# THE IMPACT OF VOLUNTARY PROGRAMS ON POLLUTING BEHAVIOR: EVIDENCE FROM POLLUTION PREVENTION PROGRAMS AND TOXIC RELEASES

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ABSTRACT:

We investigate how a class of voluntary environmental initiatives known as pollution prevention ("P2") programs affect toxic pollution. We construct a data base on federal and state-level P2 programs and exploit variation in adoption dates and program characteristics to study their effects on facility-level releases. We find convincing evidence that these mechanisms can alter polluter behavior. In particular, we find that (1) state P2 programs had a significant impact on average facility level toxic releases, reducing annual releases by 11%-15%; (2) for every $100,000 of federal matching funds awarded for state P2 activities, average facility level releases in the recipient state declined on the order of 1%-1.5%; (3) P2-induced reductions are significantly enhanced by information spillovers, diffused primarily via industry networks rather than geographic proximity; (4) facilities respond to technical assistance programs by reducing toxic releases, but only for substances that are not simultaneously regulated by formal command and control strategies; and (5) facilities respond to filing fees and non-reporting penalties by altering their toxic releases, but only for chemicals that are easily monitored by regulators.

KEY WORDS:

TRI, information spillovers, voluntary programs, toxic pollution, environmental regulation.

## THE IMPACT OF VOLUNTARY PROGRAMS ON POLLUTING BEHAVIOR: THE CASE OF POLLUTION PREVENTION PLANS AND TOXIC RELEASES

### I. INTRODUCTION

Voluntary (and so-called "quasi-regulatory") programs[1] have come to play an increasingly prominent role in environmental policy, at both the federal and state levels. There are now more than 50 such federal programs, with several dozen more at the state level.[2] A variety of programs has been implemented, including government sponsored educational outreach programs, abatement initiatives, and joint research ventures. The common objective underlying such initiatives is to improve environmental quality by "incentivizing" pollution reduction, without legally mandating changes in polluting behavior.

As described in greater detail in Section IIb, several hypotheses have been advanced to explain why polluters might participate in voluntary initiatives in ways that would lead to environmental improvements. These include stories about protecting institutional reputation, appealing to "green" consumers, deterring lobbying and boycotts by environmental groups, avoiding regulatory scrutiny -- and preempting future regulation. Despite extensive study, however, whether such programs actually lead to improvements in environmental performance remains unclear. Some studies have concluded that voluntary programs have been quite successful, while others have found

[1] We use the term "voluntary" program to include all voluntary initiatives and "quasi-regulatory" mechanisms. The latter refer to regulations or programs that do not mandate a change in polluting behavior, but may require other sorts of actions, such as filing reports. Examples include information disclosure regulations such as the Toxic Release Inventory and labeling laws.

[2] Voluntary programs have also been adopted at the industry level by industry groups or associations, and are sometimes run jointly between industry and government. These include programs such as Design for the Environment and Responsible Care.

either no effect, or detrimental effects, on environment performance. Such widely varying results may in part be due to differences in the characteristics of the programs studied. For example, while some programs directly encourage voluntary abatement (TRI 33/50 program), others involve adherence to environmentally sound management strategies (ISO 14001). Some require only the disclosure of polluter behavior (TRI, Department of Energy 1605(b)), while others primarily provide access to information (EPA Design for the Environment). There is little reason to think that responses should be identical across such disparate program types.

Methodological issues may also contribute to the difficulties in understanding and reconciling the conflicting results in the literature. These include the confounding effects of broader regulatory programs that may also influence the outcomes of interest; sample selection issues arising from the voluntary nature of the programs under study; and unaccounted for program spillover effects.

With these problems in mind, we focus here on a set of voluntary pollution prevention ("P2") programs, at both federal and state levels, that target hazardous waste, toxic waste, and toxic releases. Such 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 initiatives are particularly well suited for addressing some of the problematic aspects of the literature to date: several kinds of programs have been utilized, including those that provide information to polluters, as well as those that may enhance regulators' ability to monitor polluter behavior. P2 programs thus offer an opportunity to study differential effects across program types. We address the potentially confounding effects of over-lapping regulatory regimes by

[3] EPA OPPT Overview - Draft Version 2.0.

isolating multi-regulated pollutants in our study. Sample selection problems are controlled for by partitioning our sample into different groups for purposes of analysis. We also construct two different measures of potential spillover effects from the diffusion of information, within industries and via geographic proximity, based on the fraction of facilities exposed to P2 information-based programs outside a given facility's home state.[4] And the identification strategy we use exploits variation in exogenous program adoption dates to estimate their effects on facility-level toxic releases.

Using a balanced panel of nearly 6500 manufacturing facilities over a 16 year period, we find generally that (1) state P2 programs had a significant impact on average facility level toxic releases, reducing annual releases by 11%-15%; (2) for every $100,000 of federal matching funds awarded for state P2 activities, average facility level releases in the recipient state declined on the order of 1%-1.5%; (3) there is strong, robust evidence that P2-induced reductions are significantly enhanced by information spillovers, diffused primarily via industry networks rather than geographic proximity; (4) facilities respond to technical assistance programs by reducing toxic releases, but only of substances that are not simultaneously regulated by formal command and control strategies; and (5) facilities respond to filing fees and non-reporting penalties by altering their toxic releases, but only for chemicals that are easily monitored by regulators.

The paper is organized as follows. In Section II we provide basic regulatory background and a brief literature review. In Section III we describe our data, while in Section IV, we describe the model we estimate. In Section V we provide detailed summary statistics, and in Section VI we

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[4] We would like to thank an anonymous referee for encouraging us to explore the role of spillovers more thoroughly in this paper.

discuss our results. Section VII provides concluding remarks.

## II. BACKGROUND

*A. Relevant Regulatory Initiatives.* Described below are the most relevant regulations and programs affecting toxic releases.

*Toxic Release Inventory (TRI)*: 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, of which there were initially some 300, were required to report their toxic releases to a publicly maintained data base. Since 1988, the list of chemicals, threshold levels, and required TRI participants has evolved. Currently, over 600 chemicals are listed, and the group of required participants has expanded, among other things to include such industries as electric utilities as well as government facilities.

*TRI 33/50 Program*: TRI 33/50 was initiated as a voluntary program as part of the TRI. The EPA invited over 5000 companies to voluntarily participate in reducing releases of 17 TRI priority substances, by 1/3 (from 1988 baselines) by 1992 and by 1/2 by 1995. Target reductions were more than fully achieved by 1994. It should be noted that all TRI 33/50 chemicals are listed as hazardous air pollutants and regulated under the Clean Air Act.[5]

*Clean Air Act and Clean Water Act*: A subset of TRI substances are regulated under

[5] We have discovered that the TRI, insofar as it flags CAA-listed substances, contains significant errors. For example, all 17 TRI 33/50 substances are regulated under the CAA (section 112); only 2 are flagged as such in the TRI. At least a half-dozen or so substances that the TRI flags as CAA substances are not. We believe that those errors have not been recognized in the existing literature. So, even in studies that do try to control for the CAA substances (for example, Gamper-Rabindran (2006)), the results may still be confounded by the CAA, due to the unrecognized errors in the TRI.

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

*1990 Pollution Prevention Act*: The 1990 Pollution Prevention Act (PPA) 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 such industries as dry cleaners and producers of printed wire boards, that are known to produce large volumes of toxic releases, and are dominated by small and medium sized polluters for which investing in P2 research on their own is generally infeasible. The PPA also provides matching grants for technical assistance programs (an activity that actually began in 1988, prior to the enactment of the PPA); it also 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 reducing the cost to polluters of engaging in P2 activities through information dissemination.

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

*State P2 Programs, Community Right to Know Legislation, and Toxic Use Reduction Acts:* Several states have adopted P2, or P2-related, 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. State P2 programs include technical assistance, educational outreach, grants, and awards. In contrast with the PPA, many states also impose filing fees and prescribe non-reporting penalties for TRI reporters, either directly through P2 programs, or through expanded state-level right-to-know legislation.

A unique aspect of state P2 programs is that some have prescribed reduction goals for toxic releases and hazardous waste production. The targets, established on a state-wide basis, have ranged between 30% and 80% from some baseline year. There are, however, no associated penalties for non-compliance or other enforcement mechanisms in place.

*B. Existing Literature.* There is a substantial literature on the effectiveness of voluntary programs in the context of environmental regulation. Before turning to that literature, however, it is useful first to survey studies that focus on understanding both who might participate, and why.[6] As noted in the introduction, various explanations have been offered. They include: avoiding inspections and regulatory scrutiny (Innes and Sam (2008)); preempting future regulatory measures (Prakash and Potoski (2006); Brouhle, Griffiths, and Wolverton (2009), Khanna, Deltas, and Harrington (2009)); luring "green" consumers (Lyon and Maxwell (2008); Arora and Gangopadhyah (1995)); and deterring lobbying and boycotts (Maxwell, Lyon, and Hackett (2000);

[6] Although "voluntary" mechanisms may require some form of action by the polluters, they characteristically do not require polluters to reduce pollution levels. By "participation," then, we mean a polluter undertaking some form of action that leads (or may lead) to a reduction in its pollution level.

Baron (2001); Innes (2006)). How a polluter responds to a given voluntary program will depend upon what motivations underlie the polluter's participation decision; such considerations should influence both how we measure the effectiveness of such voluntary programs, and, ultimately how those programs are best designed.

Of the numerous voluntary environmental programs that have been adopted in the U.S., several have been widely studied. These include the TRI; TRI 33/50; ISO 14001; DOE 1605(b); Climate Wise; Responsible Care; Strategic Goals, and more.[7] But studies of the various programs has failed to reach any consensus on their effectiveness. That is true even among studies of the same program. For example, while Hamilton (1995), and Konar and Cohen (1997) find strong evidence of the TRI's effectiveness, Khanna, Quimio, and Bojilova (1998) and Bui and Mayer (2003) find little to no such effect.[8] Similarly, Pizer, Morgenstern, and Shih (2010) find support for the effectiveness of the DOE's 1605(b) program, whereas Kim and Lyon (2011) do not. Khanna and Damon (1999) and Innes and Sam (2008) both find significant effects for the TRI 33/50 program, while Gamper-Rabindran (2006) and Vidovic and Khanna (2007) do not. In this literature such examples are easy to come by.

There are several possible explanations for the apparent disparity in results. They include, of course, the usual suspects: weak identification strategies, often driven by severe data limitations;

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[7] ISO 14001 is an international certification program for environmental management practices; DOE 1605(b) is a voluntary greenhouse gas reporting program; EPA's Climate Wise is a voluntary corporate-wide greenhouse gas reduction program; Responsible Care is a voluntary program set up by the American Chemical Industry Council to improve environmental management; and the Strategic Goals Program is a joint partnership between the metal refinishing industry, government, and communities, also to improve environmental management.

[8] Khanna, Quimio, and Bojilova (1998) find no effect on aggregate releases, but find an alteration in the ratio of onsite and offsite releases.

sample selection bias; measurement error, and variation in measured outcomes (for example, toxicity weighted versus unweighted releases; total releases versus onsite or offsite releases). Of particular concern to us are the problems associated with the confounding effects of broader regulatory programs that may also affect the outcomes of interest. In the context of studies of TRI-listed substances, the effects of the Clean Air Act may be especially problematic: CAA-regulated substances constitute approximately 50% of all TRI releases by weight. (In contrast, CWA-regulated substances constitute less than 1% of TRI releases by weight.)

Another potential source of variation in findings is the influence that spillovers may have on the effectiveness of voluntary programs that provide information to polluters. Maxwell and Lyon (2008) argue generally that the standard approach of comparing "participants" to "non-participants" to determine the "effectiveness" of a program will be flawed if information obtained directly at participant facilities can spill over to non-participants, influencing conduct by the latter. The effects of such informational spillovers have, however, largely been ignored in the empirical (environmental) literature. That omission might also account for some of the disparate results that arise in studies of the effectiveness of environmental programs.

To address some of these difficulties, we use an identification strategy based on exploiting variation in the exogenous adoption dates of state P2 programs; after correcting for errors in the TRI data, we net out pollutants that face formal environmental regulations (or programs) as a way of addressing their potentially confounding effects; we parse our sample into different treatment and control groups to address sample selection issues; and we include explicit measures of spillovers to account for benefits that might flow from participating to non-participating facilities. Our estimation strategy is described in more detail in Section IV.

## III. Data

Toxic release data are taken from the EPA-TRI website (www.epa.gov/tri/tridata) for reporting years 1988-2003, with additional regulatory and chemical information taken from the EPA TRI Data Release Appendix E (Regulatory Matrix: TRI Chemicals in Other Federal Programs). The data are given by chemical and facility. Because reporting chemicals, threshold reporting levels, and required reporters changed during this period, we restrict our analysis to the subset of chemicals that were reported subject to reporting for all years 1988-2003 and for which the reporting threshold did not change. Likewise, we limit our analysis to the balanced panel of facilities in the manufacturing (SIC 2000-3999) sector that were required to report to the TRI for all years 1988-2003.

Data on federal P2 matching grants are taken from the EPA P2 website (www.epa.gov/p2). The site provides information on grant recipients (state or tribal organizations), grant proposals, and amounts received from 1988 (the first year of grant awards) forward. Eligible projects for funding involve "...work plans which offer pollution prevention (P2) technical assistance to business, promote research, or offer workshops/training in P2 practices that will prevent or reduce pollutants from entering the air, water, or land."[9] Regional EPAs have the responsibility to review P2 proposals and award any grants, as they deem appropriate. We allocate grant amounts to a state based on the location of the recipient. For grants issued to Regional EPAs or organizations that cover more than a single state, the amount is allocated to each relevant state in proportion to their shares of manufacturing value added in 1990.

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

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[9] EPA P2 website, "Pollution Prevention Grant Program FAQs"

Affairs, 0-871-931-1/97), the 1999 State TRI Program Assessment, and state environmental web sites. A total of six different P2 programs were found. They consist of technical assistance programs (such as hot-lines and on-site technical assistance), educational outreach programs (such as government sponsored seminars), grants and financial aid, award programs (for public recognition), filing fees (which are tied to TRI reporting and the number of chemicals being reported), and non-reporting penalties.

Annual state level data on debt financing, revenues, and government expenditures are taken from the United States Statistical Abstract.

## IV. Basic Model and Methodological Issues

Reduced form releases are modeled as:

$$\ln(TRI_{ijst}) = \alpha_0 + \beta\, lppa_{st-1} + \kappa\, Z1_{st} + \psi\, Z2_{st} + \mathrm{N}\, i\text{-}effect_{jst} + \nu\, i\text{-}time_{jst} + \Phi\, ip\text{-}effect_{jst} + \phi\, ip\text{-}time_{jst} + \delta_i + \sigma_j + \gamma_t + \epsilon_{ijst} \tag{1}$$

where *ln(TRI)* is the natural log of facility-level TRI releases for facility *i*, in industry *j*, state *s*, and year *t*. *lppa* is the one year lagged value of federal P2 grant money received in state *s*. *Z1* is a vector representing the existence of a particular type of P2 program (e.g technical assistance or non-reporting penalties) in state *s* in year *t,* and *Z2* is a vector of state characteristics that vary by year (for example, state-level government expenditures).

The variables *i_effect* and *ip_effect* vary across industry, state and time, and are designed to capture potential spillover effects from state-level P2 programs with an "informational" component that have previously been adopted elsewhere. The variable *i_effect* controls for industry-wide spillovers when the leakage of information occurs across facilities within the same industry.

Specifically, for facility *i* in 2-digit SIC code industry *j*, located in state *s*, in year *t*, *i_effect* is the fraction of all facilities in the country (excluding those in state *s*) that are in the same 2-digit SIC code and are located in a state that had a P2 initiative that included either technical assistance or educational outreach as of year *t*. The variable *ip_effect* is designed to capture spillover effects if the leakage of information depends not only upon being in the same industry, but also on geographic proximity. Thus *ip_effect* consists of the fraction of facilities within the same 2-digit SIC code located in bordering states, where the bordering state has adopted a P2 program with technical assistance or educational outreach as of year *t*.

The variables *i_time* and *ip_time* interact the spillover variables with a time variable that captures the number of years for which relevant -- either nation-wide for industry network effects, or in bordering states for geographically based industry network effects -- information spillovers have been available.[10]

Finally, 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.

*Requirements for consistency*: For the above to consistently estimate $\beta$, the "treatment" variable must be uncorrelated with any time-varying unobservables that affect facility level releases: in other words, $\epsilon$ must be orthogonal to the adoption of state-level P2 programs. In the case of TRI releases, the timing with which TRI information became public renders it highly unlikely that TRI data – at any level of aggregation – influenced the timing of state-level P2 programs. TRI data were

[10] The time variable begins in the first year for which any facility in the same 2-digit SIC code, located outside the home state, has access to a local P2 program that offers either technical assistance or educational outreach.

first made available for the 1988 TRI reporting year (RY) on October 3, 1990.[11] By that time, 27 states had *already* adopted a P2 program and the 1990 PPA had already been enacted. When the second year of TRI reporting (TRI RY 1989) became available on May 16, 1991, 48 states had adopted some form of P2 program. Only one state adopted a P2 program after 1992: Nebraska, which adopted a program in 1997.

If equation (1) is taken to model *toxic* releases and not just TRI releases, however, where unobserved aggregate toxic releases, $y^*$, can be thought of as the sum of (the observed) TRI releases and an (unobserved) "error" term, $\pi$, then the timing of TRI information alone will not be enough to preclude the possibility of correlation between state P2 adoption and the composite error term, $\epsilon - \pi$. To ensure that this is not the case, we run a Hausman specification test using the ratio of a state's debt to its revenue as an instrument for the state P2 adoption variable.[12] The Hausman test fails to reject the null hypothesis of exogeneity at any conventional level of significance ($p>0.90$), so we can be confident that that our exogeneity assumption is valid.

## V. Descriptive Statistics

The balanced panel of TRI facility data are from 6,486 facilities, yielding 103,776 facility-year observations between 1988-2003. This consists of approximately one-third of all available facility-year observations in the TRI during this period. Summary statistics are given in Table I.

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[11] It should be noted that TRI data was collected for the year 1987 and released to the public on June 19, 1989. The validity of that year's data, however, has long been in question and both researchers and regulators have eschewed the use of it.

[12] The instrument meets the Stock and Yugo criteria for a strong instrument with a first-stage F-statistic >100. (See Stock and Yugo, 2005.)

Annual releases of TRI substances by facilities in our panel average 196,833 pounds. Of those, by weight, 60% are air, 1% are water, and 39% are land (and underground) releases. Due to the potential confounding effects of the CAA, we also report descriptive statistics for toxic releases net of any CAA substances.[13] Over-all, 51% of all TRI releases face formal command and control regulation under the CAA ("CAA air releases"), leaving 49% ("TRI Net of CAA") of aggregate TRI releases primarily facing voluntary regulation. TRI 33/50 substances make up, on average, 26% of all facility level TRI releases, but they are all also classified simultaneously as hazardous air pollutants and face regulation under the CAA (section 112(b)). Thus, in netting out CAA regulated substances, we net out all TRI 33/50 substances as well.

The average annual level of federally funded matching grants in the sample is approximately \$121,000, with a minimum of \$0 and a maximum of \$1,105,000. The average sum of state grants awarded in a given year was just under \$200,000. In 1987, 13 states received federal matching grants, with an average state funding level of \$256,000. In 2002, 45 states received federal matching grants with an average state funding level of \$105,000. In the aggregate, New Jersey, California, and New York received the most money from the federal matching grant program although it is interesting to note that these were not the three dirtiest states in terms of toxic releases (or air quality, as measured by the criteria air pollutants) during this period.

With respect to state-level P2 programs, technical assistance programs affect 65% of facility-year observations, with 20% of all facility-year observations having educational outreach opportun-

[13] CWA substances make up approximately 2% of all TRI water releases in the sample, or under 0.1% of all TRI releases, by weight. Given the very small quantity of total (and water) releases that are affected by the CWA, we do not separate out the effects of any CWA regulations on TRI releases, although doing so does not change our results in any meaningful way.

ities. (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 affect 61% of facility-years, and 63% have non-reporting penalties.

Columns 2 and 3 of Table 1 provide summary statistics 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 31% (19% for net TRI) lower by weight after adoption of a state P2 program and CAA air releases were 40% 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, other regulatory changes, or something else, cannot be determined from the descriptive statistics alone.

We must also consider how other conditions might affect facility-level responses to P2 programs. One such condition is the possibility of "equilibrium sorting," with firms making 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 differ across groups based on such (potentially unknown) state characteristics, in which case estimates based on the entire sample may obscure important behavioral variations in the data.

To allow for this, we group facilities by whether they are located in a state that is an "early" or "late" adopter of a P2 program, relative to the adoption of the federal 1990 PPA. In Table II, Panels 1 and 2, descriptive statistics are thus given for facilities 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 (1460 facilities, or about 19% of the sample) are not included in calculating the descriptive statistics given here.

Even this crude partition discloses important differences in facility level releases across the early and late adopting states. For example, average (aggregate) facility level releases over all years in early adopting states was only 78% of those found in late adopting states. And although post-adoption average releases remained lower in early adopting states than in late adopting states, aggregate TRI releases and TRI releases net of CAA substances actually *rose* post adoption in early adopting states by 0.74% and 68.76%, respectively. Facilities in late adopting states exhibited declines in all measures of toxic releases post-adoption.

The type of P2 program adopted also differs across early and late adopting states. In particular, technical assistance programs and grants were far more common in early adopting states whereas filing fees were more common in late adopting states. Levels of non-reporting penalties were approximately the same across the groups.

Facility response to state P2 programs may also differ systematically across states depending upon whether a state includes a specified state-wide numeric reduction goal and corresponding compliance date as part of their P2 program. The potential differences in facility response may be for a variety of reasons, including (1) differences in perceived "risk" of future regulation in states with target reduction goals; (2) differential response to the adoption and compliance date; and (3) equilibrium sorting of facilities based upon unobserved characteristics of states that adopt reduction goals for toxic releases. So, in Table III, we summarize releases for facilities sorted by whether they are located in states with or without reduction goals. In Panel 1, we look at facilities in states without specific reduction goals. Over-all, facilities in these states look remarkably similar to those found in the entire sample (which is not surprising, as they constitute about 80% of our sample).

With the exception of net TRI releases, changes in average facility level releases pre- and post-adoption are within 1%-2% of those found for the whole sample. Net TRI releases in those same states post-adoption fell by 28%, however, compared to 19% in the whole sample.

In Panel 2 of Table III, releases are summarized for facilities located in states with target reduction goals (1353 facilities, or approximately 21% of all facilities in the sample). Note that, even *before* adoption, facilities located in those states had average releases that were lower than those found in other states, for both aggregate and net TRI releases.[14] And, after adoption, their releases were lower than those in states without target reductions in all categories, although the reduction in net TRI releases was small (2.62%). In terms of program types, states with target reduction goals had a 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 adopting states and states with/without reduction goals captured by the descriptive statistics suggests that there may be important differences across these facilities. For example, industry composition is significantly different across those groups, as a Kolmogorov-Smirnov test for the equality across the distribution of industries (based on 2-digit SIC) is soundly rejected ($p < 0.001$). Although not presented here, an examination of the entire unbalanced panel of all 317,604 facility-year observations between 1988-2003 also disclose very different patterns of entry and exit amongst those groups, which could reflect variations in competitive economic conditions, affecting the type of facilities that would survive in the balanced panel.

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[14] The difference in states with and withouth target reduction goals does not seem to be due to differences in CAA releases between the two groups: these were virtually identical across the groups.

## VI. RESULTS

Our results are organized, as follows. In section A we discuss the average treatment effects of federal and state P2 programs on facility-level releases. In B we check for the robustness of our estimates to the possibility of spurious correlation through falsification tests. In section C, we look more closely at how different types of state P2 programs affect facility-level releases. In all estimations, we use two measures of toxic releases: aggregate TRI releases, and TRI releases net of CAA substances. For each measure, TRI chemicals are aggregated by weight.

Although we do not report the estimated coefficients, in all specifications we include individual facility, industry (at the 2-digit SIC level), and year fixed effects. State-level governmental expenditures are included to control for time-varying state characteristics that may be related to the economic health of the state. Cluster-robust standard errors are given in parentheses.

### *A. The Effects of Federal and State P2 Programs on Facility Releases*

In Table IV, we summarize our results for the estimation of equation (1). In columns (1) and (4), the full balanced panel of facilities is included. In columns (2) and (5), we include only facilities located in states that are early P2-adopters, whereas results for facilities located in late P2-adopting states are summarized in columns (3) and (6). In each instance the first panel reports results using aggregate toxic releases, while the second reports them for TRI releases net of CAA substances.

For the full sample, we find that the effect of (lagged) federal P2 funding (*lppa*) on average facility level releases (aggregate and net) is negative, and statistically significant. The magnitude of the effect, moreover, is an order of magnitude larger for net TRI releases (coef = -1.55 e-07) than for aggregate releases (coef = -9.07e-08), suggesting that the federally funded program efforts may be targeted on less regulated toxic pollutants, where there may be less information available (for example, substances that do not fall under the CAA) on abatement and pollution prevention activities. The estimate on net TRI releases indicates that an additional $100,000 in federal matching funds received by a state in the previous year is associated with a decline in average annual facility level releases (in that state) of 1.55% in the current year.

These results hold for the subset of facilities located in early- adopting states but not for those located in late-adopting states. For the latter we find no statistically significant effect for the federal matching grant program. That is somewhat unexpected as, on average, the grant size in late-adopting states was much larger than those found in early-adopting states. So, although those states received more federal funds (on average, an annual level of $238,000 in late-adopting states versus $138,000 in early-adopting states), the grants did not seem effective at reducing releases. (The explanation for this, however, will appear to lie elsewhere.)

There may be some uncertainty about whether one year is the correct lag structure to be using for the matching grant variable, as it may take more than a year for the effects of the federal funds to be reflected in facility behavior. Although not reported here, our results are robust to including up to 4 additional lags (with all coefficients negative and statistically significant) as well as to using the *cumulative* amount of federal P2 matching grants awarded. Using a single lag thus tends to underestimate the effects of federal matching grants on average facility level releases. (In all cases, however, the absence of statistical significance in late adopting states persists.)

The average effect on facility level releases of the adoption of a state P2 program is similar to that found for the federal program: the effect is negative and statistically significant for the sample as a whole and for facilities located in early-adopting states, but not for facilities in late-adopting states. The estimated average treatment effect for net TRI releases is -17.7% (-11.0% for aggregate releases) for the whole sample, and -23.2% (-28.0%) when we look only at facilities located in early-adopting states.

One important conclusion to be drawn from these estimates is that the reductions in TRI releases resulting from both the federal matching grant program and state P2 adoptions are not due simply to reductions in substances that are formally regulated under the CAA (or are part of the TRI 33/50 program): on the whole, the greatest reductions occur in TRI substances that are not regulated under the CAA, and are thus attributable to the voluntary program. To put the magnitude of these reductions into perspective, it is useful to note that average facility releases fell, in the aggregate, by 20% for net TRI releases over the 1988-2003 sample period. By way of comparison, emissions reductions for the heavily regulated criteria air pollutant PM10 was approximately 34% between 1990-2003.

Spillover effects are captured in our model through four different variables: *i_effect* and *ip_effect*, which capture industry-network and industry-proximity spillovers, respectively; and *i_time* and *ip_time*, which interact the industry and proximity spillovers with a variable that captures the length of the period over which the spillover effects have been accruing. That period is measured by how long any informational programs have been in effect for a given 2-digit SIC code, outside of the facility's home state (and in the geographic area of interest: nationwide, or in bordering states).

Our estimates of industry network spillovers are large, negative, and significant in all specifications, including for facilities located in late-adopting states. Geographic proximity may play some role, but it is clearly dominated by industry-based networks. That is not surprising, as we would not expect information-based intra-industry spillovers to be especially dependent upon proximity. Given the magnitude of the estimated coefficients on the network spillovers, even though their effects appear to dissipate slowly over time (shown by the positive, and sometimes significant coefficient on *i_time* and *ip_time*), it seems clear that ignoring spillovers will lead to a serious underestimation of the effectiveness of P2 programs on facility-level TRI releases.

Spillovers may be of particular importance for facilities in late-adopting states, where we found no statistically significant direct effect from the federal matching grant program or the adoption of a state P2 program. It is also of note that the magnitude of the coefficient estimate on the industry-network spillover in late-adopting states is nearly twice that for facilities in early-adopting states. That is true whether we look at aggregate or net TRI releases. A plausible explanation for these findings is that, in the early adopting states, for which the coefficient estimate on the (local) P2 program is negative and significant, the impact of informational spillovers to some extent duplicates that of the local program. In that event the marginal impact of the spillovers might reasonably be expected to be smaller than in a state with no P2 program of its own, for which intra-industry spillovers from earlier adopting states may serve as the initial and might well serve as the principal mechanism by which informational aspects of state P2 programs influence facility behaviour. In all events, the difference in magnitude between the spillover coefficients across these two subsets of facilities is remarkably robust.

We also partitioned our sample into facilities located in states that did, and did not, adopt state-wide target reduction goals. For facilities in states that did adopt such targets, we need to allow for differences in responses to (1) the adoption of the program, and (2) the date by which compliance with the objective was to be met. To allow for that we introduce two variables to capture the average treatment effect of those state P2 programs, in lieu of a single adoption variable. The first of these captures the average effect during the years between the adoption and compliance dates (*between*), while the second captures the average effect post compliance date (*compliance*). We summarize these results in Tables V and VI, respectively.

Not surprisingly, the results for facilities located in states without reduction goals (Table V) are much like those for the over-all sample. That, however, is not the case for facilities located in states with reduction goals (Table VI), where we find some unusual results. For this subset of facilities, we find -- for *aggregate* TRI releases -- that average facility releases *increased* after the adoption of a state P2 program by 16.5%, and increased further (by 32%) post compliance date (column 1). We also find that, while industry-wide spillovers again reduced facility releases, geographically based spillovers increased facility releases, at least for this sub-sample as a whole. These results do not hold for the subset of facilities located in the early-adopting states, but are consistent with estimates for facilities located in the late-adopting states, although the results for the latter set of facilities are not always statistically significant. These results are unexpected and difficult to explain, but could simply be due to both the confounding effects of the TRI-CAA substances and to the small number of facilities in these few states (11 states total with target reduction goals, 3 in each subset of early/late P2-adopting states).

That explanation is corroborated by the fact that, when we look at *net* TRI releases, the unusual results disappear. For net releases, although we find no statistically significant effect of the federal matching grant program, we do find that adoption of a state P2 program reduces average facility level releases, at least for facilities located in early-adopting states (coef = -0.831, SE = 0.325). No statistically significant reductions occur, however, after the compliance date is reached. Industry-wide network spillovers continue to be of significance in reducing facility releases; their effects again appear to dissipate over time. Neither the adoption nor the compliance date for a state P2 program has any effect on facility level releases in late-adopting states.

These, then, constitute our principal findings. Taken together, they provide clear evidence that both federal and state-level P2 programs have led to significant reductions in average facility-level toxic releases, and that those reductions were not confined to formally regulated pollutants (e.g., the CAA-regulated substances). To the contrary, they were, on the whole, most pronounced among toxic pollutants subject to informal, but not formal, regulation, even after netting out TRI 33/50 substances. Beyond that, we document a central role for industry network spillovers from state P2 programs in reducing toxic releases, one that is especially pronounced in states that were late in adopting a P2 program for themselves. Our findings indicate that ignoring the effect of spillovers will lead to serious underestimation of over-all program effects.

### *B. Testing for Spurious Correlation.*

It is important to rule out the possibility that our results are the product of spurious correlation. In an ideal world, we could test for that 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 for us, as TRI data are available only starting in 1988, and 61% of the facilities in the balanced panel are in states with adoption dates during or before 1989. In lieu of this, we conduct a somewhat less clean experiment, in which we alter the adoption date for all facilities by some arbitrarily chosen length of time. Specifically, we substitute false adoption dates for each facility that are at least one year *before* its actual adoption date, and then re-estimate the "effects"of state P2 programs using the false dates. Results (for a false adoption date equal to the actual date - 1 year) are summarized in Table VII and presented for the sample as a whole, as well as for the sample broken down by facilities located in states with and without reduction goals. For facilities located in states with a reduction goal, we only make use of the adoption date for the falsification test.[15]

In all cases, we find that the coefficient on the false adoption date is insignificant. These results are robust to using a false adoption date that is 2 or more years prior to the actual date as well (in particular, though not reported, additional tests were conducted for dates 2, 3, and 4 years prior to the actual date of adoption). Collectively, we take this as convincing evidence that our results are not driven by spurious correlation.

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

Given evidence that state P2 programs do reduce average facility level toxic releases, it is reasonable to ask to what extent (if any) those reductions vary with the type of P2 program adopted. Determining which P2 programs facilities respond to may also provide insight into what might motivate the facility to participate in a P2 program. To address that question, we estimate the effects of state P2 programs on facility level toxic releases, broken down by program type. In the following regressions, we note that our principal findings on the effects of federal programs and spillovers from state programs persist, so we concentrate our discussion below on the facility-level responses to individual programs.

As described earlier, six program types were identified: technical assistance, educational outreach, grants, awards, filing fees, and non-reporting penalties. Awards programs, however, are

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[15] Although some caution should be exercised when interpreting the results for facilities located in states with reduction goals, it is valid to use only the adoption date for net TRI releases as we cannot reject the null hypothesis that the coefficient on the variables *between* and *compliance* are the same ($p = 0.07$).

not included in our analysis due to their small number of observations in our data. We limit the results that we present to the aggregate sample; the limited variation in the program types adopted makes it difficult to interpret results when we break our sample down into facilities located in early/late P2 adopting states, or facilities located in states with/without target reduction goals.

Of those five P2 program types, two provide information to polluters (technical assistance, educational outreach), one directly reduces the cost of participation (grants), one increases the cost of *non*-participation (non-reporting penalties), and one may help to increase a regulator's ability to monitor polluter response (filing fees[16]). Although each such program could, in principle, alter polluter behavior, facility response could vary by program type, depending upon the facility's underlying motivation to participate in voluntary programs.

Finally we also allow for changes in facility level response to different programs over time by including interactions between P2 program types with a time variable, that captures how long the P2 program has been in place. Results are summarized in Table VIII.

In our simplest specification for aggregate TRI releases (column 1), we find that only filing fees and non-reporting penalties have any statistically significant effect. In particular, filing fees lead to an *increase* in reported releases of almost 22%, whereas non-reporting penalties lead to a *decrease* in reported releases of approximately 23%. Although not reported here, these results are driven almost entirely by the CAA substances. What this may reflect is that regulators can more easily

[16] State-imposed filing fees are tied to TRI reporting requirements and are typically increasing in (1) the number of TRI chemicals being reported and (2) the size of the facility, based on number of employees. Because fees are tied to reported releases, this policy provides regulators an additional opportunity to scrutinize polluters (and what they are reporting) that would not necessarily exist if polluters were simply submitting their TRI reports to their state environmental agencies for submission to a publicly available data base.

verify whether a facility is reporting such releases, as well as their quantities, thereby influencing facility response.

These results are robust to the inclusion of program-time interaction variables. But when time interactions are included, state grant programs also become statistically significant. Although having a state P2 grant program leads initially to a statistically significant increase in reported releases (coef = 0.118, SE = 0.068), the effect declines the longer the state program has been in place. Within 4 years of having such a program, the net effect is a decline in average facility level releases. This could reflect how facilities use grants over time -- perhaps initially to improve pollution accounting techniques, and making capital investments that lead to reductions in reported releases only with a lag.

A somewhat different picture emerges when we look at net TRI releases. In that case, technical assistance programs are found to have a large (-20%), statistically significant effect on facility level releases. This result is robust to the addition of the program-time interaction variables. What is more, it is consistent with our findings that state P2 programs generally have a quantitatively more significant impact on net TRI releases, and that industry network effects, which operate through the transmission of information, are significant in virtually all our specifications. For net TRI releases, on the other hand, neither filing fees nor non-reporting penalties are statistically significant.

## VI. CONCLUDING REMARKS.

To return to our most central findings, our study provides strong evidence for the proposition that both federal and state P2 programs have led to significant reductions in average facility-level toxic releases. These reductions occur in both CAA-regulated TRI substances as well as in TRI substances that do not face formal regulation. We find that the adoption of a state P2 program can lead to reductions of facility level releases on the order of 11%-15%. And we find that even modestly sized federal P2 matching grants ($100,000) given to state organizations can lead to non-trivial reductions (1.5%) in facility level releases at the state level.

Spillovers from P2 programs that offer information-based support to polluters appear to play a critical role in the success of these programs. We find that these spillovers work mainly through industry networks and are not dependent upon proximity. Furthermore, they appear to be of particular importance to facilities located in late P2-adopting states. Ignoring spillovers may lead to a significant underestimation of the effectiveness of P2 programs.

Facility-level responses to the various types of P2 programs also differ. In particular, technical assistance programs are consistently effective at lowering average facility level releases of non-CAA TRI substances. This suggests that facilities may be more likely to participate in voluntary programs that lower the cost of reducing pollution. Furthermore, we find evidence that facilities respond to filing fees and non-reporting penalties by changing only their reported levels of substances that may be more easily monitored by regulators. So, if facilities are participating because they are concerned about present or future regulations, they may only be doing so with respect to pollutants that they believe the regulator can observe.

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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) | 196833 | 1294917 | 271138 | 1303268 | 186880 | 1262678 | -31.08% |
| TRI CAA Air Releases (lbs) | 101007 | 858735 | 154655 | 654657 | 93039 | 828524 | -39.84% |
| TRI Net of CAA (lbs) | 95826 | 946718 | 116483 | 1055141 | 93841 | 933581 | -19.44% |
| Federal PPA State Grant ($) | 144627 | 166273 | 199612 | 256899 | 139180 | 134924 | -30.27% |
| Technical Assistance | 0.65 | 0.48 | | | 0.65 | 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 | 0.61 | 0.49 | | | 0.61 | 0.49 | |
| Non-Reporting Penalty | 0.63 | 0.48 | | | 0.63 | 0.48 | |
| Observations | 103776 | | 8240 | | 89261 | | |

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) | 189846 | 1416522 | 185633 | 888397 | 187012 | 1392337 | 0.74% |
| TRI CAA Air Releases (lbs) | 97318 | 1056307 | 130099 | 805458 | 93293 | 1005363 | -28.29% |
| TRI Net of CAA (lbs) | 92528 | 929375 | 55534 | 337917 | 93719 | 949865 | 68.76% |
| Federal PPA State Grant ($) | 131723 | 152733 | 130325 | 155576 | 133550 | 140634 | 2.5% |
| Technical Assistance | 0.67 | 0.47 | | | 0.66 | 0.47 | |
| Educational Outreach | 0.11 | 0.31 | | | 0.10 | 0.31 | |
| Grants | 0.53 | 0.50 | | | 0.52 | 0.50 | |
| Awards Program | 0.18 | 0.38 | | | 0.18 | 0.39 | |
| Filing Fee | 0.55 | 0.50 | | | 0.56 | 0.50 | |
| Non-Reporting Penalty | 0.63 | 0.48 | | | 0.62 | 0.48 | |
| Observations | 62816 | | 1692 | | 57409 | | |

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) | 244001 | 1319807 | 310921 | 1429384 | 223548 | 1302665 | -28.10% |
| TRI CAA Air Releases (lbs) | 95720 | 333618 | 138377 | 441027 | 82065 | 293560 | -40.69% |
| TRI Net of CAA (lbs) | 148281 | 1242538 | 172544 | 1293155 | 141483 | 1246055 | -18.00% |
| Federal PPA State Grant ($) | 174261 | 175471 | 202577 | 264520 | 168596 | 132271 | -16.77% |
| Technical Assistance | 0.17 | 0.38 | | | 0.18 | 0.38 | |
| Educational Outreach | 0.14 | 0.34 | | | 0.14 | 0.35 | |
| Grants | 0.21 | 0.41 | | | 0.22 | 0.41 | |
| Awards Program | 0.00 | 0.00 | | | 0.00 | 0.00 | |
| Filing Fee | 0.67 | 0.47 | | | 0.68 | 0.47 | |
| Non-Reporting Penalty | 0.61 | 0.49 | | | 0.63 | 0.48 | |
| Observations | 17600 | | 3628 | | 12872 | | |

Table III, Panel 1. Balanced Panel of TRI Reporters in States Without Target Reduction Goals: 1988-2003

| Variable | All Years | | Before Adoption | | After Adoption | | |
|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev | Mean | Std. Dev | Mean | Std. Dev | Change |
| Aggregate TRI Releases (lbs) | 208551 | 1416431 | 297733 | 1437065 | 198030 | 1378448 | -33.49% |
| TRI CAA Air Releases (lbs) | 101499 | 938875 | 153309 | 565587 | 94241 | 910050 | -38.53% |
| TRI Net of CAA (lbs) | 107052 | 1037963 | 144424 | 1253836 | 103788 | 1018849 | -28.14% |
| Technical Assistance | 0.60 | 0.49 | | | 0.60 | 0.49 | |
| Educational Outreach | 0.17 | 0.38 | | | 0.17 | 0.38 | |
| Grants | 0.44 | 0.50 | | | 0.44 | 0.50 | |
| Awards Program | 0.14 | 0.34 | | | 0.15 | 0.35 | |
| Filing Fee | 0.63 | 0.48 | | | 0.64 | 0.48 | |
| Non-Reporting Penalty | 0.66 | 0.47 | | | 0.66 | 0.47 | |
| Observations | 82128 | | 5662 | | 71544 | | |

Table III, Panel 2. Balanced Panel of TRI Reporters in States With Target Reduction Goals: 1988-2003

| Variable | All Years | | Before Adoption | | After Adoption | | Change |
|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev | Mean | Std. Dev | Mean | Std. Dev | |
| Aggregate TRI Releases (lbs) | 152376 | 651476 | 212727 | 942748 | 141856 | 597613 | -33.32% |
| TRI CAA Air Releases (lbs) | 99138 | 436928 | 157612 | 816998 | 88183 | 337748 | -44.05% |
| TRI Net of CAA (lbs) | 53237 | 424012 | 55115 | 316933 | 53673 | 444196 | -2.62% |
| Technical Assistance | 0.84 | 0.37 | | | 0.85 | 0.36 | |
| Educational Outreach | 0.29 | 0.45 | | | 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 | 21648 | | 2578 | | 17717 | | |

Table IV: Average Treatment Effects from Federal and State P2 Programs, 1988-2003[a]

| Variables | Aggregate Releases All | Aggregate Releases Early | Aggregate Releases Late | Net Releases All | Net Releases Early | Net Releases Late |
|---|---|---|---|---|---|---|
| lppa | -9.07e-08** | -1.17e-07** | 1.03e-09 | -1.55e-07*** | -2.04e-07*** | -7.23e-08 |
| | (3.66e-08) | (5.65e-08) | (7.87e-08) | (4.82e-08) | (7.11e-08) | (1.08e-07) |
| State P2 | -0.108*** | -0.281*** | -0.0928 | -0.177*** | -0.232*** | -0.0961 |
| | (0.0379) | (0.0603) | (0.175) | (0.0475) | (0.0813) | (0.186) |
| i_effect | -1.042*** | -1.142*** | -2.002*** | -2.017*** | -1.468*** | -2.488** |
| | (0.297) | (0.386) | (0.732) | (0.404) | (0.509) | (1.028) |
| i_time | 0.00284 | -0.0196 | -0.0168 | 0.129*** | 0.100* | 0.0222 |
| | (0.0367) | (0.0470) | (0.0936) | (0.0457) | (0.0566) | (0.129) |
| ip_effect | -0.124* | -0.123 | 0.111 | -0.190** | -0.218* | -0.209 |
| | (0.0637) | (0.0912) | (0.127) | (0.0856) | (0.125) | (0.179) |
| ip_time | 0.0168* | 0.0289** | 0.00212 | 0.0209* | 0.0152 | 0.0441 |
| | (0.00937) | (0.0131) | (0.0273) | (0.0113) | (0.0160) | (0.0333) |
| Constant | 10.54*** | 10.72*** | 10.38*** | 9.590*** | 9.270*** | 11.06*** |
| | (0.248) | (0.268) | (0.745) | (0.318) | (0.314) | (0.712) |
| Observations | 95667 | 57857 | 16275 | 73189 | 44477 | 12581 |
| R-squared | 0.775 | 0.772 | 0.790 | 0.735 | 0.731 | 0.767 |

a: The full sample of facilities are used in the estimation reported in the column "All," whereas estimation results for facilities located in states that adopt a P2 program before 1990 and after 1990 are reported in the columns "Early" and "Late," respectively. Facilities that are located in states that adopt a P2 program in 1990 are excluded from the sample in the last two columns.
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table V: Average Treatment Effects of Federal and State P2 Programs for Facilities Located in States with No Target Reduction Goal

| Variables | Aggregate Releases All | Aggregate Releases Early | Aggregate Releases Late | Net Releases All | Net Releases Early | Net Releases Late |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| lppa | -1.94e-07*** | -2.64e-07*** | 4.99e-08 | -2.07e-07*** | -3.20e-07*** | -4.66e-08 |
| | (5.14e-08) | (6.89e-08) | (1.04e-07) | (6.49e-08) | (8.44e-08) | (1.47e-07) |
| State P2 | -0.141*** | -0.269*** | -0.0726 | -0.194*** | -0.257*** | -0.0872 |
| | (0.0441) | (0.0654) | (0.170) | (0.0556) | (0.0882) | (0.183) |
| i_effect | -0.898*** | -0.859** | -2.199*** | -1.638*** | -1.136** | -2.934** |
| | (0.325) | (0.402) | (0.825) | (0.447) | (0.533) | (1.175) |
| i_time | 0.00174 | -0.0381 | -0.00929 | 0.103** | 0.0872 | -0.000278 |
| | (0.0409) | (0.0495) | (0.107) | (0.0514) | (0.0596) | (0.154) |
| ip_effect | -0.183*** | -0.143 | 0.177 | -0.261*** | -0.225* | -0.185 |
| | (0.0695) | (0.0948) | (0.135) | (0.0960) | (0.130) | (0.195) |
| ip_time | 0.0135 | 0.0304** | -0.00374 | 0.0193 | 0.0171 | 0.0325 |
| | (0.0102) | (0.0133) | (0.0316) | (0.0125) | (0.0162) | (0.0386) |
| Constant | 10.64*** | 10.67*** | 11.80*** | 9.441*** | 9.143*** | 11.91*** |
| | (0.241) | (0.287) | (0.599) | (0.342) | (0.319) | (0.852) |
| Observations | 75960 | 51711 | 12036 | 58576 | 39965 | 9573 |
| R-squared | 0.776 | 0.773 | 0.802 | 0.739 | 0.736 | 0.775 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table VI: Average Treatment Effects of Federal and State P2 Programs for Facilities Located in States with a Target Reduction Goal

| | Aggregate Releases | | | Net Releases | | |
|---|---|---|---|---|---|---|
| Variables | All | Early | Late | All | Early | Late |
| lppa | 1.97e-08 | 6.18e-07* | -1.69e-07 | -6.24e-08 | 7.72e-07 | -3.63e-07* |
| | (4.89e-08) | (3.54e-07) | (1.41e-07) | (7.14e-08) | (5.97e-07) | (2.20e-07) |
| between | 0.165** | -0.492** | 0.557* | -0.0567 | -0.831** | 0.404 |
| | (0.0793) | (0.219) | (0.286) | (0.102) | (0.325) | (0.383) |
| compliance | 0.320*** | -0.319 | 0.494* | 0.130 | -0.258 | 0.228 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | (0.100) | (0.212) | (0.295) | (0.120) | (0.301) | (0.380) |
| i_effect | -2.051*** | -3.228** | -1.512 | -3.809*** | -4.329** | -1.445 |
| | (0.703) | (1.378) | (1.615) | (0.945) | (1.826) | (2.172) |
| i_time | 0.0802 | 0.124 | 0.0235 | 0.313*** | 0.181 | 0.130 |
| | (0.0840) | (0.148) | (0.189) | (0.107) | (0.207) | (0.221) |
| ip_effect | 0.386** | 0.574 | 0.0887 | 0.170 | 0.00906 | -0.450 |
| | (0.163) | (0.569) | (0.355) | (0.203) | (0.754) | (0.519) |
| ip_time | 0.00127 | -0.000656 | -0.00874 | 0.0140 | -0.0169 | 0.0115 |
| | (0.0274) | (0.104) | (0.0746) | (0.0329) | (0.137) | (0.0870) |
| Constant | 10.10*** | 10.40*** | 10.18*** | 9.708*** | 8.019*** | 8.682*** |
| | (0.575) | (1.173) | (0.784) | (0.550) | (0.780) | (0.496) |
| Observations | 19707 | 6146 | 4239 | 14613 | 4512 | 3008 |
| R-squared | 0.774 | 0.770 | 0.747 | 0.719 | 0.688 | 0.729 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table VII: Falsification Tests (False Adoption Date = Actual Date - 1)

| | Aggregate Releases | | | Net Releases | | |
|---|---|---|---|---|---|---|
| Variables | All | No Target | Target | All | No Target | Target |
| lppa | -8.05e-08** | -1.68e-07*** | 2.07e-08 | -1.70e-07*** | -1.70e-07*** | -8.05e-08 |
| | (3.65e-08) | (5.05e-08) | (5.02e-08) | (6.42e-08) | (6.42e-08) | (7.24e-08) |
| False Adoption | 0.0147 | 0.00411 | 0.0817 | 0.0327 | 0.0327 | -0.142 |
| | (0.0490) | (0.0593) | (0.0928) | (0.0746) | (0.0746) | (0.125) |
| i_effect | -0.839*** | -0.617* | -2.346*** | -1.262*** | -1.262*** | -3.829*** |
| | (0.293) | (0.319) | (0.708) | (0.438) | (0.438) | (0.944) |
| i_time | -0.00981 | -0.0142 | 0.108 | 0.0809 | 0.0809 | 0.328*** |
| | (0.0365) | (0.0406) | (0.0841) | (0.0510) | (0.0510) | (0.106) |

| | | | | | | |
|---|---|---|---|---|---|---|
| ip_effect | -0.141** | -0.221*** | 0.312** | -0.315*** | -0.315*** | 0.209 |
| | (0.0634) | (0.0688) | (0.154) | (0.0940) | (0.0940) | (0.194) |
| ip_time | 0.0181* | 0.0151 | -0.00228 | 0.0219* | 0.0219* | 0.00586 |
| | (0.00939) | (0.0102) | (0.0276) | (0.0126) | (0.0126) | (0.0330) |
| Constant | 10.53*** | 10.63*** | 10.08*** | 9.417*** | 9.417*** | 9.776*** |
| | (0.250) | (0.244) | (0.573) | (0.348) | (0.348) | (0.544) |
| Observations | 95667 | 75960 | 19707 | 58576 | 58576 | 14613 |
| R-squared | 0.775 | 0.776 | 0.774 | 0.739 | 0.739 | 0.718 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table VIII: Individual Program Effects

| Variables | Aggregate Releases | | Net Releases | |
|---|---|---|---|---|
| lppa | -7.75e-08** | -1.05e-07*** | -1.31e-07*** | -1.37e-07*** |
| | (3.70e-08) | (3.66e-08) | (4.87e-08) | (4.86e-08) |
| i_effect | -0.996*** | -0.853*** | -1.781*** | -1.732*** |
| | (0.290) | (0.287) | (0.393) | (0.391) |
| i_time | -0.00382 | -0.0644* | 0.114** | 0.0946** |
| | (0.0365) | (0.0372) | (0.0453) | (0.0465) |
| ip_effect | -0.121* | -0.0573 | -0.228*** | -0.224*** |
| | (0.0640) | (0.0631) | (0.0848) | (0.0844) |
| ip_time | 0.0172* | 0.0281*** | 0.0225** | 0.0241* |
| | (0.00944) | (0.0108) | (0.0114) | (0.0132) |
| TA | -0.0210 | -0.0468 | -0.204** | -0.261*** |
| | (0.0699) | (0.0652) | (0.0895) | (0.0874) |
| time_ta | | 0.00349 | | 0.00800 |
| | | (0.00770) | | (0.00939) |
| educ | 0.00328 | 0.0397 | 0.0962 | 0.145 |
| | (0.0798) | (0.0729) | (0.105) | (0.104) |
| time_educ | | -0.00658 | | -0.00764 |
| | | (0.00856) | | (0.0107) |
| grant | -0.0629 | 0.118* | 0.0679 | 0.145 |
| | (0.0740) | (0.0680) | (0.0952) | (0.0935) |
| time_grant | | -0.0298*** | | -0.0123 |
| | | (0.00743) | | (0.00901) |
| ffee | 0.218*** | 0.105* | 0.0601 | 0.0407 |
| | (0.0659) | (0.0613) | (0.0846) | (0.0821) |
| time_ff | | 0.0226*** | | 0.00257 |
| | | (0.00678) | | (0.00835) |
| nrpen | -0.227*** | -0.201*** | -0.131 | -0.108 |
| | (0.0681) | (0.0628) | (0.0864) | (0.0838) |
| time_nr | | -0.00665 | | -0.00572 |
| | | (0.00733) | | (0.00891) |
| Constant | 10.53*** | 10.51*** | 9.604*** | 9.612*** |
| | (0.250) | (0.250) | (0.323) | (0.323) |
| Observations | 95667 | 95667 | 73189 | 73189 |
| R-squared | 0.775 | 0.775 | 0.735 | 0.735 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1