% of trips were work related and the rest were not. Moreover, these trips tend to occur throughout the day, so there is a greater chance that these trips occur during the middle of the day when ozone levels peak.

2.A. Commuting trips

For commuting trips, we rule out the option of canceling a trip because of fixed labor supply and only compare (4b) to (4c). Since ozone levels peak during the middle of the day, they are much lower during typical commuting periods, so any health effects from ozone exposure are minimal. These derivatives imply individuals decrease the probability of driving (increase the probability of using public transit) if the environmental warm-glow outweighs the reduced travel time from emptier highways. Therefore, although STAs are designed to lower traffic volumes, they also have the perverse effect of providing an incentive to increase driving and reduce public transit use. This perverse incentive only kicks in if people respond to STAs in sufficient volume to improve traffic speeds, so it is unlikely to increase driving, but instead attenuates the effect of STAs on commuting trips. The Schreffler (2003) study finds that divers who were not aware or did not respond to STA alerts actually increased their number of trips on STA alert days; decreased highway congestion could be one reason for this observed increase.

2.B. Discretionary trips

For discretionary trips, we separately compare each of the 3 options (cancel trip, drive, public transit) to assess driving and public transit choices. Individuals decrease the likelihood of driving relative to canceling their trip if the warm glow exceeds their benefit from reduced travel time. This is the same prediction as above for commuting trips. Alternatively, individuals decrease the likelihood of driving relative to using public transit if the net effect of their warm glow less the expected health costs from public transit exceeds the reduced travel time benefit. Whether traffic decreases on net depends on the alternative mode people consider.

The model suggests that switching to public transit has low potential utility gain for discretionary trips. Canceling a trip weakly dominates public transit since it also entails receiving the warm-glow but has no negative health effects, so the probability of canceling increases relative to public transit. And, as just described, individuals increase the probability of public transit relative to driving only if the warm glow net of increased health costs exceeds the reduced travel time. Taken together, STAs have an ambiguous effect on discretionary public transit use, with the greatest likelihood of a decrease in public transit during peak ozone periods.

3. Empirical Methodology

Our goal is to estimate the demand for driving and public transit. Estimation of this equation may be hampered because STA days are not exogenously assigned. The factors that determine when an STA is issued, such as weather conditions, may also affect individual behavior, and it may be difficult to observe all of these factors. For example, STAs are more likely to be issued during particularly hot days when weather conditions are more favorable to ozone production. People may be likely to avoid the heat by staying in air-conditioned cars during these same conditions, leading to an increase in traffic. If we are unable to completely account for weather conditions or other unobservable factors correlated with STA days, then a naïve regression analysis could yield a spurious relationship or fail to find a significant relationship between STAs and transportation choices.

To account for such confounding, we use a regression discontinuity design to identify the effect of STAs (Cook and Campbell (1979)). This design assumes that all unobservable factors either do not vary around the STA trigger rule, or they evolve smoothly around the trigger rule in the same manner as the observed covariates. If days just below the STA trigger rule are identical to days just above the trigger rule, then the discontinuity in transportation choices that occurs at the trigger rule represents the causal effect of STA advisories.

To formalize this method, we estimate the following equation for both total daily volume and separately for each hour of the day:

$$(5) \qquad y_{kt} = \beta * STA_t + g(oz_t^f) + \delta_1 * W_t + \delta_2 * y_{kt-1} + \delta_3 * STA_{t-1} + \theta_k + \mu_t + \varepsilon_{kt}$$

where y is traffic or BART volume, the subscript k represents the traffic monitor or BART station, and the subscript t represents the date. We specify y in levels rather than logs because in the hourly regressions the reduced total daily volume is the relevant factor for STAs. For example, a 5% reduction at 2 a.m., when traffic volumes are low, should not have the same impact on air quality as a 5% reduction at 9 a.m., when traffic volumes are high. However, we report the percentage change in traffic from an STA for total daily volume for ease of interpretation. g is a function that relates the air quality forecast for ozone (oz^f) to transportation choices. W are other factors correlated with transportation choices, including contemporaneous and lagged observed and forecasted weather and separate dummy variables for day of week, month, and year. We include 1 lag of the dependent variable to account for any transitory shocks specific to a monitor or station, such as a highway construction project that lasts several days or longer, and lagged STA to account for any serial correlation.[12] In models using hourly measures of traffic, we include lags from the same hour on previous days rather than previous hours on the same day. θ_k is a monitor/station random effect to account for common shocks to each monitor/station. As a specification check, we also specify θ_k as a fixed effect, which captures all observed and unobserved factors constant at a given monitor or station over time. μ_t is a date specific random effect to account for the fact that STAs are issued at a daily level but we observe multiple monitors/stations per day.[13] ε is an idiosyncratic error term. Our hypothesis to test is $\beta=0$, that STAs have no effect on transportation choices.

We also extend our model for traffic conditions by including traffic monitors in Los Angeles as a control and estimating difference-in-difference models. Since the Los Angeles area is geographically close, it shares similar air quality and meteorological conditions as the Bay Area. Furthermore, the South Coast Air Quality Management District (SCAQMD), which consists of most of Los Angeles, Orange, Riverside, and San Bernardino counties, provides air quality forecasts but does not provide an STA program.[14] Therefore, we estimate a difference-

[12] Excluding both of these lags had a minimal impact on our estimates.
[13] When we include monitor or station random effect in addition to date random effects, we estimate two-way mixed effects models (Baltagi (2005)).
[14] Other metropolitan areas closer to the Bay Area, such as Sacramento, have STA programs so they cannot be used as controls. The Los Angeles area is therefore the area most similar to the Bay Area with traffic detectors and air quality forecasts but without an STA program.

in-differences model by including traffic from various monitors in Los Angeles in our main regression:

(6) $$y_{kta} = \beta_1 * STA_t + \beta_2 * a + \beta_3 * STA_t * a + g(oz_{ta}^f) + \delta_1 * W_{ta} + \delta_2 * y_{kt\text{-}1a} + \theta_k + \mu_t + \varepsilon_{kta}$$

where $a=1$ if the air quality district is the Bay Area and $a=0$ if South Coast. β_3 now represents the effect of STAs on traffic conditions.[15]

Using BART is only one of several options for people to alter their commuting behavior and reduce their contribution to pollution. They may carpool, work at home, ride their bicycle or walk to work, or take other forms of public transportation. All of these behaviors can lead to a reduction in traffic volume, but have no effect on BART use. Therefore, we expect a smaller effect on BART than on traffic volume.

To allow for a flexible specification of g, we estimate models restricting the sample to observations centered near the trigger rule. To understand how this strategy works, imagine restricting the sample to days with ozone forecast of .083 and .084 parts per million (ppm), where the trigger rule for issuing an STA is .084. We argue that any difference between the days other than the STA is random, as evidence below in Table 2 supports, so $\beta = E[y|STA=1] - E[y|STA=0]$ is the causal effect of STA on transportation choices. Since there are few observations with ozone forecasts of exactly .083 or .084, we instead restrict our sample to days centered on the trigger rule and also include the above mentioned covariates and the ozone forecast to account for any potential differences across the days above and below the trigger. We present estimates from two sample restrictions – within .02 and .01 ppm of the trigger rule – to assess the sensitivity of our estimates to the choice of g. Restricting the sample limits the generalizability of our results but is more likely to yield unbiased estimates for the existing

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[15] Using Los Angeles as a control group minimally impacted our point estimates, though it improved precision considerably.

policy (Dinardo and Lee (2004)). Since STAs do not need to be issued for ozone levels very different from the current trigger levels for attaining AQS, the treatment effect near the ozone levels where STAs are currently issued is most relevant for ozone regulation policy.

4. Data

Data on STAs and ozone forecasts come directly from BAAQMD. Ozone STAs are only issued during the ozone season, which is from June 1 to October 15, when solar radiation, sunlight, and heat are at their peak.[16] STA alerts are issued when the ozone forecast was predicted to exceed .081 ppm in 2003 and 2004 and .084 ppm in 2001 and 2002.[17] This change in the trigger rule is due to changes in federal air quality standard for ozone, and not an endogenous policy change to influence responses to STAs. Because we observe the ozone forecast for each region within BAAQMD, we follow the decision rule in equation (2) and use the maximum forecast across the regions for each day. Table 1 shows the number of STAs issued by year in the full and RD sample. There are a total of 23 STAs issued over the 4 years and, in our most restrictive RD sample, there are 44 days when the air quality forecast is within .010 ppm of the trigger rule.

We are unaware of individual level data on transportation choices observed on a daily basis, so instead use daily aggregate measures. For one measure, we use traffic data from the Freeway Performance Measurement System, which is a joint project of the University of California at Berkeley and various California state agencies. This system collects real-time traffic flow and speed from freeways sensors throughout the State of California to generate various performance measures. The traffic monitors measure the number of vehicles passing

[16] During the winter season, 'Spare the Air Tonight' may be issued to reduce particulate matter from wood burning stoves and fireplaces and motor vehicles.
[17] .081 ppm corresponds to 92 on the air quality index, an alternative scale frequently used for conveying air quality forecasts, and .084 corresponds to 100.

through a roadway and the speed of each vehicle in five minute intervals. We use data from 92 traffic monitors available in the BAAQMD and 50 monitors available in SCAQMD. We choose Bay Area Monitors so that there is a monitor on every freeway in the San Jose, Oakland, and San Francisco area. Given the large amount of monitors available, we use data from randomly selected monitors within these freeway segments. In SCAQMD we select 50 monitors at random from Los Angeles County.

While several performance measures are available from the traffic data, we use "traffic flow" as the dependent variable, which is the number of vehicles passing a detector during a given time period. This variable, aggregated appropriately, measures the total number of vehicles on that segment of the road. Although measures are available at 5 minute intervals, we must be cautious in not defining too narrow of a window that reflects traffic conditions in addition to traffic volume. For example, if heavy traffic congestion from 8:00 a.m. to 8:05 a.m. leads to slower driving speeds for the entire 5 minutes, then flow will indicate fewer vehicles on the road. Therefore, we compute all day traffic (6 a.m. – 12 p.m.) so that all vehicles clear the road and separate hourly measures within that time period.[18]

Although traffic flows are not necessarily an indication of trip reductions (it could reflect automobile accidents, road construction, etc.), our econometric analysis will not be affected as long as these other factors vary smoothly around the discontinuity. That is, if construction delays are similar both above and below the STA trigger level, then changes in traffic volume attributed to the STA will reflect changes in transportation choices.

For another measure of transportation, we use ridership on the Bay Area Rapid Transit (BART), the major commuting rail system in the region. This data, obtained from the San Francisco Metropolitan Transit Authority, consists of hourly station entrances and exits at each

[18] We omit volumes before 5 a.m. because they are considerably smaller than volumes throughout the day.

of the 43 stations. BART stations are mainly located in the San Francisco and Oakland areas. We compute comparable measures of the dependent variable to the traffic data. To increase responses to STAs, BAAQMD began offering free rides on BART in 2004 to all passengers when an STA is issued. In that year, fare collection gates remained opened on STA days, so entrances and exits were not counted. Therefore we omit this year from the BART analysis[19], though any effect on ozone levels will be capture in our ozone model.

Table 1 also shows summary statistics for the traffic and BART measures. Monitors in the Bay Area average flows of over 65,000 vehicles per day. BART stations average roughly 6,000 passengers per day. In terms of distribution throughout the day, traffic volumes in the Bay Area are widely dispersed between the hours of 7 a.m. and 7 p.m., while BART volume shows stronger commuting rush hour patterns. These patterns suggest that BART use is more heavily concentrated among regular commuters than road traffic and that discretionary trips are a lower proportion of BART ridership than road traffic.

For the other covariates included in our model, daily pollution data are readily available from the California Air Resources Board. There are 31 ozone monitors in the BAAQMD, and we use measures of both 1-hour and 8-hour maximum, both of which are regulated by AQS during the time period we study. We obtain daily data on weather from the Surface Summary of the Day (TD3200) from the National Climatic Data Center (NCDC). Using the numerous weather stations available in the Bay Area, we assign temperature and precipitation at the county level.[20] Since weather forecasts are an important component of ozone forecasts, we also add data on weather forecasts at the county level, obtained from coded city forecast (FPUS46)

[19] It is also unclear whether we should include these days because BART use may change because of price changes in addition to warm-glow.
[20] Data from weather stations from some entire counties were missing for several months in 2003. These values were replaced with measures from the nearest county.

provided by the Monterrey station (KMTR), available from the NCDC. The weather forecasts include the predicted high and low temperatures and cloud cover, which we capture by using a set of dummy variables. Given the different sources of data used, we limit the analysis to the years where all data exists, which consists of 2001 through 2004 for traffic and 2001-2003 for BART.

In Table 2, we present evidence to support the quasi-experimental random assignment the regression discontinuity design affords. In this Table we assess whether the covariates given in *W* in equation (5) are correlated with STA status. To do this, we present the difference in means on STA versus non-STA days, with the overall means of each variable in column 1.[21] We present this for the entire sample, shown in column 2, and for our RD samples after adjusted for the ozone forecast, shown in columns 3 and 4. For example, on STA days the maximum temperature is 14 degrees higher on average than non-STA days using all observations, but is less than 1 degree higher in the sample within .02 ppm of the STA trigger. The covariates do not balance when using the entire sample: differences for 5 of the 8 variables are statistically significant, raising potential confounding concerns. When we employ the regression discontinuity design, however, all of the covariates are balanced. This supports the notion that STAs can be treated as exogenous when exploiting the RD design so that any difference in transportation choices can be causally attributed to STAs.

5. Results for Transportation Choices

The first set of results, shown in Table 3, presents estimates of the effect of STA on total daily traffic volume in Panel A and BART ridership in Panel B. For comparison purposes, column 1 presents results using the entire sample and ignoring the ozone forecast. The results

[21] Although there are multiple stations per date, we use only 1 observation per date in this Table to properly account for the Moulton effect.

indicate a drop in traffic from STAs of approximately 1100 vehicles per monitor, but this is not statistically significant. When we estimate our preferred RD design, the effect doubles in size to over 2300 vehicles and becomes statistically significant. Moving to the more restrictive RD sample reveals a comparable estimate of 2000 vehicles, implying our estimates are not particularly sensitive to the functional form of the RD. These estimates suggest total daily traffic volumes decrease by 3-3.5% when an STA is issued and also indicate that naïve regressions that do not properly account for how STA days differ from non-STA days are biased.

Immediately below these results, we also present results using traffic monitor fixed effects. Thus far, we have used a traffic monitor random effect, which assumes that any monitor specific factors are uncorrelated with STAs. The fixed effect accounts for all observed and unobserved time-invariant factors specific to each monitor, so it offers one robustness check for our model. Our estimates are virtually unaffected by including the fixed effect, suggesting total daily traffic decreases in response to STAs.

For the BART results, in Panel B, we find that STAs are associated with an increase in total daily use of about 35 riders per station, which is less than a one percent change in total daily volume, but this estimate is not statistically significant. This estimate is comparable across all specifications, suggesting STAs are not associated with total daily use of public transit as measured by BART volume.

As previously mentioned, responses to STAs may vary by time of day depending on the nature of one's trip. In Figures 1 and 2 we plot the separate estimates of the STA coefficients with confidence intervals for each hour of traffic and BART volumes, respectively. We include estimates from only the RD samples within .02 ppm of the trigger and with monitor/station random effects, though estimates using fixed effects and a narrower window yielded comparable results.

Examining the response to STAs by hour of day reveals several interesting patterns. For traffic, we find large, statistically significant decreases in traffic during and immediately after morning hours, no evidence of a response throughout the middle of the day and into the evening rush hour, and decreases after 8 p.m., though smaller than morning decreases. The responses outside of rush hour are consistent with discretionary trips responding (Schreffler (2003)). The decrease in morning but not evening rush hour further suggests responses come from discretionary trips since commuting involves round trip travel. Given that ozone concentrations typically peak in the late afternoon and responses later in the day are unlikely to impact ozone levels, it is somewhat surprising to see traffic decreases after 8 pm. We offer two possible explanations for the unwarranted night response: 1) the evening commuting trip for those individuals who reduce the morning rush hour trip is either later than typical commuters or is pushed back later than normal, possibly to reduce exposure to ozone; 2) people may not be aware of the ozone formation process and peak pollution periods, so they obtain their warm glow when shifting activities is easiest. In support of this, STAs do not specify when people should alter their behavior. Furthermore, the Bay Areas also offers the STA tonight program during the winter, which encourages people to reduce PM 2.5 concentrations via reduced driving (and reduced use of fireplaces and woodstoves), so individuals may confuse the two. Overall, these patterns tend to support the change in traffic volume is come from discretionary trips, though we can not rule out other explanations.

Turning to the hourly BART results, we find evidence of varying responses throughout the day consistent with model predictions, though they are generally imprecise. The two largest increases in BART use occur at 9 a.m. and 6 p.m., with both estimates borderline statistically significant.[22] Both occur during rush hour, in the hour immediately after peak hourly entrances occur. Given that we estimate an effect for those who do not typically use BART, this just off-peak response could represent the increased marginal time associated with switching to public transit. These results are consistent with our prediction that the largest response for BART occurs during commuting hours.

We also find instances of decreases in BART use from 2-4 p.m., with the 3 p.m. estimate statistically significance in certain specifications. Since STAs provide information about expected air quality at a level where health concerns may arise, people may respond to STAs by reducing public transit trips in order to lower their exposure to pollution . Ozone levels peak around 3 p.m., so the decrease in BART during these hours coupled with no change in traffic volumes suggests the cancellation of public transit trips is consistent with evidence of avoidance behavior. The potential health benefits from the information contained in STAs are important to consider, but from a regulatory perspective, the goal of STAs is to reduce ozone concentrations.[23]

To further gauge the sensibility of our estimates, we compare them to estimates from other studies (Cummings and Walker (2000), Welch et al. (2005)), though we recognize ours may differ because of two important methodological differences: 1) other studies do not account for ozone forecasts, so the results are most comparable to our estimates without controlling for ozone forecasts and 2) other studies include traffic lags from the previous hour, rather than the previous day (as we do), to estimate whether traffic patterns changed within a day. For determining whether these programs have an effect on transportation choices, it is appropriate to

[22] The effect at 9 am is statistically significant with a window of +/- .01 ppm of the STA trigger, though the point estimate is comparable to the .02 ppm window.

[23] See Neidell (2007) for a more complete analysis of the effect of air quality information on avoidance behavior.

examine how transportation patterns change when an STA is issued vs. when an STA is not issued, i.e. across days. Cummings and Walker (2000) examine a similar voluntary program in the Atlanta, GA area on hourly traffic volumes and found statistically insignificant effects, just as we do in estimates that do not employ the RD design. Welch et al. (2005) examined the impact of ozone advisories on hourly public transit in Chicago, IL, and found considerably smaller impacts, though a similar pattern of increases during peak commuting periods and decreases during non-peak hours.[24] Given that these findings are comparable to results from our regressions that ignore ozone forecasts, we contend that the insignificant effects found elsewhere may be due to confounding.

6. Results for Ozone Concentrations

Given that we find evidence that STAs affect transportation choices, we now focus on whether such changes affect ozone levels. A structural model of ozone formation that accounts for ozone-related emissions and environmental conditions, such as the Community Multi-Scale Air Quality modeling system, is beyond the scope of this paper. Instead, we estimate a reduced form equation that relates ozone levels to STAs. This model provides estimates of the precise policy effect we seek to understand: do STAs affect ozone levels? Although we estimate models using the individual hourly ozone concentrations (results available from authors upon request),[25] we only provide estimates using daily ozone as defined by AQS because it is the policy variable of interest.

We estimate the same model as in equation (5) except we use the maximum 8-hour and 1-hour ozone level at each monitor and include a monitor random or fixed effect. Shown in

[24] Although estimates from Welch et al. (2005) are reported as statistically significant, standard errors were not adjusted to account for observing multiple stations within a day, so the estimates may not be statistically significant if valid standard errors are reported.

[25] Similar to results using daily ozone, we find no statistically significant estimates of the effect of STAs on hourly ozone levels using the same hours as in Figures 1 and 2.

Table 4, we find STAs have a statistically significant effect on 8-hour or 1-hour ozone levels in our model that uses all observations and does not employ the RD design. These estimates suggest that ozone levels *increase* by roughly .003 ppm when STAs are issued, the opposite effect of the intended policy. Finding a spurious correlation between STA and observed ozone levels is not surprising because STAs are issued when ozone is expected to be high, so there is a strong possibility for omitted variable bias.

When we use our RD design, however, this perverse effect goes away. Estimates are now in the expected direction, indicating decreases in ozone from STAs, but are not statistically significant. The standard errors are fairly wide, though, so it is not possible to rule out considerable effects. For example, based on the upper limit of the 95% confidence interval in the more restrictive RD sample, 1-hour ozone levels may decrease by as much as .001 ppm. Given air quality standards of .012 ppm for 1-hour ozone, a decrease of .001 could be meaningful for obtaining AQS if ozone forecasts are accurate. This extreme case aside, these results suggest the decrease in traffic from issuing STAs does not appear sufficient for delivering a significant impact on ozone levels.

One caveat to this analysis is that the estimation approach used to estimate the STA effect on ozone levels simplifies the process by which ozone precursors react with natural conditions to form ozone. It is likely that there is considerable geographic heterogeneity in the effect of STAs on monitors because landscape features and the distribution of vehicle emissions may concentrate ozone effects in certain areas. Also, temporal difference in the STA effect on ozone levels may arise because wind direction varies by day. Although we claim our estimate is the policy effect of interest, a more advanced model of air shed processes that better accounts for this process may be better suited for this analysis, but this is beyond the scope of an economics paper.

Although we do not find a statistically significant effect of STAs on ozone levels, benefits to the policy may accrue in neighboring air quality districts. Ozone and its precursors, such as NOx, can be transported hundreds of miles, leading to intra-regional environmental impacts (U.S. EPA (1998)). Therefore, STAs issued in the Bay Area may affect ozone levels in the Central Valley and Sacramento, a topic that needs to be explored in more detail.

These results are consistent with those of Davis (2006), who found no statistically significant effect on ozone levels from a driving restriction program in Mexico City that bans all vehicles from driving one day per week based on the last digit of the license plate. Although it is possible the effects of STAs on air quality differ because of the different context of the policy – a voluntary program in a developed country as opposed to a mandated program in a developing country – these studies together suggest that such driving reduction programs may not be achieving the desired results.

7. Conclusion

As policy makers discuss ways to improve environmental quality, the adoption of voluntary programs is a potentially efficient mechanism. 'Spare the Air' is one such program targeted at individuals, but it is unknown whether the program is achieving the desired results. This paper seeks to inform agencies in deciding whether or not to adopt such a program, and to address more generally the role of voluntary information programs, though we recognize several peculiarities of STAs that may preclude extending our findings to other programs.

We find that individuals respond to STAs by reducing ozone-causing activities, but not in sufficient volume to have a significant effect on ozone in the Bay Area. Since the Bay Area has the advantages of well-developed alternative transportation modes and an environmentally aware population, our evidence casts doubt on whether metropolitan areas without these advantages can enjoy even limited success with Spare the Air type programs. Although further outreach efforts to encourage more drivers to change behavior appear necessary for the STA program to be effective, the counteracting free-rider problem of improved speed from lower traffic volumes may limit the ultimate effectiveness of this program and should not be ignored. Therefore, our analysis casts doubt on whether this particular voluntary program can improve environmental quality, and suggests alternative programs without counteracting incentives may be more effective.

The results are also relevant to whether the recent decision to offer free fares to BART passengers on STA alert days is a cost-effective way to increase the effect of STAs. Clearly, the answer hinges on how many extra people switch from driving to BART on STA days as a result of the fare elimination, something we can not answer because the free fare policy has only been implemented for a few days and entrances were not recorded on these days.[26] Since the free fare applies to all passengers, regardless of their usual transportation choice, the program costs the city at least $365,000 in lost revenue each day an STA is issued.[27] Switching would have to be very elastic for the program to justify its costs, so our analysis casts some doubt on whether offering free fares to all passengers on STA days is worth the benefit.

A necessary component of this analysis that policymakers must also consider is the costs to individuals from changing behavior. Carpooling, delayed or cancelled trips, and taking public transit impose time costs to consumers that policy makers must acknowledge. Although these

[26] Furthermore, the free fare policy was associated with numerous complaints about overcrowding (Matier and Ross (2006).
[27] Table 1 indicates approximately 260,000 riders on the BART per day during smog season. Valuing the trips at the minimum fare of $1.40 yields $364,659.

costs are voluntarily absorbed by consumers, the STA responses are based on a government signal that altruism is particularly valuable on certain dates. Therefore, policymakers need to know these costs and weigh them in its decisions, making this a priority for future research.

7. References

Andreoni, James (1995). "Warm-glow or cold-prickle: The effects of positive and negative framing on cooperation in experiments." *Quarterly Journal of Economics* 110(1): 1-21.

Air Resources Board (2003). "The 2003 California Almanac of Emissions and Air Quality." Available at http://www.arb.ca.gov/aqd/almanac/almanac03/almanac03.htm.

Baltagi, Badi (2005). Econometric Analysis of Panel Data. John Wiley & Sons: England.

Bergman, Cynthia (2004). "EPA Issues Designations on Ozone Health Standards." U.S. EPA Press Release, April 15.

Bui, Linda and Christopher Mayer (2003). "Regulation and Capitalization of Environmental Amenities: Evidence from the Toxic Release Inventory in Massachusetts." *The Review of Economics and Statistics* 85(3): 693-708

Chang LT, Koutrakis P, Catalano PJ, Suh HH (2000). "Hourly personal exposures to fine particles and gaseous pollutants--results from Baltimore, Maryland." J Air Waste Manag Assoc. 50(7): 1223-35.

Clarke, H. (2003). "International Biodiversity Conservation Agreements. Natural-Resource-Modeling." *Natural Resource Modeling* 16:245-257.

Cook, Thomas and Donald Campbell (1979). *Quasi-Experimentation: Design and Analysis Issues for Field Settings*. Boston, MA: Houghton Mifflin.

Cummings, Ronald, and Mary Beth Walker (2000). "Measuring the effectiveness of voluntary emission reduction programs." *Applied Economics*, 32, 1719-1726.

Davis, Lucas (2006). "The Effect of Driving Restrictions on Air Quality in Mexico City." Mimeo, University of Michigan.

Dinardo, John and David Lee (2004). "Economic Impacts of New Unionization on Private Sector Employers: 1984-2001." *Quarterly Journal of Economics* 119(4).

Freeman, A.M. (2003). The measurement of environmental and resource values: Theory and methods. Resources for the Future, Washington, DC.

Hamilton, James (1995). "Pollution as News: Media and Stock Market Reactions to the Toxics Release Inventory Data." *Journal of Environmental Economics and Management* 28(1): 98-113.

Khanna, M., W. Quimio, and D. Bojilova (1998). “Toxic Release Information: A Policy Tool for Environmental Protection.” *Journal of Environmental Economics and Management* 36 (3): 243-266.

Konar, Shameek, and Mark Cohen (1997). “Information as Regulation: The Effect of Community Right to Know Laws on Toxic Emissions.” *Journal of Environmental Economics and Management* 32:109-124.

Matier, Phillip, and Andrew Ross (2006). “Freebie 'Spare the Air' rides a BART free-for-all.” SFGate.com, July 26.

Morgenstern, Richard D. and William A. Pizer (Eds.) (2007). <u>Reality Check: The Nature and Performance of Voluntary Environmental Programs in the United States, Europe, and Japan.</u> Resources for the Future: Washington, DC.

Neidell, Matthew (2007). “Information, Avoidance Behavior, and Health: The Effect of Ozone on Asthma Hospitalizations.” *Journal of Human Resources*, forthcoming.

Racherla, P. N., and P. J. Adams (2006). “Sensitivity of global tropospheric ozone and fine particulate matter concentrations to climate change.” J. Geophys. Res., 111, D24103

Schreffler, Eric (2003). “Quantification methods for identifying emission reductions resulting from seasonal and episodic public education programs.” Air Resource Board Final Research Report, ARB contract No. 98-318.

Lieu, Sue, Patricia Kwon, and Shah Dabirian (2003). “Final Socioeconomic Report for 2003 Air Quality Management Plan.” South Coast Air Quality Management District.

Reiss, Peter and Matthew White (2003). "Demand and Pricing in Electricity Markets: Evidence from California's Energy Crisis." NBER Working Paper #9986.

U.S. Environmental Protection Agency (1998). “The Regional Transport of Ozone: New EPA Rulemaking on Nitrogen Oxide Emissions.” EPA Document #456-F-98-006, Research Triangle Park, NC.

U.S. Environmental Protection Agency (1999). “Guidelines for Reporting of Daily Air Quality – Air Quality Index (AQI).” EPA Document #454-R-99-010, Research Triangle Park, NC.

U.S. Environmental Protection Agency (2003). “Air Quality Criteria Document for Ozone”, First External Review Draft, available at http://www.epa.gov/ncea/ozone.htm.

van der Klaauw, Wilbert (2002). “Estimating the Effect of Financial Aid Offers on College Enrollment: A Regression-Discontinuity Approach.” *International Economic Review*, Vol 43(4).

Welch, Eric, Xiaohua Gu, and Lisa Kramer (2005). “The effects of ozone action day public advisories on train ridership in Chicago.” *Transportation Research* Part D 10 (2005) 445–458.

Figure 1. Effect of STA on Traffic by Hour

+/- .02 ppm of trigger

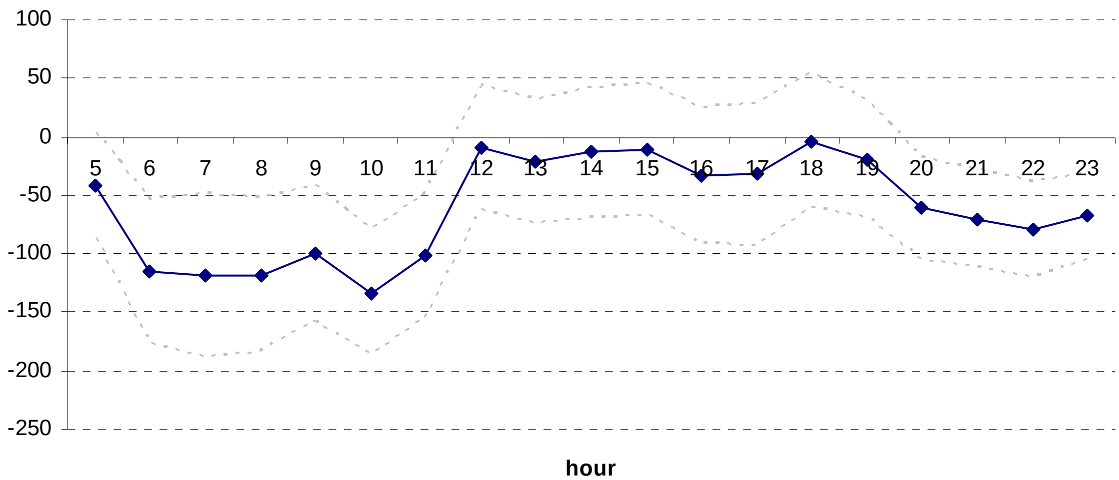

Figure 2. Effect of STA on BART by Hour

+/- .02 ppm of trigger

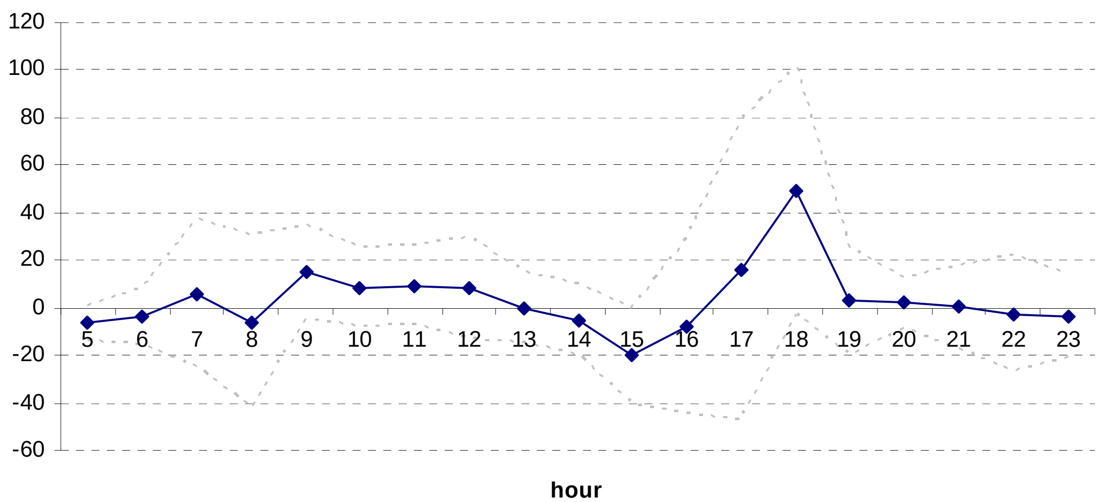

Table 1. Summary Statistics

A. Number of STAs by Year

year	STA=1	All observations STA=0	+/- 20 ppb of trigger STA=0	+/- 10 ppb of trigger STA=0
2001	4	130	23	7
2002	7	127	32	8
2003	9	125	63	21
2004	3	131	38	8
Total	23	513	156	44

B. Means of Dependent Variables

	Bay Area Traffic		BART	
Hourly values	mean	std. dev.	mean	std. dev.
5	1,664	989	70	69
6	2,792	1,608	216	194
7	3,760	2,016	518	445
8	3,896	1,824	631	477
9	3,870	1,570	375	246
10	3,803	1,423	250	141
11	3,903	1,433	237	146
12	4,013	1,457	256	193
13	4,074	1,473	257	229
14	4,298	1,542	271	296
15	4,423	1,606	333	445
16	4,520	1,660	476	754
17	4,604	1,706	696	1,310
18	4,277	1,611	582	1,108
19	3,684	1,395	313	533
20	3,058	1,222	177	286
21	2,780	1,167	144	241
22	2,351	1,116	137	299
23	1,715	952	102	238
all day	65,856	23,755	6,057	5,912

	ozone 1-hour		ozone 8-hour	
	mean	std. dev.	mean	std. dev.
all day (ppm)	0.0532	0.0208	0.0426	0.0149

Table 2. Difference in means of covariates across STA status

	1	2	3	4
	mean	All observations	+/- .02 ppm of trigger	+/- .01 ppm of trigger
precipitation	0.184	-0.079	0.027	0.026
		[0.75]	[0.61]	[0.78]
max. temperature	81.92	14.198	0.994	-1.713
		[0.00]	[0.60]	[0.52]
precipitation (in.) (lag)	0.184	-0.109	-0.011	-0.007
		[0.65]	[0.83]	[0.94]
max. temperature (lag)	82.015	11.657	0.871	-0.554
		[0.00]	[0.68]	[0.86]
forecast max. temperature	81.524	12.401	1.707	1.562
		[0.00]	[0.29]	[0.54]
forecasted sunny outlook	0.637	0.337	-0.014	-0.100
		[0.00]	[0.90]	[0.44]
forecasted partly cloudy outlook	0.326	-0.299	0.014	0.100
		[0.00]	[0.90]	[0.44]
holiday (lag)	0.024	0.020	0.034	-0.014
		[0.54]	[0.61]	[0.87]

Note: Value in each cell is the difference in means across STA status. Columns 3 and 4 adjust for ozone forecast. p-value that variable equal across STA status in brackets.

Table 3. Effect of STA on all day traffic and BART

	1	2	3
	all observations	+/- .02 ppm of trigger	+/- .01 ppm of trigger
A. Traffic			
monitor random effect	-1105.965	-2332.260**	-2009.982*
	[823.082]	[857.489]	[1010.082]
	-{0.017}	-{0.035}	-{0.031}
monitor fixed effect	-995.185	-2111.731*	-1683.411
	[822.683]	[856.634]	[1008.854]
	-{0.015}	-{0.032}	-{0.026}
Observations	70805	24073	8768
# of days	536	179	67
# of monitors	142	142	142
B. BART			
station random effect	34.584	40.273	29.448
	[86.777]	[114.965]	[173.317]
	{0.006}	{0.007}	{0.005}
station fixed effect	32.496	41.398	39.162
	[86.697]	[114.636]	[171.911]
	{0.005}	{0.007}	{0.006}
Observations	21391	7160	2520
# of days	536	179	67
# of stations	43	43	43

* significant at 10%; ** significant at 5%; *** significant at 1%. Value in each cell represent the STA coefficient from a separate regression. Standard errors in brackets. All regression include dummy variables for lagged holiday, lagged STA, month, year, and day of week, controls for contemporaneous and once lagged precipitation, contemporaneous and once lagged quadratic in temperature, forecasted maximum temperature, and dummy variables for forecasted outlook. Numbers in braces represent the percent change in traffic from STA, obtained by dividing the estimated coefficient by the corresponding mean from Table 1.

Table 4. Effect of STA on 1-hour and 8-hour ozone

	1	2	3
	all observations	+/- .02 ppm of trigger	+/- .01 ppm of trigger
A. 1-hour ozone			
monitor random effect	0.0030*	-0.0012	-0.0014
	[0.0018]	[0.0031]	[0.0049]
	{0.056}	-{0.022}	-{0.026}
monitor fixed effect	0.0029*	-0.0012	-0.0016
	[0.0017]	[0.0030]	[0.0048]
	{0.054}	-{0.023}	-{0.030}
Observations	6406	2139	777
# of days	536	179	65
# of monitors	12	12	12
B. 8-hour ozone			
monitor random effect	0.0027*	-0.0009	-0.0017
	[0.0014]	[0.0026]	[0.0040]
	{0.063}	-{0.020}	-{0.040}
monitor fixed effect	0.0026*	-0.0009	-0.0019
	[0.0014]	[0.0024]	[0.0038]
	{0.061}	-{0.021}	-{0.045}
Observations	6406	2139	777
# of days	536	179	67
# of monitors	12	12	12

* significant at 10%; ** significant at 5%; *** significant at 1%. Value in each cell represent the STA coefficient from a separate regression. Standard errors in brackets. All regression include dummy variables for lagged holiday, lagged STA, month, year, and day of week, controls for contemporaneous and once lagged precipitation, contemporaneous and once lagged quadratic in temperature, forecasted maximum temperature, and dummy variables for forecasted outlook. Numbers in braces represent the percent change in traffic from STA, obtained by dividing the estimated coefficient by the corresponding mean from Table 1.