Are Management-Based Regulations Effective? Evidence from State Pollution Prevention Programs

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Abstract

This paper evaluates a recent innovation in regulating risk called management-based regulation. Traditionally, risk regulation has either specified a particular means of achieving a risk-reduction goal or specified the goal and left the means of achieving that goal up to the regulated entity. In contrast, management-based regulation neither explicitly imposes the means, nor the ends. Rather, what is required is that each regulated entity review its production processes and develop a set of goals and procedures that will reduce risk. I evaluate the effectiveness of management-based regulation by taking advantage of policy variation that occurred when 14 states adopted such regulations for toxic chemical control in the 1990s. Using panel data for just over 31,000 manufacturing plants in the United States, I investigate whether facilities subject to management-based regulations had larger changes in total quantities of toxic chemical releases, engaged in more pollution prevention activities, or reported fewer toxic chemicals to the Toxics Release Inventory (TRI). The results indicate that management-based regulation has had a measurable positive effect on the environmental performance of manufacturing plants. In particular, plants subject to management-based regulation experienced larger decreases in total pounds of toxic chemicals released and were more likely to engage in source reduction activities. *© 2007 by the Association for Public Policy Analysis and Management*

INTRODUCTION

Over the last decade there has been an increase in the use of non-traditional regulatory instruments for pollution control. Perhaps in no environmental area has this increase been more pronounced than in the area of toxics chemical control. While emissions of toxics to the air are still regulated using traditional command-and-control regulations, toxic chemicals have also been regulated using: information disclosure programs such as the Toxics Release Inventory (TRI); voluntary programs such as the 33/50 program; industry self-regulation initiatives such as the American Chemistry Council's Responsible Care program and the set of environmental management standards set by the International Organization for Standardization (ISO); and through the use of innovative management-based regulations.

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There is now a growing empirical literature examining the consequences of these innovative regulatory initiatives.[1]

This paper contributes to that empirical literature by examining the effectiveness of one type of innovative regulatory instrument—management-based regulation (MBR)—at improving environmental performance. Management-based regulation requires each regulated entity to engage in its own review and planning process and develop a set of internal rules and initiatives consistent with achieving the regulation's objectives (Coglianese & Lazer, 2003). During the early 1990s, 14 states adopted management-based regulations for toxic chemical use and release. These state-level programs provide a natural experiment of the effects of MBR on environmental performance. Data collected from the Toxics Release Inventory provide outcome measures of the policies' effects on environmental performance at the plant level. Using a panel of 31,000 manufacturing plants from 1988–1999, this paper employs a difference-in-difference strategy to determine whether facilities subject to MBR have larger changes in total quantities of TRI chemical releases, engaged in more source reduction activities, or reported fewer toxic chemicals under the TRI program controlling for other factors that might explain differences in environmental performance across plants.

The analysis suggests that management-based regulation has had a measurable positive effect on the environmental performance of manufacturing plants. Plants subject to management-based regulation experienced larger decreases in total pounds of toxic chemicals released and were more likely to engage in source reduction activities. In particular, plants subject to management-based regulations reduced pollution levels by an average of 60,000 pounds, or 30%, more than comparable plants not subject to these regulations. Plants subject to MBR are more likely to engage in source reduction (also known as pollution prevention) activities. However, MBR did not affect the number of chemicals reported by facilities, which suggests that the observed reductions in pollution are due to real changes at the facility rather than strategic changes in chemical use and reporting. These results are robust to tests designed to determine whether the estimated effect of MBR is capturing variance due to the policy change or whether the effect includes variance in unobservable facility or state characteristics.

This paper begins with some background on management-based regulation and its use in regulating toxic chemicals. The estimation strategy is then detailed, followed by information on the data used in the study. The results and robustness tests are then presented and the final section offers some conclusions and recommendations.

BACKGROUND

What Is Management-Based Regulation?

Traditionally, regulation has either specified a particular means of achieving a goal or specified the goal and left the means of achieving that goal up to the regulated entity. In the case of pollution control, technology standards are an example of reg-

[1] Work that has been done include studies of the effect of the Toxics Release Inventory, an information-based regulatory initiative (Bui & Mayer, 2003; Hamilton, 1995, 2005; Khanna, Quimio, & Bojilova, 1998; Konar & Cohen, 1997), and the 33/50 program which was evaluated by Arora and Cason (1995, 1996) and Khanna and Damon (1999). Alberini and Segerson (2002) provide a survey of the theoretical and empirical literature on voluntary environmental initiatives. Potaski and Prakash (2005) and Toffel (2005) examine the effect of voluntary adoption of ISO 14000 standards. King and Lenox (2000) examine the effect of the American Chemistry Council's Responsible Care Program.

ulating the means, while performance standards and market-based instruments (such as tradeable permits and pollution charges) are examples of regulation that mandates the ends to be achieved while leaving the precise means up to the regulated entity. Management-based regulation neither explicitly imposes the means, nor the ends. Rather, what is required is that each regulated entity review its production processes and develop a set of goals and procedures that will reduce pollution.

There is a wide range of policy initiatives that might fall under the umbrella of management-based regulation. A management-based regulation might be as simple as requiring firms to issue an explicit policy statement on their strategies for achieving the public goal. A more sophisticated regulation might require that plants or firms engage in a review of their production processes, identify alternative production techniques or input mixes that would achieve the public goal, and evaluate the feasibility of these alternatives. And, finally, a management-based regulation might require outside approval of the management plan either by the regulatory agency or by a third-party auditor.

Management-based regulation has been used to regulate risk in several different policy areas in the United States, including food safety, industrial safety, and pollution control. Theoretical analysis of MBR as a regulatory instrument suggests that MBR is most appealing when the population of regulated entities is heterogeneous and the capacity of the regulator to assess more traditional "output" measures (such as pollution, severity of accidents, and so forth) is limited (Coglianese & Lazer, 2003). In addition, MBR may be desirable when there is uncertainty surrounding the nature of the risk to be regulated, such that traditional standard setting may be viewed as too permanent or when the information necessary to issue traditional regulations is too great (Bennear, 2006a).

While MBR may be a desirable regulatory alternative in theory, it can only be considered of value as a regulatory tool if there is empirical evidence that these regulations are effective. There are two related, but distinct, questions one could ask about the effectiveness of MBR. The first is does MBR reduce risk? Clearly, if MBR does not actually reduce risk there is no reason to consider it as a regulatory alternative. However, even if MBR does reduce risk, it may still not be a desirable regulatory alternative. The viability of MBR would then depend not just on the benefits of MBR (the risk reductions), but also on the cost of attaining these benefits in comparison to other regulatory alternatives. For both questions, the natural first step is to assess whether the regulations actually reduce risk. This paper answers that question for the case of MBR applied to toxic chemical policy.

Management-based Regulation of Toxic Chemicals

During the late 1980s and early 1990s, there was a general legislative push toward pollution prevention and away from traditional command-and-control regulation. Advocates of the pollution-prevention approach argued that traditional regulation, which focused on end-of-pipe treatments, often resulted in transferring pollution from one medium to the other. For example, requiring the use of a scrubber to reduce particulate emissions to the air may increase transfers of this waste to landfills.[2] Advocates also believed that pollution prevention was good for industry,

[2] There is very limited empirical evidence on the importance of cross-media transfers. Greenstone (2003) examines whether these inter-media transfers were significant in the iron and steel industry and found that decreases in air emission were not accompanied by increases in water discharges and releases to landfills in this particular industry.

because pollution itself could be viewed as a waste of resources, and thus, prevention of pollution might lead to more efficient production processes. As part of this broad movement, many states began experimenting with alternative approaches to pollution prevention. Fourteen states adopted management-based regulations that required detailed pollution prevention planning, record-keeping, and reporting at the plant level.

The state programs share many common requirements. All states require that plants in the regulated domain track the use of regulated toxic chemicals through all stages of their production process, identify alternative production techniques or input mixes that would reduce the use and release of these toxic chemicals, and evaluate each of these alternatives for technical and economic feasibility.[3] While all 14 state programs share this common core structure, the programs differ along several dimensions.

- **Domain of regulated facilities:** There are four types of facilities that come under the scope of the state pollution prevention regulations—large quantity hazardous waste generators (LQGs) (defined as a facility that generates more than 2,200 pounds of hazardous waste per month); small quantity hazardous waste generators (SQGs) (defined as a facility that generates between 220 and 2,200 pounds of hazardous waste per month); manufacturing facilities that are required to report releases under the federal TRI program; and facilities that have to report on their toxics use information to local health and safety authorities under the Superfund Amendments and Reauthorization Act (SARA) Section 312. There is substantial, but not perfect, overlap between these groups. Most SARA Section 312 facilities also report to TRI. However, many LQGs do not report to TRI because they are not manufacturing facilities (for example, hospitals can be LQGs, but are not manufacturing facilities) and many TRI facilities are not LQGs.
- **Public access to plans:** Most states do not require plants to file their pollution prevention plans publicly, arguing that this allows plant managers to develop more detailed plans without concern that they may reveal proprietary information to competitors. In these states, inspectors can view a facility's plan only during an inspection visit. Only Arizona and New York require agency review of a facility's plan.
- **Third party review:** Two states, Massachusetts and California, require that the pollution prevention plan be reviewed by an approved third party auditor for completeness. In Massachusetts, a plant employee can petition to be the auditor under some circumstances.
- **Frequency of progress reports:** All states require filing of progress reports, but the frequency of these filings varies, from once every year to once every four years. Unlike the pollution prevention plans themselves, the progress reports are public.

[3] Facilities can choose to implement MBR in a variety of ways. Some facilities may satisfy their state's MBR requirements through the use of an environmental management system certified by some other authority, such as the International Organization for Standards (ISO). One might be concerned about the interactions of these programs with the state-level regulations. However, ISO 14001 standards were not issued until 1996, by which time nearly all state-level MBRs were in place. In each year between 1996 and 1999 (the end of the timeframe for this analysis), fewer than 151 (of over 20,000 facilities) were ISO certified and fewer than 43 of these ISO certified facilities were in states with MBRs. Other authors have examined the effect of voluntary compliance with the American Chemistry Council (King & Lenox, 2000) and ISO (Potaski & Prakash, 2005; Toffel, 2005) standards.

- **Toxics use reporting:** Four states—Massachusetts, New Jersey, Vermont, and Oregon—require facilities to report their use of toxic chemicals. All large manufacturing facilities are required to report their *releases* of toxic chemicals annually under the TRI program, but these four states require additional filing of toxics *use* information. Releases measure emissions, discharges, and transfers of chemical outputs from the production process, while use measures the amount of chemical inputs to the production process.

A summary of state program characteristics is provided in Table 1.

Previous Findings on the Effect of State Pollution-Prevention Programs

There has been little systemic study of the effectiveness of the pollution prevention programs. At least two states have conducted evaluations of their programs. Massachusetts found support for the success of their overall pollution prevention legislation. A program evaluation conducted in 1997, three years after the management-based regulation went into effect, found that the vast majority (81 percent) of plants surveyed intended to implement at least some of the source reduction improvements identified in their plan. The survey also found that most plant managers stated they would continue the planning process even if the legislation were removed. However, the survey did find differential results across plants of different sizes, with smaller plants realizing fewer benefits from the program (Keenan, Kanner, & Stoner, 1997). Another study of the Massachusetts TURA program found that this program did have an impact on toxic chemical use and release, but only in the initial years after adoption (Coglianese & Nash, 2004).

New Jersey also conducted an official review of its program in 1996, four years after implementation. They found evidence that planning was *net* beneficial to plants, with the cost savings associated with pollution prevention activities outweighing the cost of planning. However, they also found that these results were not uniform across facilities with smaller facilities receiving fewer benefits (Natan, Miller, Scarborough, & Muir, 1996).

Two papers have examined the effects of state-level pollution prevention programs without focusing specifically on pollution prevention planning requirements. Bui (2005) examines the differences in air emissions between refineries in states with pollution prevention programs that set a specific state-wide target for reductions, states that have a pollution prevention program without state-wide targets, and states that have no program. She finds that refineries located in states with more stringent regulation of toxic chemicals have significantly lower levels of emissions than refineries in states with weaker regulations. Maxwell, Lyon, and Hackett (2000) look at the changes in TRI emissions of 17 key toxic chemicals from 1988 to 1992 at the aggregate state level adjusted by the value of shipments. They compare states with any pollution prevention legislation in place by 1991 to states without such legislation and find no statistically significant effect of state-legislation on the change in toxic releases of these 17 chemicals.

Tenney (2000) compares the changes in production related releases and wastes for 14 states, 7 of which have MBRs and 6 of which have voluntary pollution prevention programs.[4] She finds that, after adjusting for changes in production, states with mandatory programs (MBRs) showed greater progress in reducing toxic releases

[4] Voluntary programs differ greatly by state and include technical assistance centers and recognition programs, among other features.

Table 1. Description of state pollution prevention programs

	Types of Facilities Required to Plan	Toxic Use Reporting	Progress Reports	Public or Third Party Review	Program Implementation Date	Planning Date
Arizona	TRI reporters LQGs Users of more than 10,000 lbs of a toxic chemical (even if not a TRI reporter) Voluntary Participants	No	Annual	Public	1991	1992
California	LQGs	No	Every four years	Third Party	1989	1991
Georgia	LQGs	No	Biennial	No	1990	1992
Maine	TRI reporters LQGs SARA Section 312 Reporters	No	Biennial	No	1990	1993
Massachusetts	TRI reporters	Yes	Annual	Third Party	1990	1994
Minnesota	TRI reporters with non-zero releases LQGs	No	Annual	No	1990	SIC 35-39 in 1991, 1992 for all others
Mississippi	TRI reporters LQGs	No	Annual	No	1990	1992
New Jersey	TRI reporters	Yes	Annual	No	1991	1992
New York	LQGs	No	Annual	Public	1990	Phase in beginning in 1991 based on tons of waste generated
Oregon	TRI reporters LQGs SQGs	Yes	Annual	No	1989	1991
Tennessee	LQGs SQGs	No	Annual	No	1992	LQGs in 1992, SQGs in 1994
Texas	TRI reporters LQGs SQGs	No	Annual	No	1991	Phase in beginning in 1993 based on tons of waste generated
Vermont	TRI reporters with non-zero releases LQGs SQGs	Yes	Annual	No	1991	Phase in LQGs in 1992, SQGs in 1993, TRI in 1996
Washington	TRI Reporters LQGs	No	Annual	No	1988	1992

and hazardous waste than states with voluntary programs. However, several states selected for the study have pollution prevention planning programs that only apply to a subset of plants that report to the Toxics Release Inventory program. In particular, California, Georgia, and Tennessee have programs that only require planning for large quantity hazardous waste generators. A comparison of average TRI releases across these states can be misleading because the programs do not apply to all facilities within the state. The paper also does not correct for other differences across states or for differences in the timing of regulation in different states.

This paper builds on the previous efforts and analyzes the effect of management-based pollution prevention regulations, accounting for the fact that state rules may apply to a subset of plants, adjusting for other plant- and state-level differences, and adjusting for differences in the timing of MBR implementation in different states. The method for identifying this effect is discussed in the next section.

ESTIMATION STRATEGY

This paper seeks to identify the change in environmental performance relative to the change that would have occurred if the management-based regulation had not been implemented. That is, it seeks to identify the *causal effect* of management-based regulation on measures of environmental performance.

Define Y_0 to be the environmental performance outcome of a plant in the absence of MBR and Y_1 to be the environmental performance outcome of a plant with MBR. The causal effect of the regulation would then be $Y_1 - Y_0$. The fundamental problem of causal inference is that we cannot observe both Y_1 and Y_0 for the same plant at the same time and therefore, cannot directly calculate the effect of the program.

The identification strategy used in this paper is to compare the change in three measures of environmental outcomes—toxic releases, source reduction activities, and the number of toxic chemicals reported to the TRI—for plants that are subject to MBR to the change in measures of environmental outcomes for plants that are not subject to MBR. This "difference-in-difference" (DID) estimator recognizes that plants are likely to have different environmental performance levels even in the absence of MBR and does not include these differences in the estimate of the effect of the program. Rather, the effect of the program is measured as the average difference between pre-regulation and post-regulation outcomes for the facilities subject to the regulations and the difference between pre- and post-regulation outcomes for facilities that are not subject to the regulation, conditional on other observable determinants of environmental performance.[5]

A major concern in policy evaluations is the potential endogeneity of the policy variable. In particular, there is concern that plants subject to the policy are different from plants not subject to the policy in unobservable ways, and that these unobservable characteristics are also correlated with the outcome measure. If this is the case, then the estimate of the effect of the policy will erroneously pick up the effect of the unobservables, thereby biasing the results.

At first blush, the DID estimator may appear to eliminate this endogeneity concern. Refer to plants that eventually are subject to the management-based regulations as "ever-MBR" plants and plants that are never subject to the regulations as "never-MBR" plants. The DID estimator allows ever-MBR plants to differ from

[5] Toffel (2005) uses a similar difference-in-differencestrategy to assess the effect of ISO 14000 management systems on environmental performance. He also uses propensity score matching to restrict the sample of facilities that is analyzed.

never-MBR plants even in the absence of regulation. These pre-regulation differences are subtracted from the post-regulation differences to get the treatment effect. Unfortunately, differencing the data does not eliminate the potential endogeneity concern; it simply redefines it. For the DID estimator, the identifying assumption is that the policy variable is exogenous to the trend (changes) in the outcome variable. This implies that in the absence of regulation, environmental performance among ever-MBR plants would not trend differently than never-MBR plants. In other words, plants are allowed to have different levels of environmental performance, but these differences must be constant over time (Angrist & Krueger, 1999). In analyzing the results, it is important to test for the validity of the exogeneity assumption and the sensitivity of the results to different specifications. These tests are included in the robustness test section below.

To obtain a simple differences-in-differences estimate of the effect of MBR, we can utilize a standard "fixed-effect" regression model:

$$y_{it} = \delta M_{it} + \sum_{t=1988}^{1999} \gamma t + c_i + u_{it} \tag{1}$$

where y_{it} is the measure of environmental performance, M_{it} is an indicator for whether the plant was subject to MBR in that period, t are year dummy variables, and the error term consists of two components, a time-constant facility effect, c_i, and a time-specific shock, u_{it}.[6] This equation estimates a common non-linear time path across plants shifted by a plant-specific fixed-effect and then captures the incremental change in environmental performance among plants that are subject to MBR.

The above DID estimator assumes that all of the difference in the trend in environmental performance among plants is due to the policy. However, the trend in environmental performance of MBR and non-MBR plants may differ if the composition of plants in the two groups differs in ways that are correlated with environmental performance. For example, different industrial sectors may experience different rates of technological change that lead to different changes in environmental performance. If the industrial composition differs for ever-MBR and never-MBR states, then not accounting for these differences will bias the DID estimator. One way to account for this possibility in a regression model is to include covariates.[7]

Similarly, one may wish to allow for different time trends in environmental performance across states. State environmental stringency may differ in ways that are correlated with MBR adoption and also with trends in environmental performance. Nearly all major environmental statutes are established at the federal level, but

[6] A concern with using plant-level data to evaluate the effect of a state-level regulation is that individual plants with a given state in a given year are not independent. If there is correlation in an observable variable (namely the policy variable) within a group (state), then it is possible that there are correlations in unobservable variables within the group as well. If the observations are not independent within a group, then the standard errors reported from an ordinary least squares regression will be downward biased, giving a false sense of precision to the estimates (Moulton, 1990). Moulton's findings suggest that clustering the standard errors at the state-year level is appropriate in this case. However, recent work by Betrand, Duflo, and Mullainathan (2002) argues that clustering at the state-year level may still result in underestimated standard errors and, hence, overestimated precision of the statistical findings. Their findings suggest that the standard errors are most likely to be underestimated when both the dependent and regulatory variable are serially correlated. In the present study, at least two of the dependent variables are likely to be serially correlated (total pounds released and number of chemicals reported) and the policy variable is certainly serially correlated. The Betrand et al. results suggest that clustering the standard errors at the state level corrects the precision of the estimates. That is the approach taken here.

[7] In a fixed-effects framework, time invariant variables can only be included if they are interacted with time-varying covariates. Any effect of time invariant variables on the level of environmental performance is absorbed by the fixed effect.

implemented at the state level. States with stronger preferences for environmental protection have the discretion to write more stringent permits, conduct more frequent inspections, and adopt MBR for pollution prevention. Moreover, if there are unobservable (to the researcher) factors that affect state adoption of MBR, there may be unobservable factors that affect trends in environmental performance in the state. I include state-specific trends to account for differences across states that are not a function of MBR.[8] Thus, the MBR variable should be picking up deviations from the state-specific trend that occur in the year(s) the program is in effect.

The regression equation to be estimated is then given by:

$$y_{it} = \delta M_{it} + \sum_{s=1}^{49} \gamma_s t_s + X_{it}\beta + \sum_{t=1988}^{1999} (Z_i * t)\phi_t + c_i + u_{it} \tag{2}$$

where t_s is a state-specific time trend, X_{it} are time-varying covariates, Z_i are time-constant variables, and y_{it}, M_{it}, c_i, and, u_i are as previously defined.

Both of the above regression equations assume that MBR results in a one-time change in the level of environmental performance. However, it might be the case that MBR itself changes the trend in environmental performance. For example, the pollution prevention plan might suggest changes in capital investment that occur over several years. To allow for this, we can also estimate the following:

$$y_{it} = \sum_{d=0}^{8} \delta_d M_{id} + \sum_{s=1}^{49} \gamma_s t_s + X_{it}\beta + \sum_{t=1988}^{1999} (Z_i * t)\phi_t + c_i + u_{it} \tag{3}$$

where d equals the number of years since MBR went into effect. All three specifications are employed in this analysis.

DATA

Sample Frame

A panel dataset of over 31,000 manufacturing plants in the United States was used for the analysis. The sample was constructed from annual reports filed by facilities under the federal TRI program.[9] Because facilities report separately for each of the regulated chemicals that they use, manufacture, or process, data were aggregated to the facility level for the analysis.[10]

It is worth noting that real concerns have been raised about the validity of TRI data as measures of environmental performance (Bennear, 2006b; Graham & Miller, 2001; Natan & Miller, 1998; United States Government Accounting Office, 1991). Primary concerns include measurement errors in self-reported data (U.S. Government Accounting Office, 1991), truncation bias due to arbitrary reporting thresholds (Bennear 2006b), and issues with how releases are estimated and

[8] Ideally, one could control for state-specific time effects using non-parametric state-year interactions. But the set of state-year interactions is perfectly collinear with the treatment variable, and hence, a treatment effect is not identified in this model. While state-specific time trends parametrically impose linearity, the inclusion of these trends is preferable to ignoring difference in state time effects altogether.

[9] All manufacturing facilities with 10 or more employees that manufacture or process more than 25,000 pounds or use more than 10,000 pounds of one of the nearly 600 listed chemicals are required to annually file a report documenting their releases of these toxic chemicals to different environmental media (for instance, air, water, land).

[10] Over time, the list of reportable chemicals has been expanded, and occasionally contracted. In order to ensure that data from different years are comparable, only reports on chemicals that were on the reporting list in the initial reporting year (1987) and that have not since been delisted are included.

changes in measurement and reporting methods (Natan & Miller 1998). However, these measurement issues are likely to be common among facilities in all states, and therefore are not expected to seriously bias the state-level comparison. In addition, these data are the only longitudinal data on toxic chemical releases, the type of releases targeted by state pollution prevention programs.[11]

Outcome Variables

Three measures of environmental performance were used. The first measure is the level of reported toxic pollution releases in pounds. Beginning in 1987, plants were required to report annually their total pounds of chemicals released to air, water, land, and disposed using underground injection to the TRI. The measure of pollution used in the analysis is the sum of these releases to all media, for all original chemicals reported by the plant in a given year.

The second measure of environmental performance used in the analysis is the frequency of source reduction activities. Beginning in 1991, facilities were required to report on source reduction activities on the TRI reporting forms. On each chemical reporting form, plants were asked to list the source reduction activities that they engaged in during that reporting year. Source reduction activities are organized into eight broad categories: improved operating practices, inventory control, spill and leak prevention, raw materials modifications, process modifications, cleaning and degreasing, surface preparation and finishing, and product modifications. These data are used to construct two additional outcome variables. The first takes a value of 1 if the plant engaged in any source reduction activities during the year. The second is the sum of the number of categories of source reduction activities the plant engages in each year. The count of source reduction activities falls between 0 and 8.

The third measure of environmental performance is the number of chemicals reported to the Toxics Release Inventory in a given year. Facilities are only required to report *releases* of toxic chemicals if they *use* a chemical in excess of one of the reporting thresholds. Bennear (2006b) shows that the existence of these reporting thresholds can create incentives for facilities to decrease their use of a chemical to avoid the regulatory costs associated with reporting, a response known as threshold-regarding. This decrease in use does not necessarily result in real decreases in pollution, but may result only in decreases in reported pollution. In this paper, I examine the effect of MBR on the number of chemicals reported to determine if there is any evidence of threshold-regarding behavior. If we observe that MBR leads to both pollution reductions and decreases in reporting, then we may be concerned that some of this decrease is due to threshold-regarding behavior by plants.[12]

Policy Variable

Data on state-level pollution prevention programs were provided by the National Pollution Prevention Roundtable (1996). Additional information on program details

[11] In fact, the TRI data are some of the only longitudinal data on any measure of environmental performance. For this reason, TRI data are frequently used as outcome measures for environmental program evaluations (Bennear & Coglianese, 2005).

[12] For models of total releases, facilities that never reported any releases were dropped from the sample. For all models, facilities without a valid SIC code were dropped from the sample.

was gathered from state Web sites and through phone conversations with state pollution prevention employees.

As discussed previously, state programs differ in the domain of regulated facilities. The following nine states impose management-based regulations on all plants that are required to file forms under the Toxics Release Inventory: Arizona, Maine, Massachusetts, Minnesota,[13] New Jersey, Oregon, Texas,[14] Vermont, and Washington. Since the sample only contains plants that report to the TRI, for these nine states the policy variable is simply equal to 1 for all plants during years when the program was in effect.

In addition, there are five states that imposed management-based regulations on LQGs or otherwise base regulatory requirements on hazardous waste generation. These states are: California, Georgia, Mississippi, New York,[15] and Tennessee. For these states, the formation of the policy variable is more complicated. Data on hazardous waste generators is available from the Biennial Reporting System (BRS) database maintained by the United States Environmental Protection Agency. As the name suggests, it contains information on hazardous waste generation reported every two years.[16] Thus, for states whose planning requirements are based on hazardous waste generation, the treatment variable is constructed by assigning to the treatment group any facilities that are large quantity generators in the year nearest the year the regulation went into effect.[17]

Control Variables

In order to get a valid estimate of the effect of management-based regulations, it is necessary to control for other factors that might affect the trend of environmental performance. There are three categories of variables that are included as control variables—facility-specific control variables, variables representing other regulations, and political and economic variables.

[13] Minnesota's program had two phases. In 1991, MBRs became binding for plants in SIC 35-39. Plants in all remaining SICs were subject to MBR beginning in 1992.

[14] The Texas regulations were phased in based on total tons of chemicals released. Facilities generating more than 100 tons per year were subject to MBR beginning in 1993. More plants were subject to MBR in each subsequent year with the smallest plants, those generating less than one ton per year, subject to MBR in 1997. Total pounds of chemicals released were converted to tons and facilities were assigned to regulatory cohorts accordingly.

[15] The state of New York phased in its planning requirements beginning with the largest generators of hazardous waste and subsequently adding smaller generators in subsequent years. Due to reorganization of the state environmental protection offices, data on which facilities were subject to the planning requirement in each year could not be provided by the State of New York. Thus, all New York facilities were deleted from the sample to avoid incorrectly assigning these plants to the ever-MBR or never-MBR group. This results in a loss of between 2.9 and 4.3 percent of facilities each year, and between 0.9 and 2.7 percent of total releases each year.

[16] Recently, EPA constructed a unique facility identifier called the Facility Registry System (FRS) ID that enables researchers to more readily link data collected by different EPA program offices. The FRS ID was linked to each observation in the BRS and TRI databases and then these two databases were merged. Thirteen facilities have multiple entries in the BRS database for a given FRS ID. Each duplicate observation was flagged and the facility was assigned LQG = 1 if any of the observations with that FRS ID were designated large quantity generators.

[17] An alternative way to determine which plants are subject to the regulation is to use LQG status in the closest year, rather than in the year the regulation took effect. However, after the regulation takes effect, plants may have a greater incentive to reduce toxic waste sufficiently, in order to no longer be considered an LQG. In other words, LQG status is endogenous after the regulation takes effect. Thus, I assume plants are subject to the regulation if they were an LQG at the time the regulation went into effect. The results are robust to changes in this definition.

Facility-specific Controls

Source reduction opportunities may differ for different industries. If states that adopt MBR have a different composition of plants by industry than states that do not adopt, then failure to control for differences in the trends by industry will bias the estimate of the effect of MBR. The trends in environmental performance are estimated separately for each two-digit SIC code.

Similarly, facilities that are large quantity generators of hazardous waste are subject to all hazardous waste disposal regulations under the Resource Recovery and Conservation Act (RCRA) and, thus, the trend in environmental performance may be different for LQGs than for facilities that are not classified as LQGs. A separate trend for LQGs is included to account for these differences.[18]

Finally, one might also be concerned that changes in releases are a pure function of changes in production levels. As a first approximation, it seems reasonable to believe that most of the production-related variance in releases is between facilities—some facilities are consistently larger than others. This time-invariant cross-sectional variation is captured by the fixed effect. However, there is some facility-specific production variation over time, and the fixed effect does not pick up this time-varying component. Unfortunately, there is no good way to correct for these changes. The TRI does not collect output data. Beginning in 1991, facilities were asked to provide a production ratio which measures how the current year's production level compares to the previous year's production level. However, this variable does not explain variations in releases. Robustness tests are done to see if the absence of production level data affects the results.

Other Regulations

Another potential source of bias results from differential stringency of other environmental regulations. It may be that different states have different levels of environmental stringency in addition to whether they adopt MBR. The inclusion of state-specific time trends in Equations 2 and 3 partially addresses this issue.

In addition, I include a direct measure of regulatory stringency. Under the Clean Air Act, EPA sets ambient air concentration levels for six criteria air pollutants: particulate matter (PM), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone, carbon monoxide (CO), and lead. Counties that exceed the ambient air standards are designated as non-attainment counties. Facilities in non-attainment counties are subject to more stringent emissions requirements. While the ambient air standards refer to only these six criteria air pollutants and are not directly applicable to toxics emissions, these emissions categories are not unrelated. Emissions of toxics may also be classified as particulate matter, for instance.[19] Other studies (Becker & Henderson, 2000; Greenstone, 2002; Henderson, 1996) have found that facilities in non-attainment counties have greater increases in ambient air quality, and it might be expected that in response to changes made to accommodate these other regulations, facilities in non-attainment counties are more likely to engage in source reduction activities and have greater reductions in toxic chemical

[18] One might wish to control for other RCRA regulations in addition to LQG status. RCRA regulation is significantly more important for large quantity generators and hence the inclusion of separate time trend for these facilities accounts for most of this regulatory variation. These are also the regulations that are most likely to be correlated with MBR (and hence pose a threat to the validity of my treatment effect estimation), as many states only require MBR for large quantity generators.

[19] Greenstone (2003) links TRI chemicals to criteria air pollutants.

releases.[20] To control for differences in environmental performance induced by exogenous changes in regulation due to county attainment status, a dummy variable is included that takes a value of 1 if the county in which the facility is located was in non-attainment for at least one criteria air pollutant during that year.[21]

Political and Economic Controls

Facilities in different states may have different pollution prevention outcomes because of differences in the political climate in their state that have little or nothing to do with the mandatory planning requirements. To the extent that these differences among states are relatively constant over time, the state-specific time trends will pick up much of this variation. In addition, I include the average score from the League of Conservation Voters for all congressional representatives and senators in the state.[22] The League of Conservation Voters assigns all federal congressional representatives and senators a score based on their voting record on key environmental policies during that congressional session.

The state-level unemployment rate from the Bureau of Labor Statistics is also included as a control for time-varying economic characteristics at the state level that may affect environmental performance.

Table 2. Summary statistics.

	All Facilities		MBR Facilities		Non-MBR Facilities	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Total Releases (1,000s of pounds)	131	1,668	164	1,768	122	1,639
Air Releases (1,000s of pounds)	84	723	92	452	81	782
Water Releases (1,000s of pounds)	3	101	4	99	3	102
Source Reduction Activity (Binary)	0.31	0.46	0.38	0.49	0.29	0.45
Source Reduction Activity (Count)	0.54	0.96	0.68	1.07	0.50	0.93
Reports	3.4	3.8	3.9	4.8	3.2	3.5
League of Conservation Voters Score	49.6	21.1	54.2	25.6	48.3	19.5
Unemployment rate	5.6%	1.5%	5.8%	1.5%	5.5%	1.5%
Large Quantity Generator	0.50	0.49	0.70	0.50	0.45	0.50
County is in Non-attainment for at least one criteria air pollutant	0.53	0.50	0.72	0.45	0.47	0.50

[20] One might think that non-attainment status would only affect TRI releases to air. However, Greenstone (2003) shows that non-attainment status affects TRI releases to all media in the iron and steel industry.
[21] Data on attainment status by county for the years 1992–1999 were taken from EPA's Green Book (United States Environmental Protection Agency, 2003). Data on attainment status for the years 1988–1992 were graciously provided by Michael Greenstone.
[22] Average state-level scores were compiled from the League of Conservation Voters, National Environmental Scorecard (1988–1999).

Summary statistics for all variables used in the analysis can be found in Table 2.

RESULTS

The models in Equations 1 through 3 are estimated as a linear fixed effect model for total chemical releases. For source reduction activities, two models are estimated. The first is a conditional logit model, where the dependent variable takes a value of 1 if the facility engaged in any source reduction activities during the year, and 0 otherwise.[23] The second is a fixed effect negative binomial model where the dependent variable is the number of categories of source reduction activities the facility engaged in during the year.[24] For total chemical reports, both a linear fixed effect and fixed effect negative binomial model are estimated.

Toxic Releases

The simplest DID estimator that can be obtained in the fixed-effect framework is the specification given in Equation 1. It includes fixed effects for each facility, year dummy variables to capture the time path, and a variable that indicates if the facility is subject to the mandatory planning requirements in that year. The results of this specification are presented in the first column of Table 3. The coefficient on the planning regulation variable is negative, but not statistically significant. However, the simple DID estimator may not adequately control for other variables that explain changes in release levels and might also be correlated with whether the facility is subject to MBR. The next four columns address this concern by employing variants of the specification in Equation 2.

Column 2 includes a state-specific time trend. This allows the trends in releases to differ across states for reasons that are not related to MBR adoption. With state-specific trends included, the coefficient on the MBR variable is negative and statistically significant, suggesting that MBR adoption causes an average decrease in releases of 78,000 pounds. The effect diminishes slightly when linear time trends for large quantity generators of hazardous waste and linear trends for each two-digit SIC code are included (column 3). When these facility characteristics are allowed to affect the change in releases in a strictly linear fashion, the effect of MBR is negative and statistically significant, but slightly smaller with an average decrease of 62,000 pounds. To help interpret the magnitude of this decrease in pollution, the average level of releases for plants in the two years prior to MBR is 161,000 pounds. Thus, a 62,000 pound reduction is roughly a 30 percent decrease.

[23] For discrete measures of environmental performance, such as reported source reduction activities, the fixed-effect estimator is generally not consistent (Chamberlain, 1980). However, a traditional probit or logit model may also lead to inconsistent estimates if different facilities have different time-constant environmental propensities and these propensities are correlated with a plant's likelihood of being subject to MBR. To account for possible correlation, the differences-in-differences estimator for the effect of management-based regulations on discrete measures of environmental performance is obtained using a conditional logit model (Wooldridge, 2002). This model uses the sum of positive outcomes over time as a sufficient statistic for the facility-specific time-invariant effect. By conditioning on this sufficient statistic, consistent estimators of a "fixed-effects" flavor can be estimated.

[24] Both of these modeling approaches have advantages and disadvantages. Reducing the dependent variable to a binary indicator does not use all of the information available on facility behavior. However, simply adding up how many categories of source reduction activities a facility reported may over- or understate the total number of activities at the plant. For example, one activity may fall into two categories or multiple activities may fall into one category. Both model results are reported and, as the results below indicate, the results are not sensitive to this specification issue.

Table 3. Difference-in-difference estimates for total pounds of chemicals released. Standard errors clustered by state in parentheses.

	1	2	3	4	5	6
Management-Based Regulation	-18.5	-78.3 ***	-62.2 **	-48.5	-52.4	
	(41.7)	(29.3)	(30.2)	(30.0)	(29.4)	
First Year of MBR Implementation						-31.8
						(21.6)
Second Year of MBR Implementation						-69.0 *
						(38.0)
Third Year of MBR Implementation						-75.6 *
						(43.4)
Fourth Year of MBR Implementation						-121.3 *
						(64.5)
Fifth Year of MBR Implementation						-151.2 *
						(81.5)
Sixth Year of MBR Implementation						-180.6 *
						(100.8)
Seventh Year of MBR Implementation						-177.9
						(127.7)
Eighth Year of MBR Implementation						-115.5
						(131.9)
Ninth Year of MBR Implementation						-163.7
						(111.5)
County is in Non-attainment for at least one criteria air pollutant					21.0	23.3
					(34.0)	(34.4)
League of Conservation Voters Score					-0.04	-0.02
					(0.34)	(0.39)
State Unemployment Rate					1269.6	1155.6
					(1176.6)	(1205.4)
Year Controls	Yes #					
State Trends		Yes #	Yes #	Yes #	Yes #	Yes #
Large Quantity Generator Trends			Yes #			
Large Quantity Generator-Year Interactions				Yes #	Yes #	Yes #
Two-digit SIC trends			Yes #			
Two-digit SIC interactions				Yes #	Yes #	Yes #
Adjusted R^squared	0.485	0.490	0.491	0.491	0.491	0.491
Number of observations	233,213	233,213	233,213	233,213	233,213	233,213
Number of plants	31,115	31,115	31,115	31,115	31,115	31,115
Years	1988-1999	1988-1999	1988-1999	1988-1999	1988-1999	1988-1999

*** significant at 1% level
** significant at 5% level
* significant at 10% level
# F-test of all coefficients in group equal to zero rejected at 1% level

When facility-specific characteristics are allowed to affect the trend in a non-linear fashion the effect of MBR is no longer statistically significant (column 4), but is roughly of the same magnitude. Column 5 also includes time-varying covariates for regulatory stringency, political and economic characteristics of the plant, and the community in which the plant is located. These characteristics are not statistically significant and have little effect on the coefficient for MBR, which is also not statistically significant in this specification.

All of these specifications assume MBR has a one-period effect on releases. However, we might think that MBR actually affects the trend in releases over a longer time period. To allow for this, we can employ the specification in Equation 3. The results of this specification are given in column 6. The effect of MBR is negative and statistically significant for five of the first six years after implementation, even when

general facility specific time interactions are included.[25] Taken together, the results suggest that MBR has had an effect on toxic chemical releases.[26]

Other Outcome Measures

The previous results indicate that MBR has had a demonstrable effect on total pounds of chemicals released. This section presents the results for two other measures of environmental performance that can be used to help distinguish how these reductions in releases were obtained. The first measure is the frequency of source reduction activities reported by the firm. The second measure is the number of chemicals reported by the firm. If MBR has a significant positive effect on the frequency of reported source reduction activities, this would imply that plants respond to MBR by improving operating practices, modifying their production process, or modifying their product. If the effect of MBR is to decrease the number of chemicals reported, this would imply that plants respond by reducing their use of toxic chemicals below the reporting threshold, potentially to avoid regulation.

Table 4 provides regression results for source reduction activities. Columns 1 and 2 report results for the conditional logit model where the dependent variable takes a value of one if the facility engaged in any source reduction activities. Columns 3 and 4 report results from the fixed-effects negative binomial model where the

Table 4. Difference-in-difference estimates for frequency of reported source reduction activities.
Standard errors in parentheses.

	Conditional Logit		Fixed-Effect Negative Binomial	
	1	2	3	4
Management-Based Regulation	**0.26** ***	**0.19** ***	**0.09** ***	**0.06** *
	(0.04)	**(0.06)**	**(0.02)**	**(0.03)**
Year Controls	Yes #		Yes #	
State Trends		Yes #		Yes #
Large Quantity Generator Trends				
Large Quantity Generator-Year Interactions		Yes #		Yes #
Two-digit SIC trends				
Two-digit SIC interactions		Yes #		Yes #
Number of observations	89,962	89,962	106,309	106,309
Number of plants	15,803	15,803	15,046	15,046
Years	1991-1999	1991-1999	1991-1999	1991-1999

*** significant at 1% level
** significant at 5% level
* significant at 10% level
# F-test of all coefficients in group equal to zero rejected at 1% level

[25] The magnitude of the coefficients does decrease slightly in year 8, but we are identifying these coefficients of significantly fewer facilities (only facilities in states that adopted MBR in 1991 and 1992). The coefficients are not significant after year 6, so it would be inappropriate to place too much weight on their magnitudes.

[26] Models were also run on total releases to air and water separately, as in Helland and Whitford (2003). The pattern of results was very similar for all three groupings. In particular, non-attainment status was not significant for air releases or for water releases. This is likely due to the fact that non-attainment status does not vary much over time, and all of this variation is captured in the facility fixed-effect and the state-level time trends.

dependent variable is the number of source reduction activities.[27] In all models, the effect of MBR is positive and statistically significant, indicating that facilities subject to MBR are more likely to report engaging in source reduction activities and are likely to engage in more of these activities.

Table 5 presents the results for total number of reports. The first two columns contain results from the linear fixed-effects model and the final two columns contain results from the fixed-effects negative binomial model. In all but the most simple model, the effect of MBR is not statistically significant and is quite small. These results indicate that facilities are not responding to MBR by strategically lowering their chemical use below reporting thresholds.

Taken together, the results from Tables 3–5 suggest that MBR has had a positive impact on facility-level environmental performance. Facilities reduced total levels of releases, engaged in more SRA, and did not strategically reduce reporting.

Robustness Tests

The results presented above rely on the assumption that the policy variable is exogenous to the trend in total releases. This section contains results from additional specifications for the toxic releases model designed to test whether the policy variable is indeed capturing variance due to the policy alone, or whether this variable is capturing other variance in unobservable facility or state characteristics.

The results of these tests are provided in Table 6 for a specification that includes state trends, trends for 2-digit SIC codes, and trends for large quantity generators of hazardous waste. The baseline results are provided in column 1 for comparison.

Table 5. Differences-in-differences estimates for number of chemicals reported. Standard errors in parentheses.

	Fixed-Effect Linear Model		Fixed-Effect Negative Binomial	
	1	2	3	4
Management-Based Regulation	-0.13 **	-0.004	-0.02 ***	0.01
	(0.07)	(0.063)	(0.01)	(0.01)
Year Controls	Yes #		Yes #	
State Trends		Yes #		Yes #
Large Quantity Generator Trends				
Large Quantity Generator-Year Interactions		Yes #		Yes #
Two-digit SIC trends				
Two-digit SIC interactions		Yes #		Yes #
Number of observations	253,098	253,098	249,580	249,580
Number of plants	35,462	35,462	31,944	31,944
Years	1988-1999	1988-1999	1988-1999	1988-1999

*** significant at 1% level

** significant at 5% level

* significant at 10% level

F-test of all coefficients in group equal to zero rejected at 1% level

[27] Other specifications were estimated (similar to those reported for total pounds of chemicals released); the results of these specifications are consistent with the results that are reported here. As with total reported releases, political and economic covariates were not statistically significant and their inclusion or exclusion did not affect the estimate of the treatment effect. Results were also similar if a fixed effect poisson model was used.

The first set of tests generates proxy policy variables applicable to plants in years where MBR is not actually in effect. Since there was no policy in effect during those years, these proxy variables should *not* be statistically significant. Column 2 contains the results from a test where the proxy policy takes a value of one, two years prior to the actual enactment of the policy. In column 3, the proxy policy takes a value of 1 in the year prior to the actual enactment of the policy. In both cases, the effect of the proxy policy is not statistically different from 0.

Column 4 presents results from a third proxy policy. This proxy policy takes advantage of the fact that some states have MBRs that only apply to a subset of plants. Plants that are not subject to MBR in those states should not have statistically significant decreases in releases. If they do, then the analysis might be capturing other factors in the state rather than the policy itself.[28] In this case, the proxy policy is not statistically significant and the point estimate is actually positive. Thus, it appears as though the policy variable is picking up variation from the policy itself and not variation from other state-specific or facility-specific characteristics. This provides support for the exogeneity of the policy variable conditional on changes in observable covariates, which is the identifying assumption underlying the DID estimator.

The final column presents the results of the analysis if the sample is restricted to plants that report to TRI for every year between 1988 and 1999 (the balanced panel). In general, this restriction was not imposed on the analysis because there is more post-regulation data than is actually required to estimate the effect of the policy for many plants. If a plant is subject to MBR in 1992 and goes out of business

Table 6. Total pounds of chemicals released, robustness tests.
Standard errors clustered by state in parentheses.

	1	2	3	4	5
	Baseline Case	Proxy Regulation (2 years prior to actual)	Proxy Regulation (1 year prior to actual)	Proxy Regulation (states where policy applies to a subset of plants)	Balanced Panel
Management-Based Regulation	**-62.2 ****	**-14.2**	**-34.6**	**64.6**	**-109.3 ****
	(30.2)	**(36.2)**	**(25.7)**	**(52.5)**	**(54.4)**
Adjusted R^squared	0.491	0.491	0.491	0.491	0.515
Number of observations	233,213	233,213	233,213	233,213	105,828
Number of plants	31,115	31,115	31,115	31,115	8,819
Years	1988-1999	1988-1999	1988-1999	1988-1999	1988-1999

All regressions include state-specific trends, 2-digit SIC code trends, and LQG trends

*** significant at 1% level

** significant at 5% level

* significant at 10% level

[28] The proxy policy takes a value of 1 for small quantity generator in California, Georgia, Tennessee, and Mississippi, because the MBRs in these states only apply to LQGs. The proxy policy also takes a value of 1 for plants in SICs 20–34 in Minnesota beginning in 1991. Only plants in SIC 35–39 are subject to MBR in that year. Finally, the proxy policy takes a value of 1 for all plants in Texas that generate fewer than 100 tons of toxic chemical releases, beginning in 1993. The actual policy only affects plants with releases greater than or equal to 100 tons in that year.

in 1996, we still have five years of post-policy data on this plant and might introduce bias by throwing out these observations.[29] Nonetheless, it would be reassuring to know that the effect of the policy is negative and statistically significant when the analysis is restricted to the balanced panel. This would rule out several possible concerns. The first concern is that dirtier plants are more likely to be inefficient and more likely to go out of business. If this occurs in years where MBR is also adopted, then the policy variable will pick up a decrease in the average that is due to the exit of a high-polluting plant rather than MBR. The second concern is that if production levels decline in the years prior to plant closure and production levels are correlated with pollution releases, then plants that close may have larger decreases in releases over time, but these decreases are not due to any policy shift.[30] However, there is no evidence that either of these effects occurs. In the balanced panel, facilities subject to MBR had an average decrease in reported releases of 109,000 pounds, relative to plants not subject to regulation (Table 6). This decrease is relative to a pre-regulation average level of releases of 387,000 pounds. Thus MBR resulted in a 28 percent decrease, which is roughly the same magnitude as the effect estimated in the unbalanced panel.

CONCLUSIONS AND POLICY IMPLICATIONS

The analysis presented in this paper suggests that MBR has had a measurable positive effect on the environmental performance of manufacturing plants. In particular, plants that are subject to MBR experienced larger decreases in total pounds of toxic chemicals released (of about 28 to 30 percent of pre-regulatory releases). The results also indicate that these reductions were likely the result of real changes in environmental management at the facility. Plants subject to MBR were more likely to engage in source reduction (pollution prevention) activities and likely to engage in more of these activities than plants not subject to MBR. However, MBR did not appear to cause facilities to report for fewer chemicals, suggesting that the decreases in pollution are not an artifact of reporting changes. These results are robust to several tests of the identifying assumptions.

These findings suggest that MBR can be an effective regulatory tool—it is more effective than the status quo of no regulation. Of course, this does not necessarily mean that MBR is a desirable regulatory tool. The desirability hinges on whether MBR is more effective or more cost-effective than alternative approaches to pollution control. However, traditional regulations have not been used much in the toxics chemical area, making infeasible direct comparison of MBR with alternatives. But theoretical explorations (Bennear, 2006a ; Coglianese & Lazer, 2003) offer some insights as to when MBR may be a more desirable alternative, in particular when the population of regulated entities is heterogeneous and regulation of other direct measures of risk are infeasible or undesirable.

While direct comparisons of MBR to other regulations may not be possible, future research should explore the interactions of MBR with other regulatory and self-regulatory regimes. Do self-regulatory programs (such as ISO 14000 or the American Chemistry Council's Responsible Care program) substitute for state reg-

[29] This begs the question of why data through 1999 are used at all. The TRI data through 1999 are used to ensure that the last cohort of regulated plants, those subject to MBR in 1997, have two years of post-regulation data.

[30] If production levels fall in the years prior to a plant closure, then restricting the sample to the balanced panel also provides a partial test of the bias created by the inability to control for production levels.

ulations, or complement them? This could be explored by evaluating whether MBR was more or less effective among plants that also participated in these initiatives. While more research remains to be done, the findings of this paper, namely that MBR reduces chemical releases, is a critical step in understanding the potential of MBR as a regulatory alternative.

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