# The Impact of Quasi-Regulatory Mechanisms on Polluting Behavior: Evidence From Pollution Prevention Programs and Toxic Releases

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(First Draft: January 2010)
Current Draft: January 2011

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The author gratefully acknowledges funding from the EPA STARS program, grant # RD832850. The author would also like to thank Peter Max Dion and Xi Zhang for their excellent research assistance as well as Wayne Gray, Tom Lyon, Sheila Olmstead, Ron Shadbegian, T. S. Sims, Ann Wolverton, and participants of the 2010 Environmental and Natural Resource Economics World Congress, EPA Benefits of Information Disclosure Conference, and Brandeis University's Department of Economics Brown Bag lunch for helpful comments. All errors are my own.

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ABSTRACT:

To date, there is little convincing evidence on the effectiveness of "quasi-regulatory" mechanisms. Here I investigate how quasi-regulatory policies known as pollution prevention ("P2") programs affect toxic pollution. I construct a data base on state-level P2 programs as well as the 1990 federal Pollution Prevention Act (PPA) and exploit variation in state adoption dates and program characteristics to study their effects on facility-level toxic releases. I find strong evidence that these mechanisms can affect pollution outcomes. In particular, I find that (1) the 1990 PPA has had a significant effect on toxic releases; (2) state programs geared to reducing the costs of P2 activities led to significant reductions in toxic releases; and (3) the response to P2 programs that increased the regulators' ability to monitor polluting behavior could either increase or decrease reported releases, depending on the regulators' ability to verify the accuracy of the reported releases.

KEY WORDS:

TRI, quasi-regulation, voluntary programs, toxic pollution.

# The Impact of Quasi-Regulatory Mechanisms on Polluting Behavior: The Case of Pollution Prevention Plans and Toxic Releases

## I. Introduction

Environmental regulation in the United States has evolved slowly from the traditional command and control strategies dominant during the early 1970s to the more market-based regimes that we see today. Those market-based approaches include voluntary programs and initiatives, or "quasi-regulations," aimed at incentivizing pollution reduction without legally requiring abatement by polluters. Quasi-regulatory mechanisms are becoming more frequently used by regulators, particularly for pollutants that are not easily regulated using command and control strategies. Currently, there are more than 50 such voluntary programs and initiatives at the federal level,[1] with several dozen more at the state level. Given the growing reliance that regulators are placing on such mechanisms it is important to understand how, (if at all) they affect polluter behavior.

To date, much of the empirical work on the effectiveness of quasi-regulatory mechanisms has been unconvincing.[2] That stems, in part, from the difficulty of separating the effects of the various elements of formal and informal environmental regulations that confront polluters. Weak identification strategies dictated by data limitations have also proved problematic. To address some of those problems, I make use of micro-level data on toxic releases, and focus on a particular set of quasi-regulatory initiatives called pollution prevention ("P2") programs. I develop a detailed data set on P2 programs and exploit variation in adoption dates to estimate their effects on facility level

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[1] Brouhle, et al., 2004

[2] For a strong over-view, see Brouhle, et al., 2004. See also Bennear (2007) and Stafford (2003).

behavior. The potentially confounding effects of various formal regulatory measures, as well as international agreements, are also addressed. Different control groups are used to validate the robustness of the results.

The programs that I study include the federally mandated Pollution Prevention Act (PPA) of 1990 as well as 38 different state-level P2 programs. Those programs primarily target hazardous waste, toxic waste, and toxic releases. P2 programs aim to reduce pollution by encouraging "source reduction and other practices that reduce or eliminate the creation of pollutants through: increased efficiency in the use of raw materials, energy, water, or other resources; or [the] protection of natural resources by conservation."[3] P2 programs range from offering awards that publicly acknowledge exemplary pollution prevention initiatives to implementing non-reporting penalties; from providing free on-site technical assistance and educational outreach, to joint research initiatives between local government and industry.

Using a balanced panel consisting of more than 7100 manufacturing facilities over a 16 year period, I find strong evidence that both federal and state P2 programs have had a significant effect on polluter behavior. In particular, I find that (1) the 1990 PPA was responsible for reductions in average facility level releases of between 65%-76%; and that (2) the adoption of state P2 programs corresponded to a decline in average facility releases of between 11.5% - 12.4%. I also find that the state "adoption" effect is much larger for facilities located in early adopting states (24%) than in late adopting states (5%). Those results are robust to using either the balanced or unbalanced panel of manufacturing facilities, as well as to changes in the range of years used in the analysis. A test to determine whether the results are driven by spurious correlation is soundly rejected.

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[3] OPPT Overview - Draft Version 2.0.

Of the different state P2 programs that I study, programs that reduced the cost of participation, in particular, technical assistance and educational outreach programs have been the most successful at reducing toxic releases. I find, however, that the timing of the reductions depends upon a number of factors, including the length of time the program has been in place as well as whether other states have already adopted similar programs. There is a strong evidence to suggest that spill-over effects play an important role in the effectiveness of these types of programs.

State P2 programs that increase the ability of regulators to monitor polluters, such as filing fees and non-reporting penalties, are also found to have had an effect on polluter behavior. Surprisingly, filing fees tend to increase reported releases. This, however, could reflect a change in *reporting* behavior, and not necessarily a change in *polluting* behavior. Non-reporting penalties, over-all, however, were mostly ineffective at altering facility behavior, except in the case of toxic substances that could be easily monitored by regulators. For those substances, non-reporting penalties led to lower levels of reported releases. I argue that the ineffectiveness of non-reporting penalties may reflect a fundamental problem facing regulators of toxic releases that arises because regulators cannot validate the accuracy of the self-reported toxic releases.
that arises with toxic releases as regulators cannot validate the accuracy of the self-reported TRI data.

The paper is organized as follows. In Section II I provide regulatory background on federal and state level statutes. Section III describes the data used in the estimation, while Section IV discusses the model used in the estimation. Section V provides basic summary statistics for the data and in Section VI I discuss estimation results. Section VII concludes.

## II. BACKGROUND

Toxic substances are those that are either known to be, or are suspected of being, hazardous to human health at low levels of exposure. Their storage, handling, transportation, and disposal are all strictly regulated. Yet, for many of these substances there is no formal regulation of their *release* into the environment. In part, this may be due to the mandate given to the EPA to set standards that protect health and human welfare. If a substance is known to be toxic at low levels of exposure, the appropriate emissions standard may be zero. Banning a substance, however, is not always feasible. Given that difficulty, regulations of toxic releases, as a whole, are not as well defined or as comprehensive as those facing conventional pollutants. Instead, toxic releases often face quasi-regulations aimed at promoting voluntary abatement. I describe below the most relevant regulations applicable to toxic releases.

*Clean Air Act and Clean Water Act*: A subset of TRI chemicals is regulated under the Clean Air Act, and its amendments. Such air pollutants may be regulated as hazardous air pollutants (HAPs) under the National Emissions Standard for Hazardous Air Pollutants (NESHAP), or as conventional pollutants (fine particulate matter (PM) or volatile organic compounds (VOCs)) under the National Ambient Air Quality Standards (NAAQS). In general, these regulations impose technology standards. The Clean Water Act also affects a subset of TRI chemicals, although the set of regulated chemicals is significantly smaller. Such substances also face technology based standards. In most instances, these standards are industry and (typically) state-specific.

*Toxic Release Inventory*: The Toxic Release Inventory was introduced by the 1986 Emergency Planning, Community Right to Know Act. Originally, only facilities in the manufacturing sector (SIC 2000-3999) that either used or manufactured more than a threshold level of a TRI "listed" substance were required to report their toxic releases to a publicly maintained data base. In 1988, approximately 300 substances were listed as TRI chemicals. The list of chemicals, threshold levels, and required TRI participants has changed over time. Currently, over 600 chemicals are listed, and the group of required participants has expanded to include such industries as electric utilities as well as government facilities

*TRI 33/50 Program*: The 33/50 program was initiated as a voluntary program in conjunction with TRI reporting. The EPA invited over 5000 companies to voluntarily participate in reducing releases of 17 TRI priority substances, by one-third by 1992 (from 1988 baselines) and by one-half by 1995. The program was deemed a success: target reductions were more than fully met by 1994.

*1990 Pollution Prevention Act*: The 1990 Pollution Prevent Act authorized the EPA to support the adoption of source reduction techniques by business, governments, and other organizations. In part, this support comes in the form of federally operated P2 programs such as Design for the Environment (DfE), which involves joint government-industry research initiatives to provide detailed information on source reduction activities. DfE has targeted industries such as dry cleaners and producers of printed wire boards, which are known to produce large volumes of toxic releases, and are dominated by small and medium sized polluters for whom investing in P2 research on their own is generally infeasible. The PPA also provides grants to states for state technical assistance programs and, promotes the exchange of information through the EPA's Pollution Prevention Resource Exchange (P2Rx), which supports 8 regional P2 information centers. Those programs are all aimed at lowering the cost to polluters of engaging in P2 activities through information dissemination.

Aside from direct support of P2 activities, the PPA requires that TRI reporters include information on source reduction and recycling activities. It also established a national awards program to "recognize a company or companies operating outstanding or innovative source reduction programs."

*Pollution Prevention Programs and Toxic Use Reduction Acts (TURAs):* Several states have adopted P2 legislation apart from the federal PPA. Some 27 state P2 programs were adopted prior to 1990, the first in 1984. Such programs focus on the reduction of solid and hazardous wastes as well as toxic releases. Much like the federal PPA, state P2 characteristics include programs for technical assistance, educational outreach, grants, and awards. But in contrast with the PPA, many states impose filing fees and non-reporting penalties for TRI reporters.

Another aspect unique to state programs is that some have prescribed reduction goals for toxic releases and hazardous waste production. The objectives have ranged from 30% - 80% from some baseline year. Such reduction targets are established on a state-wide basis, universally, however, there are no penalties for non-compliance or other enforcement mechanisms in place.

*Montreal Protocol*: The Montreal Protocol is an international agreement, entered into in 1987 to be effective on January 1, 1989. Signatories of the Protocol agreed to a phase-out plan for the use (consumption and production) of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), both of which are monitored by the TRI. The plan allowed for an increase in "Group 1 of Annex A" substances up through 1992 (with allowable increases capped at 150% of 1986 levels), but then required a rapid phase-out; to a target of no more than 25% of 1986 levels by 1994, and complete elimination by 1996. Slower phase-outs were prescribed for other substances.

## III. DATA

Toxic release data are taken from the EPA-TRI website (www.epa.gov/tri/tridata) for reporting years 1988-2003. The data are given by chemical and facility. Because threshold reporting levels, reporting chemicals, and required reporters changed during this period, the bulk of my analysis is restricted to that set of chemicals that are reported for all years between 1988-2003, for which the reporting threshold did not change. I also limit myself to the balanced panel of facilities in the manufacturing sector which have been required to report to the TRI since 1988 (SIC 2000-3999).

Information on state-level pollution prevention legislation and programs are taken from a variety of sources, including the Right-to-Know Planning Guide (1997, the Bureau of National Affairs, 0-871-931-1/97), the 1999 State TRI Program Assessment, and state environmental websites. A total of six different P2 programs were found. These consisted of technical assistance programs, educational outreach programs, grants and financial aid, award programs, filing fees, and non-reporting penalties.

In addition to the different programs offered, state P2 programs also differed in one other important dimension – their level of stringency. To capture this difference, I classify states into 1 of 2 categories: low and high stringency states. Low stringency states are those that have no target reduction goals for toxic releases, whereas high stringency states are those that have state-wide numeric reduction goals for toxic releases with specific compliance dates.

## IV. Basic Model and Methodological Issues

To estimate the effect of P2 programs on releases, (reduced form) releases are modeled as:

$$\ln(TRI_{ijst}) = \beta_0 + \beta_1 PPA_t + \Gamma z_{st} + \delta_i + \sigma_j + \gamma_t + \epsilon_{ijst} \tag{1}$$

where *ln(TRI)* is the natural log of facility-level TRI releases for facility *i*, in industry *j*, state *s*, and year *t*. *PPA* is an indicator variable controlling for the 1990 PPA which takes on the value of 1 from 1990 - 2003, and 0 otherwise. *Z* is a vector of P2 state-level programs, differentiated by their basic characteristics (eg. provision of technical assistance or non-reporting penalties) that take the value of 1 if the state has a particular program in a given year, and 0 otherwise. Indicator variables are included to capture various fixed effects at the facility ($\delta$), industry ($\sigma$), and year ($\gamma$) level. $\epsilon$ is assumed to be a well behaved random error term with a conditional mean of zero.

For the above to consistently estimate $\beta_1$ and $\Gamma$, the "treatment" variables must be uncorrelated with any time-varying unobservables that affect facility level releases: in other words, $\epsilon$ must be orthogonal to the adoption of federal and state-level P2 programs. It is important to recognize that it is unlikely that any endogeneity arises due to *facility level* releases being correlated with federal and state-level P2 adoption dates or program choices, primarily because individual facilities are not generally large enough to influence the state level regulatory environment.[4]

## V. Descriptive Statistics

The balanced panel of TRI facility data are from 7157 facilities, yielding 114,512 facility-year observations between 1988-2003. This consists of approximately 33% of all available facility-year observations in the TRI. Summary statistics are given in Table I.

Average, annual facility level releases of TRI substances are 251,996 pounds. Of those, by weight, 57% are air, 2% are water, and 41% are land (and underground) releases. Due to the potential confounding effects of the CAA and the 1990 CAAA, I also report descriptive statistics for toxic releases net of any CAA substances. In total, 39% of all TRI releases face formal command

[4] Endogeneity would be far more likely if releases were aggregated to the industry or state level.

and control regulation under the Clean Air Act ("CAA air releases"), leaving 61% ("TRI Net of CAA") of aggregate TRI releases primarily facing quasi-regulations. TRI 33/50 substances make up, on average, 21% of facility level TRI releases, but almost all of those substances are also regulated under the CAA. TRI 33/50 substances net of CAA substances only constitute 0.04% of average facility level aggregate TRI releases. Montreal Protocol substances contribute under 2% of aggregate TRI releases, and Montreal Protocol substances net of CAA substances make up approximately 0.3% of aggregate TRI releases.

With respect to state-level P2 programs, technical assistance programs affect 65% of facility-year observations with approximately 20% of facility-years having educational outreach opportunities. In all instances, educational outreach is offered in conjunction with a technical assistance program. Grants are offered in 43% of facility-years, and 11% have award or recognition programs. Filing fees are instituted in 61% of facility-years, and 64% have non-reporting penalties.

In columns 2 and 3 of Table 1, summary statistics are given for the facilities pre and post adoption of a state P2 program, with the average change between those periods shown in the last column. Data for the year of adoption is *not* included in either column. On average, aggregate facility level releases were more than 39% (37% for net TRI) lower by weight after the adoption of a state P2 program. Net TRI 33/50 substances were 22% lower, net Montreal Protocol substances were 86% lower, and CAA air releases were 44% lower. Although these reductions are impressive, whether they can be attributed to the adoption of P2 programs or to other factors such as improvements in abatement technology over time, changes in output levels, regulatory changes, or something else, cannot be determined from the descriptive statistics, alone.

In determining how facility level toxic releases respond to P2 programs, care should be given to the possibility of "equilibrium sorting" where firms make location choices based on compatibility with certain state characteristics. For example, "green" firms may be more likely to locate in more environmentally forward states. If so, facility response may systematically differ across groups based on these (potentially unknown) state characteristics, in which case, estimates based on the whole sample may obscure important behavioral patterns in the data. To allow for this, I also group facilities by: (1) whether they are located in a state that is an "early" or "late" adopter of P2 programs, relative to the 1990 PPA, and (2) whether they are located in a state which has a "low" P2 stringency level (no target reduction goal) or a "high" P2 stringency level (specified target reduction goal).

In Table II, Panels 1 and 2, facilities are grouped by whether they are located in a state that adopted a P2 program before 1990 ("early" adopter) or after 1990 ("late" adopter). Facilities located in states that adopted a state program in 1990 are not included in the calculations of the descriptive statistics given here. There are important differences in facility level releases across the early and late adopting states. For example, average, aggregate releases in early adopting states were only 60% as large as the releases in late adopting states. Early adopting states also had a relatively small reduction in aggregate TRI releases, with a large *increase* in TRI releases, net of CAA substances. For all other measures of toxic releases, early adopters showed reductions, post adoption, but those reductions were much smaller than those found in late adopting states. Furthermore, late adopting states showed reductions in all measures of toxic releases.

The choice of P2 programs also differs dramatically across early and late adopting states. In particular, technical assistance programs and grants were far more commonly available in early adopting states, relative to late adopting states, whereas filing fees and non-reporting penalties were more common in late adopting states.

Table III, Panel 1 summarizes releases for facilities located in states with low P2 stringency. Note that even *before* adoption, facilities located in the most stringent P2 program states have average releases that are lower than those found in other states, for all measures of toxic releases, except for CAA air releases, where the average facility level release is almost the same. And after the adoption of a P2 program, facility releases in the high P2 states fell by more than for those in low P2 states, again, with the exception for CAA air releases. CAA air releases actually fell more in the lower-stringency states so that post-adoption, average facility level releases were lower in low P2 states than in high P2 states. The most stringent P2 states also had a much higher rate of technical assistance and educational outreach, but a lower rate of grant support, filing fees and non-reporting penalties.

The differences in pre/post adoption facility level releases across early/late adopters and low/high stringency states captured by the descriptive statistics suggests that there may be important differences across these facilities. There are also important distinctions that exist at the state and industry levels between these groups. (Table IV provides data on the number of facilities found in each group.) In particular, an examination of the *unbalanced* panel of TRI reporters shows that the pattern of entering and exiting facilities (measured by the ratio of entering (or exiting) facilities to the number of facilities in the balanced panel) differs significantly in high P2 stringency states (see Table V). Here, the ratio is almost double in magnitude compared to that found in low P2 stringency states. This elevated level of entry and exit could reflect a higher level of competitiveness in the manufacturing sector. Industry composition also differs by group as evidenced by the sound rejection ($p = 0.000$) of the Kolmogorov-Smirnov test for the equality across the distribution of industries (based on 2-digit SIC). Although not presented here, data from the U.S. Census' County Business Pattern shows that the percentage of small facilities within the manufacturing sector is stable across time within groups, where the percentage is given by the number of manufacturing facilities (by 4-digit SIC within the given state) with between 10 and 50 full time employees divided by the total number of manufacturing facilities operating in that industry-state for that year. So, although there are differences across these groups, we can rule out that both the changes in releases over time within these groups, and the differences across these groups, are attributable to changes in industry composition or structure.

## IV. RESULTS

Regression results are given for three of the four different facility groupings discussed in the previous section. Results for facilities located in low stringency states are given below, broken down by adoption date (early/late). Due to both a lack of variation in, and a high level of correlation between, state P2 programs in high stringency states, results for these facilities are not included here, but are available upon request.

Four different measures of toxic releases are used in the analysis. The first consists of aggregate TRI releases for all TRI reporting chemicals in the balanced panel (as described in Section III). These chemicals are aggregated by weight across all pollution media. To address the issue of confounding effects from the CAA, the 1990 CAAA, and other potentially important policies, I also include measures for TRI releases, TRI 33/50 releases, and TRI Montreal Protocol releases, all *net* of CAA substances.

### *A. The Effects of State P2 Program Adoption on Facility Releases*

If P2 programs affect facility level releases, it should be the case that facilities that have access to P2 programs differ from facilities that do not have such access. Although the descriptive statistics suggest that this may be the case, they do not establish a causal relationship. An event-study, however, can be used to determine whether the adoption of a state P2 program affects facility level releases, under the assumption of state-program exogeneity – which is reasonable at the *facility* level but would be much harder to defend at a higher level of aggregation. Regressing the natural log of toxic releases (at time t) on an indicator variable which takes on the value of 1 if a facility in year t is located in a state which has an active P2 program in year t, and 0 otherwise (and controlling for year, industry (at the 2-digit SIC level), and facility level fixed effects) allows for the average treatment effect to be estimated. Regression results for aggregate toxic releases and toxic releases net of CAA substances are summarized in Table VI.[5]

First, note that in all cases, the effect of the 1990 PPA is negative and statistically significant. This is consistent with the generally held belief that the federal program was successful and helped polluters to reduce pollution levels. With respect to the adoption of a state P2 program, for both aggregate toxic releases and toxic releases net of CAA substances, the effect on facility level releases of the adoption of a state P2 program is negative, and statistically significant (for aggregate TRI releases, $\beta = -0.115$, SE = 0.03 and for TRI releases net of CAA substances, $\beta = -0.124$, SE = 0.03), even when taking into account year, industry, and facility level fixed effects. Interestingly, when facilities are grouped by whether the state is an early or late adopter relative to the 1990 PPA,

[5] Regression results for other subsets of TRI substances, such as CAA substances, and net air releases, as well as for the unbalanced panel, are available upon request. All of these results are consistent with those presented here.

adoption is only significant in early adopting states.[6] [7] This is consistent with a story of spill-over effects. If information leaks from early to late adopting areas, the effectiveness of P2 programs in late adopting states may be much smaller, with benefits having accrued prior to the adoption of a state program. The average treatment effect for facilities located in early adopting states is estimated at -23.3% (SE = 0.05) for aggregate TRI releases, and -24.2% (SE = 0.06) for TRI releases, net of CAA substances. To put these numbers into perspective, average facility releases fell by 66% and 69.5%, respectively, for aggregate TRI releases and net TRI releases over the sample period. So, in each case, approximately 35% of the reduction in releases can be attributed to the adoption of a state P2 program.[8]

Finally, the coefficient on adoption continues to be negative for facilities located in late-adopting states for both measures of toxic releases, but is imprecisely estimated in both cases.

*B. Testing for Spurious Correlation.*

Before continuing, it is important to rule out the possibility that the event study results are due to spurious correlation. In an ideal world, one could test for this by choosing an arbitrary adoption date taken from before the start of any state P2 program and testing for the significance of the "false" adoption date. Unfortunately, that option is foreclosed from us as TRI data only start in

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[6] Note that this is the case even though the descriptive statistics show that facilities in early adopting states became (on average) dirtier after the adoption of a state P2 program. The descriptive statistics results are due to behavior exhibited by 15 facilities in the data set. These facilities are in SIC codes 28 and 33 and their "adverse" effects on releases are captured by the facility fixed effects.

[7] The event study results are robust to the inclusion of industry-year fixed effects in lieu of individual industry and year fixed effects.

[8] As another comparison, emissions reductions for the heavily regulated criteria air pollutant, PM10, was approximately 34% between 1990-2003.

1987 and 61% of the facilities in the balanced panel have adoption dates that fall on or before 1989. I can, however, conduct the experiment where I take facilities that are located in late-adopting states (adoption post 1990), and for this group, construct a false adoption date in 1987. This is a somewhat less "clean" test than the ideal one because if there are any spill-over effects from "treated" facilities to "non-treated" facilities, these effects may still be captured by the false adoption date. I would expect, however, that even in that case, both the magnitude of the coefficient as well as the level of significance would be much smaller in the false regression than in the true regression.

Results for the false adoption-date regressions are summarized in Table VII. Regression results are presented for pooled (low-stringency state) facilities and are not broken down by early/late adopters as the construction of the false adoption date reclassifies all late adopting facilities as early adopters. For both aggregate TRI releases and TRI releases net of CAA substances, the false adoption date variable is not statistically significant at any reasonable level. These results hold whether I use the balanced or the unbalanced panel of TRI reporting facilities.

One additional comment should be made regarding this test. It could be said that it is not surprising to find the "false" adoption date to be insignificant when the effect of the true adoption date is not statistically significant in late adopting states. But, given that the sign is the same and that both the difference in magnitude, as well as the difference in statistical significance is large, I would argue that this result does provide reassurance that the strategy employed here is valid and that the results are not likely to be due to spurious correlation.

*C. The Effects of Individual State P2 Programs on Facility Releases*

Given the evidence that state P2 program adoption affects facility level releases, I turn next to estimating the effects of individual P2 programs. As described earlier, six different state programs were identified: technical assistance programs, educational outreach, grants, awards, filing fees, and non-reporting penalties. Due to the small number of observations, awards programs are not included in the analysis.

In general, P2 programs may be classified into one of two groups: cost-reducing programs and monitoring programs. Cost-reducing programs are believed to encourage participation in P2 programs by reducing the cost to the polluter of engaging in pollution prevention activities or abatement. These would include grant programs, which would directly lower the cost of participation, as well as technical assistance and educational outreach programs, which would indirectly lower the cost of participation by providing information to polluters on pollution prevention and abatement activities. Although in theory, all three of these programs could lead to a reduction in facility level releases, the manner in which this might occur may differ depending upon whether costs are reduced directly or indirectly. In particular, when cost-reduction occurs through the provision of information, two important considerations must be taken into account. The first is that there may be a period of "learning" which takes place so reductions may not occur immediately. And second, there may be informational spill-overs that occur from areas with P2 programs to areas without P2 programs.

Monitoring programs are programs that increase the ability of a regulator to directly, or indirectly monitor polluter behavior and encourage participation in P2 programs by signaling to polluters that regulators are watching to see whether they are responding to the quasi-regulatory mechanisms. This is believed to induce polluters to engage in pollution reducing, risk-management strategies. In the case of P2, filing fees and non-reporting penalties belong to this group by (1) encouraging polluters to report to the TRI (via non-reporting penalties, which increase the cost of *non*-participation) and (2) having polluters provide summary information to state regulators on their polluting behavior (via filing fees, which increase the cost of participation). It is not clear, however, how facilities might respond to these programs in light of the fact that regulators have limited (or no) ability to validate the *accuracy* of the reported release data. On the one hand, increased regulatory scrutiny may lead to a reduction in pollution if the polluter believes that regulators will adopt more stringent regulatory measures if the polluter does not voluntarily abate. On the other hand, increased regulatory scrutiny may lead to a change in reporting behavior if the polluter believes that regulators will look more carefully at the accuracy of the reporting, in which case, reported releases may increase as over-reporting will be less likely to incur any penalty than under-reporting.

Table VIII summarizes regression results from estimating Equation (1) with indicator variables for each of the 5 identified programs, as well as an indicator variable that is used to capture the effects of the federal level 1990 PPA. Because high P2 stringency states are not included in the analysis, it does not matter whether adoption or compliance dates are used as they are identical. To capture the possibility that the effects of a particular program (in particular, technical assistance and educational outreach programs) may change over time, I have included a term which interacts the state and federal program variables with a variable that measures the time since P2 adoption.

Columns 1-3 of Table VIII, panel 1 summarize the results for aggregate TRI releases. Column 1 includes all facilities, whereas Column 2 and 3 break the sample down by early and late adopting states. In all three specifications, the variable on Federal is negative and statistically significant. The largest effect is found for facilities located in early adopting states. For these facilities, the effects of the Federal program, however, dissipate over time. After approximately 15 years, the average effect, still remains larger than the effect found for facilities located in late adopting states (holding all other factors constant). Recall, however, that facilities in late adopting states start off much cleaner than those found in early adopting states.

In early adopting states, technical assistance programs have a positive effect on releases, but the effect slowly declines over time. The opposite holds true for educational programs, where there is a large, negative effect on releases initially, which dissipates over time. Of the state programs which can increase regulatory monitoring, only filing fees have a statistically significant effect, and are found to increase reported release levels. In late adopting states, of the different state level programs, only technical assistance programs have any statistically significant effect on facility level releases. And here, I find that their effects increase over time.

Because of the potential for confounding effects from the CAA and the 1990 CAAA, it is important to take care when interpreting the above results. So, to alleviate some of those issues, in Columns 4-6 I summarize regression results based on TRI releases *net* of any CAA substances.

When using only TRI releases net of CAA substances, I find that for the entire sample, (column 4), the effect of the Federal program is much larger (-1.5 versus -0.31), and dissipates somewhat more slowly over time. No state programs, however, have any statistically significant effect. When the sample is broken down into early and late adopters, however, a different picture emerges. First, facilities located in early adopting states have a much larger (negative) response to the Federal program with the effect slowly dissipating over time, the longer the state has had a P2 program in place. Technical assistance programs lead to lower facility level releases as well, and their effects increase slowly over time. Educational outreach continues to have a large, negative (and statistically significant) effect on facility releases upon adoption. Although non-reporting penalties do not have any effect on facility releases, filing fees lead to an increase in average facility level releases.[9]

When compared to facilities located in late adopting states, the Federal program has a much smaller (but still statistically significant) effect on average facility level releases. The effect of technical assistance programs, however, is large (negative), and statistically significant with no "learning" time. In fact, the effects of the technical assistance programs decline the longer the state has had a P2 program. No other state P2 programs have any statistically significant effect on average facility releases.

It is also interesting to look at the effects of P2 programs on TRI substances that are affected by other policies, such as the voluntary TRI 33/50 program and the Montreal Protocol. So, in Table VIII, Panel 2, I re-estimate equation (1) for these two measures of toxic releases, again, net of any CAA substances. While Montreal Protocol substances appear to be unaffected by any state P2 programs, that is not the case for TRI 33/50 substances. Although this sub-category of chemicals constitute a very small portion of over-all TRI releases, technical assistance programs appear to have a strong effect on their level of releases – with a slightly larger effect being found for facilities in late adopting states. Similar to TRI CAA substances, non-reporting penalties also appear to lower the level of TRI 33/50 substances as well, although in this case, the coefficient is only precisely estimated for the entire sample of reporters, and not for early/late adopters. One possible explanation for this result is that unlike the bulk of TRI releases, for both TRI CAA and 33/50 substances, regulators are able to monitor pollution releases and validate reported releases more easily. In that case, non-reporting and under-reporting can be identified more readily and penalized, making a non-

[9] One exception is TRI CAA air releases. For this group of toxic releases, non-reporting penalties have a very strong, negative effect on facility releases.

reporting penalty a more viable threat to polluters.

There is some question as to whether these results might be the result of using a balanced panel which only contains facilities that are in operation for a full 16 years. Although the results are not presented here, regressions based on the *unbalanced* panel of TRI reporters yield remarkably consistent results, throughout, strongly suggesting that the estimated effects of P2 programs on facility level releases are not due to special characteristics of the long-lived facilities used in the balanced panel.

## VI. CONCLUDING REMARKS.

The provision of government sponsored programs that are designed to encourage pollution prevention and abatement are a growing part of the regulatory arsenal used to manage environmental quality, but are not well understood. In this study, I find strong evidence to support the proposition that both federal and state P2 programs have had an effect on facility level toxic releases, but the effects depend critically not only on the relative timing of the program's adoption but also on the changes in their effects over time. This first factor is related to the benefits associated with spill-over effects that can occur when P2 programs collect and disseminate information to polluters. Providing this public good allows facilities in late adopting states to take advantage of the information made available in early adopting states, which can translate into more rapid reductions in pollution.

The second factor is related to two different effects. The first relates to the possibility that the type of information, or how the information is used by a given facility, may change over time. For example, if facilities do not have the accounting capability to measure their toxic releases, they may want to engage in improving their accounting methodologies before tackling any actual P2 or abatement activities. If so, it would not be surprising to see a change over time in the measured effects of facility level TRI releases to the adoption of a P2 program. The second relates to changes in a facility's motivations for responding to a P2 program. If the impetus for responding to a P2 program is to minimize the risk of more stringent regulations in the future, if the perceived risk changes over time, the facility's response may also change. In the case of P2 programs and toxic releases, since the first P2 programs were first adopted in 1984, there have been no real changes in the regulation of toxic pollutants (with the exception of those that were adopted under the 1990 CAAA). The lack of any formal regulatory action may be responsible for the reduced effectiveness of P2 programs over time. This begs the question, then, of whether the changes in polluting behavior caused by P2 programs is, in fact, permanent, or temporary in nature.

Evaluating the over-all effectiveness of P2 programs on toxic polluter behavior is made even more difficult by the fact that it is almost impossible to validate the accuracy of the toxic release data. This problem is reflected in the facility level response to filing fees and non-reporting penalties. It appears to be the case that filing fees affect a polluter's reporting behavior, but not necessarily their polluting behavior. And it is precisely because regulators cannot verify the data that this response can occur. Non-reporting penalties are, likewise, affected, in that they are only effective for the subset of TRI substances that can be most easily monitored by regulators: CAA substances, and TRI 33/50 chemicals. Without the ability to validate the quality of the data, regulators cannot easily determine whether the program is affecting polluting reporting or polluting behavior. Clearly, it is the latter that is desired, but improving the ability to validate the toxic release data should be an integral part of any regulatory measure.

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Table I. Balanced Panel of TRI Reporters, Manufacturing Sector: 1988-2003

| | All Years | | Before Adoption | | After Adoption | | |
|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev | Mean | Std. Dev | Mean | Std. Dev | Change |
| Aggregate TRI Releases (lbs) | 251995.60 | 1883485.0 | 388133.40 | 2265480.00 | 233345.80 | 1814341.00 | -39.88% |
| TRI CAA Air Releases (lbs) | 97574.31 | 389993.00 | 158576.80 | 735738.70 | 89334.78 | 325800.90 | -43.66% |
| TRI Net of CAA (lbs) | 154421.3 | 1779415 | 229556.70 | 2019116 | 144011 | 1733725.00 | -37.26% |
| TRI 33/50 Net of CAA (lbs) | 92.38 | 2136.93 | 112.03 | 1127.34 | 87.43 | 2243.25 | -21.96% |
| TRI Mtl. Protocol Net of CAA (lbs) | 801.53 | 12471.34 | 3200.23 | 29387.37 | 458.23 | 8133.94 | -85.68% |
| Technical Assistance | 0.65 | 0.48 | | | 0.66 | 0.48 | |
| Educational Outreach | 0.20 | 0.40 | | | 0.19 | 0.39 | |
| Grants | 0.43 | 0.50 | | | 0.43 | 0.50 | |
| Awards Program | 0.11 | 0.31 | | | 0.12 | 0.32 | |
| Filing Fee | 0.60 | 0.49 | | | 0.60 | 0.49 | |
| Non-Reporting Penalty | 0.64 | 0.48 | | | 0.64 | 0.48 | |
| Observations | 114512 | | 9077 | | 98513 | | |

Table II, Panel 1. Balanced Panel of TRI Reporters, Early Adopters: 1988-2003

| | All Years | | Before Adoption | | After Adoption | | |
|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev | Mean | Std. Dev | Mean | Std. Dev | Change |
| Aggregate TRI Releases (lbs) | 242374.50 | 1991367.00 | 241648.50 | 998161.50 | 236563.10 | 1995552.00 | -2.10% |
| TRI CAA Air Releases (lbs) | 88620.71 | 335686.80 | 129319.20 | 781571.50 | 85147.10 | 305719.50 | -34.16% |
| TRI Net of CAA (lbs) | 153753.80 | 1912556.00 | 112329.30 | 561706.50 | 151416.00 | 1925640.00 | 34.80% |
| TRI 33/50 Net of CAA (lbs) | 106.11 | 2647.93 | 151.23 | 1859.73 | 100.03 | 2710.50 | -33.68% |
| TRI Mtl. Prot.Net of CAA (lbs) | 744.23 | 11420.89 | 3038.49 | 27229.98 | 542.82 | 9093.68 | -82.14% |
| Technical Assistance | 0.67 | 0.47 | | | 0.66 | 0.47 | |
| Educational Outreach | 0.11 | 0.31 | | | 0.11 | 0.31 | |
| Grants | 0.53 | 0.50 | | | 0.52 | 0.50 | |
| Awards Program | 0.18 | 0.38 | | | 0.18 | 0.38 | |
| Filing Fee | 0.54 | 0.50 | | | 0.55 | 0.50 | |
| Non-Reporting Penalty | 0.63 | 0.48 | | | 0.63 | 0.48 | |
| Observations | 69600 | | 1879 | | 63606 | | |

Table II, Panel 2. Balanced Panel of TRI Reporters, Late Adopters: 1988-2003

| | All Years | | Before Adoption | | After Adoption | | |
|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev | Mean | Std. Dev | Mean | Std. Dev | Change |
| Aggregate TRI Releases (lbs) | 293821.60 | 1691795.00 | 405644.40 | 2039116.00 | 256799.80 | 1539453.00 | -36.69% |
| TRI CAA Air Releases (lbs) | 97654.76 | 352834.20 | 140994.50 | 467988.30 | 83539.67 | 306536.50 | -40.75% |
| TRI Net of CAA (lbs) | 196166.90 | 1612005.00 | 264649.80 | 1911955.00 | 173260.10 | 1477547.00 | -34.53% |
| TRI 33/50 Net of CAA (lbs) | 63.08 | 963.90 | 99.51 | 937.01 | 52.28 | 979.14 | -47.46% |
| TRI Mtl. Prot. Net of CAA (lbs) | 740.36 | 10305.54 | 2504.69 | 20054.92 | 167.36 | 2875.52 | -93.32% |
| Technical Assistance | 0.18 | 0.39 | | | 0.18 | 0.39 | |
| Educational Outreach | 0.14 | 0.35 | | | 0.15 | 0.35 | |
| Grants | 0.22 | 0.42 | | | 0.23 | 0.42 | |
| Awards Program | 0.00 | 0.00 | | | 0.00 | 0.00 | |
| Filing Fee | 0.66 | 0.47 | | | 0.68 | 0.47 | |
| Non-Reporting Penalty | 0.60 | 0.49 | | | 0.62 | 0.49 | |
| Observations | 19360 | | 4004 | | 14146 | | |

Table III, Panel 1. Balanced Panel of TRI Reporters in Low P2 Stringency States: 1988-2003

| | All Years | | Before Adoption | | After Adoption | | |
|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev | Mean | Std. Dev | Mean | Std. Dev | Change |
| Aggregate TRI Releases (lbs) | 233345.80 | 1814341.00 | 404880.70 | 2132174.00 | 244928.70 | 1920269.00 | -39.51% |
| TRI CAA Air Releases (lbs) | 89334.78 | 325800.90 | 158987.50 | 676098.50 | 88374.10 | 310790.40 | -44.41% |
| TRI Net of CAA (lbs) | 166621.9 | 1877035 | 245893.2 | 1946842.00 | 156554.6 | 1850123.00 | -36.33% |
| TRI 33/50 Net of CAA (lbs) | 104.09 | 2365.66 | 127.51 | 1223.90 | 98.29 | 2471.46 | -22.92% |
| TRI Mtl. Prot. Net of CAA (lbs) | 774.96 | 11634.13 | 3131.57 | 25665.82 | 466.58 | 8245.53 | -85.10% |
| Technical Assistance | 0.66 | 0.48 | | | 0.61 | 0.49 | |
| Educational Outreach | 0.19 | 0.39 | | | 0.17 | 0.38 | |
| Grants | 0.43 | 0.50 | | | 0.44 | 0.50 | |
| Awards Program | 0.12 | 0.32 | | | 0.15 | 0.35 | |
| Filing Fee | 0.60 | 0.49 | | | 0.63 | 0.48 | |
| Non-Reporting Penalty | 0.64 | 0.48 | | | 0.67 | 0.47 | |
| Observations | 90640 | | 6232 | | 78978 | | |

Table III, Panel 2. Balanced Panel of TRI Reporters in High P2 Stringency States: 1988-2003

| | All Years | | Before Adoption | | After Adoption | | |
|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev | Mean | Std. Dev | Mean | Std. Dev | Change |
| Aggregate TRI Releases (lbs) | 211663.40 | 1548451.00 | 351448.40 | 2533109.00 | 186517.20 | 1299935.00 | -46.93% |
| TRI CAA Air Releases (lbs) | 103566.80 | 476493.90 | 157677.10 | 852045.40 | 93218.68 | 380481.70 | -40.88% |
| TRI Net of CAA (lbs) | 108096.6 | 1344774.00 | 193771.30 | 2168960.00 | 93298.47 | 1147249.00 | -51.85% |
| TRI 33/50 Net of CAA (lbs) | 47.89 | 808.55 | 78.14 | 878.77 | 43.53 | 824.47 | -44.29% |
| TRI Mtl. Prot. Net of CAA (lbs) | 902.40 | 15236.71 | 3350.64 | 36232.21 | 424.46 | 7666.34 | -87.33% |
| Technical Assistance | 0.84 | 0.37 | | | 0.85 | 0.36 | |
| Educational Outreach | 0.29 | 0.46 | | | 0.28 | 0.45 | |
| Grants | 0.39 | 0.49 | | | 0.40 | 0.49 | |
| Awards Program | 0.00 | 0.00 | | | 0.00 | 0.00 | |
| Filing Fee | 0.50 | 0.50 | | | 0.49 | 0.50 | |
| Non-Reporting Penalty | 0.52 | 0.50 | | | 0.52 | 0.50 | |
| Observations | 23872 | | 2845 | | 19535 | | |

Table IV: Tabulation of Number of Facilities by Different State Groupings[a]

| | Low Stringency | High Stringency | Total |
|---|---|---|---|
| Early Adopter | 3891 | 459 | 4350 |
| Late Adopter | 870 | 340 | 1210 |
| Total | 4761 | 799 | 5560 |

[a] Note that the table *excludes* observations from states that adopt a P2 program in 1990.

Table V: Facility Entry and Exit by Different State Groupings Using the Unbalanced Panel of TRI Reporters, 1988-2003

| | Number of Entering Facilities | Number of Exiting Facilities |
|---|---|---|
| Early Adopting State | 12372 | 13334 |
| Late Adopting State | 3722 | 3977 |
| Low Stringency State | 16558 | 16972 |
| High Stringency State | 4109 | 5104 |

Table VI: The Effect on Facility Level Toxic Releases from the Adoption of a State P2 Program: Facilities in Low Stringency P2 States, 1988-2003.

| Variables | Aggregate TRI Releases | | | TRI Releases: Net of CAA | | |
|---|---|---|---|---|---|---|
| | All | Early | Late | All | Early | Late |
| Federal PPA | -0.765*** | -0.648*** | -0.358*** | -0.653*** | -0.535*** | -0.641*** |
| | (0.0401) | (0.0592) | (0.0771) | (0.0515) | (0.0752) | (0.0991) |
| Adoption Date | -0.115*** | -0.233*** | -0.0716 | -0.124*** | -0.242*** | -0.0541 |
| | (0.0278) | (0.0505) | (0.104) | (0.0349) | (0.0641) | (0.117) |
| Year Indicators | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Industry Indicators | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Facility Indicators | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Constant | 10.63*** | 10.52*** | 11.56*** | 9.618*** | 9.478*** | 11.42*** |
| | (0.115) | (0.179) | (0.213) | (0.195) | (0.243) | (0.379) |
| Observations | 84016 | 57438 | 13198 | 68624 | 47141 | 10940 |
| R-squared | 0.776 | 0.777 | 0.802 | 0.754 | 0.754 | 0.788 |

Table VII: Testing for Spurious Correlation Using False Adoption Dates

| Variables | Aggregate TRI Releases | TRI Releases: Net of CAA |
|---|---|---|
| Federal PPA | -0.248*** | -0.746*** |
| | (0.0507) | (0.0613) |
| False Adoption Date | -0.00458 | -0.0441 |
| | (0.0491) | (0.0630) |
| Year Indicators | ✓ | ✓ |
| Industry Indicators | ✓ | ✓ |
| Facility Indicators | ✓ | ✓ |
| Constant | 10.69*** | 9.659*** |
| | (0.116) | (0.183) |
| Observations | 79708 | 65150 |
| R-squared | 0.785 | 0.763 |

Table VIII, Panel 1: The Effect of State P2 Programs on Facility Toxic Releases in Low Stringency P2 States, 1988-2003.

| Variables | Aggregate TRI Releases | | | Aggregate TRI Releases, Net of CAA Substances | | |
|---|---|---|---|---|---|---|
| | All | Early | Late | All | Early | Late |
| Federal PPA | -0.311*** | -3.961*** | -0.251*** | -1.499*** | -4.393*** | -0.453*** |
| | (0.0433) | (0.727) | (0.0915) | (0.256) | (0.937) | (0.117) |
| Time_PPA | 0.0417*** | 0.189*** | -0.0319 | 0.0346** | 0.225*** | -0.0385 |
| | (0.0144) | (0.0476) | (0.0246) | (0.0174) | (0.0614) | (0.0274) |
| Technical Assistance | 0.0967 | 0.348** | -0.641*** | -0.0324 | 0.217 | -1.613*** |
| | (0.0637) | (0.153) | (0.243) | (0.0820) | (0.200) | (0.290) |
| Time_TA | -0.0114*** | -0.0196*** | 0.00948 | -0.00665* | -0.0104** | 0.0744*** |
| | (0.00279) | (0.00328) | (0.0191) | (0.00353) | (0.00415) | (0.0246) |
| Educational Outreach | -0.140* | -0.537** | 0.307 | -0.127 | -0.607** | 0.831* |
| | (0.0740) | (0.230) | (0.356) | (0.0984) | (0.306) | (0.473) |
| Time_Educ | 0.00922** | 0.0161*** | -0.0175 | 0.00554 | 0.00310 | -0.0296 |
| | (0.00378) | (0.00479) | (0.0289) | (0.00491) | (0.00632) | (0.0380) |
| Grants | -0.0964 | -0.246 | -0.288 | 0.107 | -0.511 | -0.371 |
| | (0.0754) | (0.313) | (0.210) | (0.102) | (0.432) | (0.296) |
| Filing Fees | 0.193*** | 0.445** | 0.308 | 0.157* | 0.568** | -0.0683 |
| | (0.0632) | (0.209) | (0.203) | (0.0844) | (0.280) | (0.285) |
| Non-Report. Penalties | -0.142** | 0.0366 | -0.296 | -0.175* | 0.489 | -0.0480 |
| | (0.0689) | (0.335) | (0.209) | (0.0916) | (0.461) | (0.289) |
| Year Indicators | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Industry Indicators | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Facility Indicators | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Constant | 10.58*** | 10.23*** | 11.60*** | 9.593*** | 9.063*** | 11.47*** |
| | (0.117) | (0.194) | (0.221) | (0.196) | (0.301) | (0.380) |
| Observations | 84016 | 57438 | 13198 | 68624 | 47141 | 10940 |
| R-squared | 0.776 | 0.777 | 0.803 | 0.754 | 0.754 | 0.790 |

Table VIII, Panel 2: The Effect of State P2 Programs on Facility Releases in Low Stringency P2 States, 1988-2003.

| Variables | TRI 33/50 Releases, Net of CAA Substances | | | Montreal Protocol Releases, Net of CAA Substances | | |
|---|---|---|---|---|---|---|
| | All | Early | Late | All | Early | Late |
| Federal PPA | -1.426*** | | -1.452*** | | -1.935* | -5.384 |
| | (0.433) | | (0.524) | | (1.075) | (3.920) |
| Time_PPA | -0.0108 | 0.138 | 0.0122 | 0.0205 | 0.0241 | 0.288 |
| | (0.0297) | (0.109) | (0.0477) | (0.0339) | (0.0652) | (0.325) |
| Technical Assistance | -0.149 | 0.203 | 0.344 | -0.143 | -0.108 | -0.294 |
| | (0.171) | (0.535) | (0.738) | (0.0903) | (0.182) | (0.190) |
| Time_TA | -0.0288*** | -0.0245*** | -0.113*** | 0.00486 | -0.00252 | 0.0649 |
| | (0.00766) | (0.00856) | (0.0426) | (0.0213) | (0.0265) | (0.0859) |
| Educational Outreach | 0.155 | 1.460 | -1.257 | 0.147 | 0.246 | 0.803 |
| | (0.197) | (1.030) | (1.008) | (0.135) | (0.229) | (0.539) |
| Time_Educ | 0.00499 | -0.00899 | 0.132** | -0.00791 | 0.000965 | -0.342 |
| | (0.00930) | (0.0120) | (0.0634) | (0.0297) | (0.0330) | (0.258) |
| Grants | 0.331* | 1.353 | 0.669 | 0.0629 | 0.413 | -0.255 |
| | (0.196) | (1.113) | (0.613) | (0.147) | (0.304) | (0.423) |
| Filing Fees | 0.296* | -0.866 | 0.599 | -0.107 | -0.126 | -0.355 |
| | (0.168) | (1.016) | (0.575) | (0.108) | (0.168) | (0.369) |
| Non-Report. Penalties | -0.594*** | -1.945 | -1.075* | 0.110 | -0.282 | 0.241 |
| | (0.180) | (1.221) | (0.577) | (0.141) | (0.343) | (0.347) |
| Year Indicators | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Industry Indicators | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Facility Indicators | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Constant | 7.951*** | 10.53*** | 3.946*** | 10.18*** | 9.938*** | 10.78*** |
| | (1.149) | (1.524) | (1.051) | (0.279) | (0.165) | (0.476) |
| Observations | 26750 | 18784 | 3931 | 5271 | 3509 | 1033 |
| R-squared | 0.816 | 0.812 | 0.840 | 0.834 | 0.835 | 0.839 |