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

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Abstract: This paper evaluates the effectiveness of management-based regulations in reducing pollution. Management-based regulations do not establish strict pollution reduction standards, but rather require each regulated entity to engage in its own review and planning process and develop a set of internal rules and initiatives consistent with achieving reductions in pollution. I develop a model of facility-level response to management-based regulation that provides predictions about the circumstances under which these regulations are likely to be effective. I then test these predictions empirically by taking advantage of a natural policy experiment that occurred when fourteen states adopted management-based 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. The analysis suggests 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.

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1 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 Responsible Care program developed and implemented by members of the Chemical Manufacturers Association,[1] and through the use of innovative management-based regulations. However, the empirical literature examining the consequences of these innovative regulatory initiatives is relatively sparse.[2]

This paper examines 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 and Lazer, 2003). During the early 1990s, fourteen 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 differences-in-differences 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 for fewer toxic chemicals under

[1] Now known as the American Chemistry Council.

[2] Work that has been done include studies of the effect of the Toxics Release Inventory, an information-based regulatory initiative (Hamilton 1995, Konar and Cohen 1997, Khanna, Quimio, and Bojilova 1998, Bui and Mayer 2003) 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.

the TRI program controlling for other factors that might explain differences in environmental performance across plants. Using a separate panel of 5,000 chemical manufacturing plants, the paper investigates whether the effect of management-based regulations differs by facility characteristics.

The analysis suggests 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. 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. The results also suggest that the effect is greater for plants with larger marginal benefits of pollution reduction and greater complementarity between planning effort and pollution reduction.

The paper begins in Section 2 with a model of plant response to MBR. Section 3 provides background information on the use of MBR in the toxic chemicals arena. The estimation strategy used to evaluate the effectiveness of the regulations is outlined in Section 4, while Section 5 describes the data used in estimation. The results of the estimation are described in Section 6. Section 7 contains conclusions and policy recommendations.

2 Theory of management-based regulation

2.1 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 regulating 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 their 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 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.[3] The primary use of MBR has been in food safety, where the United States has implemented a system known as the Hazard Analysis and Critical Control Point (HACCP) for controlling pathogen contamination in the food supply. Under the HACCP program food processors are required to evaluate their production process and identify potential sources of food contamination, develop systems to eliminate or reduce those risks, and develop detailed records of their safety activities. MBRs have also been implemented in the area of industrial safety. The Occupational Safety and Health Administration adopted a set of regulations that required firms to implement management systems to assess the risk from chemical accidents, and develop rules and procedures to reduce those risks.

MBRs are often appealing to the regulator, particularly in circumstances when the heterogeneity and complexity of the regulated entities makes traditional standard setting time-consuming and costly (Coglianese and Lazer, 2003). However, MBR can only be considered a viable regulatory tool if there is evidence that these regulations are effective at reducing risk. There are two related, but distinct questions one could ask about the

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[3] In the economics literature there is a strong distinction between the term risk and the term uncertainty, with risk denoting situations in which the probability of each outcome is objectively knowable. Throughout this paper, the term risk takes on its common language definition, namely that of "danger" or "harm" rather than the traditional economic definition. Thus risk regulation merely denotes regulation of activities that generate harm regardless of whether the probabilities of each potentially harmful outcome are known, *a priori*.

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. That is the focus of this paper. Before turning to the empirical analysis, it is helpful to examine a simple model of MBR. The model highlights conditions under which MBR is likely to be effective and provides a foundation for the empirical analysis.

2.2 A simple model of management-based regulations

The concept of the government requiring plants to evaluate their production process with an eye toward opportunities to reduce risk, but allowing plants the discretion to adopt only those activities that the plant finds profitable, appears at odds with the commonly held concept that plants act as profit-maximizers.[4] If the plant is profit-maximizing it should always be reviewing its production processes and actively seeking and implementing cost-saving changes. If the regulation does not require plants to do anything that is not in their own best interest, how could government-mandated planning requirements change the outcome?

One simple answer is that plants are not optimizing. The Porter hypothesis (Porter and Van der Welte 1995) argues that government regulation can actually improve competitiveness by focusing management attention on environmental performance thereby causing firms to uncover "win-win" opportunities that enhance environmental performance and also increase profits. While such "win-win" opportunities may occasionally exist, there is little evidence that they are widespread (Palmer, Oates, and Portney 1995). A more compelling argument in favor of MBR would be one that

[4] This is the type of management-based regulation examined in this paper—regulation that mandates planning, but does not explicitly mandate implementation. Of course, regulation could be constructed that does require implementation. Coglianese and Lazer (2003) outline four categories of management-based regulation: Scenario A, no mandate required; Scenario B, mandate necessary at the planning stage; Scenario C, mandate necessary at the implementation stage; and Scenario D, mandate necessary at both the planning and implementation stages. This model address Scenario B.

demonstrates that there are circumstances under which improvement in environmental performance is possible even when all plants are profit-maximizing. The following model illustrates that this can, indeed, be the case.

Let the expected gross value of the plant be given by:

$$V(r, p),$$

where p is planning effort, r is pollution reduction effort, and $V(\bullet)$ is concave. The gross expected value of the plant is the expected value of the stream of operating profits less expected tort and regulatory liabilities. The *gross* value of the plant includes everything but the costs of planning or reduction activities. Thus the *net* value of the plant is given by:

$$V(r, p) - C_R(r, p) - C_P(p)$$

where $C_R(r, p)$ is the cost of risk reduction and $C_P(p)$ is the cost of planning and both are convex cost functions.

The plant's problem is given by:

$$\max_{r,p} V(r, p) - C_R(r, p) - C_P(p).$$

The first-order optimality conditions[5] for this problem are given by:

$$\frac{\partial V(r^*, p^*)}{\partial r} = \frac{\partial C_R(r^*, p^*)}{\partial r} \quad \textbf{(1)}$$

$$\frac{\partial V(r^*, p^*)}{\partial p} = \frac{\partial C_P(p^*)}{\partial p} + \frac{\partial C_R(r^*, p^*)}{\partial p} \quad \textbf{(2)}$$

The first condition implies that plants choose the optimal level of pollution reduction effort such that the marginal equals the marginal costs of reduction. The second equation is similar, but in this case the plant chooses the optimal level of planning such that the marginal benefit equals the marginal cost of planning less any impact of planning on the cost of pollution reduction.[6]

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[5] Since the value function is concave and the cost functions are convex, these conditions are sufficient for a maximum.

[6] Applying Blackwell's Theorem, it must be the case that the effect of planning on the cost of pollution reduction is non-positive. The firm can always chose the same methods of reduction after planning and

So far the model describes how a plant optimally chooses its level of reductions and planning. The model has not yet explained why *government-mandated* planning increases environmental performance. Equation (1) gives the conditions for optimally choosing the level of reduction effort for a given level of planning. In this context, MBR can be considered an exogenous increase in planning effort. Defining *r* implicitly as a function of *p* and totally differentiating (1) with respect to *p* yields:

$$\frac{dr}{dp} = -\frac{\dfrac{\partial^2 V}{\partial r \partial p} - \dfrac{\partial^2 C_R}{\partial r \partial p}}{\dfrac{\partial^2 V}{\partial r^2} - \dfrac{\partial^2 C_R}{\partial r^2}} \qquad \textbf{(3)}$$

The concavity of the value function and the convexity of the cost functions imply that the denominator is negative and because of the minus sign in front, the sign of $\frac{dr}{dp}$ will take the same sign as the numerator.

The sufficient conditions for MBR to be an effective policy instrument are then the conditions necessary to insure that the numerator is positive, namely that planning and reductions are complements. That is:

$$\frac{\partial^2 V}{\partial r \partial p} - \frac{\partial^2 C_R}{\partial r \partial p} > 0\,. \qquad \textbf{(4)}$$

This inequality implies that increased planning effort increases the value of reduction effort. There are several ways for this inequality to hold. Two with easy interpretations are:

$$\frac{\partial^2 V}{\partial r \partial p} > \text{and} \frac{\partial^2 C_R}{\partial r \partial p} = 0 \text{ or}$$

$$\frac{\partial^2 V}{\partial r \partial p} = 0 \text{ and} \frac{\partial^2 C_R}{\partial r \partial p} < 0\,.$$

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incur the same costs, or planning might reveal ways to make those reductions less costly. See Blackwell (1953) and Savage (1954).

The first suggests that increased planning effort increases the marginal value of reductions. This might be the case if planning reveals information about the relative toxicity of different chemicals used in the production process, thereby allowing the plant to better target its reduction dollars on efforts that reduce the use of chemicals most likely to result in tort or regulatory liability.[7] The second set of inequalities implies that increasing planning lowers the marginal costs of pollution reduction. This is the more conventional belief about the relationship between management effort and pollution, namely that more focused attention on pollution control possibilities leads plants to discover ways to reduce pollution for less money.[8]

Complementarity of planning and reductions is still not sufficient to guarantee that MBR will be effective at increasing pollution reductions. If all plants optimally choose a level of planning greater than or equal to the level mandated by the government, then the mandate will not increase planning and will not increase reductions. If however, there exists a set of plants where the optimal planning level, that is the level of planning p* satisfying **(2)**, is less than the government-mandated level of planning, p^m, then this subset of plants will be forced by regulation to engage in more planning and through complementarity this will result in increased reductions.

The final sufficiency condition is that some plants choose a positive level of reduction after regulation. The circumstances under which this will occur are:

$$\frac{\partial V\left(0, p^M\right)}{\partial r} - \frac{\partial C_R\left(0, p^M\right)}{\partial r} > 0$$

This inequality implies that given the government mandated level of planning, at zero reductions the marginal benefits of reduction are greater than the marginal costs. This inequality will hold if reductions are goods, ignoring their direct costs,

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[7] This would also be the case if mandated planning changes the internal dynamics of the firm. For example, government-mandated planning might increase the power of the environmental manager in plant decision-making.

[8] There is an abundance of anecdotal evidence to suggest that these complementarity conditions may hold in practice. Manyindo (1998) contains a detailed compendium of case studies from individual companies that have successfully investigated pollution prevention alternatives and discovered means to reduce pollution at lower costs. There is also some empirical evidence to suggest that management effort and pollution reduction are complements. Gunningham, Kagan, and Thorton (2003) examine environmental performance of several pulp and paper mills and found that management style and management effort was a significant determinant of environmental performance. See also Thornton (2001).

$\frac{\partial V(r, p^M)}{\partial r} > 0$, and marginal costs are not too high. The constraint that increased pollution reductions increases the gross expected value of the plant, may seem controversial. To be clear, pollution reductions are costly so increasing these reductions need not increase the *net* expected value of the plant, and generally one would not expect this to be the case. The easiest interpretation of the positive effect on gross value is that pollution itself does not generate a positive price in some market and potentially lowers the gross expected value of the plant by increasing expected tort and regulatory liability.[9]

The idea that pollution might lower expected gross value seems reasonable given legal and regulatory institutions in the United States. In particular, tort litigation can be provide powerful incentives to continue to reduce pollution that results in measurable impacts on others, even if the plant is in full compliance with regulatory requirements. If a plaintiff can show beyond a preponderance of the evidence that a plant's activities resulted in harm, they can obtain compensation for those damages in court. These liabilities can be substantial. Superfund liabilities average $40 million per site for pollution releases that were not regulated, and hence legal, at the time they occurred.[10] In the United States, lack of regulation or compliance with existing regulation, does not lessen a plant's liability for harm. In this institutional setting, higher levels of toxic pollution releases leave a plant more vulnerable to litigation and decrease the expected gross value of the plant. Similarly, higher pollution levels leave a plant more vulnerable to future environmental regulation, which also lowers the expected gross value.[11] Hence, reductions in toxic pollution might be expected to have a non-negative impact on expected gross value, which is exactly what the second inequality implies.

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[9] That pollution does not have any value to the plant is not necessarily true, one plant's pollution waste might server as another plant's inputs. For example, wastewater treatment facilities often sell the sludge from their treatment processes to farmers as fertilizer. For MBR to necessarily result in improvements in environmental performance it will have to be the case that these opportunities do not exist or are sufficiently small relative to the cost of pollution.

[10] Superfund liabilities are only one example of potential tort liabilities. In 2002, Dow Chemical estimated its Superfund liability at $394 million and estimated liabilities from asbestos related claims at sites acquired from Union Carbide at $2.2-2.4 billion (Dow, 2002).

[11] Maxwell, Lyon, and Hackett (2000) develop a model of self-regulation as a strategic tool to pre-empt government regulation. In their model, political entry by consumers desiring increased stringency of environmental regulation is costly. Thus, firms can pre-empt this entry and the resulting increased stringency by engaging in some clean-up efforts that otherwise would not be in their best interest.

Figure 1 illustrates the solution to the plants' optimization problem. Without loss of generality, the figure depicts a case where the plant chooses a positive level of both planning and reductions before regulation. It is clear that if both reduction and planning are goods (the marginal benefits are positive) and the marginal costs of planning and reductions are sufficiently low, firms optimally choose to engage in some level of both pollution reduction and planning even in the absence of regulation.

Figure 2 illustrates the effect of MBR combining all three conditions: (1) planning and reductions are complements, and (2) some firms optimal planning levels are less than the government-mandated level, (3) some plant chooses a positive level of reductions. The graph depicts the marginal benefits and marginal costs of pollution reduction for a single plant. Pre-regulation the plant optimally selects reduction level, r*, and planning level, p*. The regulation requires that the plant expend more planning effort than it would have otherwise chosen, that is the regulation requires the plant to expend $p^m > p^*$. Complementarity implies either that this increase in planning increases the marginal benefits of reduction (shifts the marginal benefit curve out and to the right) or decreases the marginal cost of reductions (shifts that marginal cost curve down and to the right). Either way, when forced to increase planning effort through regulation, complementarity implies that the firm will then optimally choose to engage in more reduction activity.

Note that this is not a "win-win" situation from the plant's perspective. The plant would have had higher net profits at the original optimum (p*,r*). From the plant's perspective the government is forcing them to engage in too much planning. However, given that they are required by regulation to spend the effort planning, complementarity implies they will also choose to reduce more.[12] Firms are worse off than if not regulated, but better off than if they engaged in extra planning at the old reduction level.

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[12] By analogy, imagine that the government wants to increase personal savings. In general, financial planning and personal savings are complements and most people optimally choose to engage in some level of both financial planning and personal savings. If the government required that every person keep a detailed record of all expenditures, develop a plan to reduce expenditures and increase savings, and file regular reports on these activities it is likely that this mandated level of financial planning would be viewed by many as excessive. However, forced to divert time from other leisure activities to financial planning, it is also likely that many people will discover opportunities to save more.

This model highlights the sufficient conditions for MBR to induce profit-maximizing plants to improve environmental performance. The model also yields predictions about the magnitude of the effect of MBR. MBR is likely to be more effective when the marginal benefit of reduction is large, when there is greater complementarity between planning effort and pollution reductions, and if the regulation requires planning levels greater than what most plants would optimally choose in the absence of regulation.

The model also suggests conditions under which MBR might be a particularly desirable regulatory alternative. If the sufficiency conditions hold, then requiring increased planning effort will increase risk reductions. If reductions are difficult to measure, but planning is relatively easy to measure, then the government can potentially focus on monitoring planning effort rather than monitoring risk reductions. In fact, in a positive analysis of the circumstances under which MBR has been used for risk regulation we see some evidence that MBR is used when planning effort is more easily monitored than risk reductions. In both food safety and industrial safety the risks are low probability, making measuring changes in risk difficult. Monitoring planning effort in these cases is easier for the regulator. However, the reasonableness of this approach is predicated on the fact that the three sufficient conditions hold. The remainder of the paper empirically tests whether MBR, as applied to toxic chemical control, resulted in decreases in risk from toxic chemicals and evaluates whether the observed responses to MBR are consistent with the predictions from this model. The next section briefly describes the nature of the state pollution prevention regulations and the remainder of the paper presents empirical evidence regarding the effectiveness of MBR in reducing risk from toxic chemical releases.

3 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 for the pollution-prevention approach argued that traditional regulation, which focused on end-of-pipe treatments, often resulted in transferring pollution from one media 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.[13] Advocates also believed that pollution prevention was good for industry since 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. While all fourteen 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 Toxics Release Inventory (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 since they are not manufacturing facilities (e.g., hospitals can be LQGs, but are not manufacturing facilities) and many TRI facilities are not LQGs.

[13] 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.

- **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 every year to every four years. Unlike the pollution prevention plans themselves, the progress reports are public.
- **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.

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

3.1 Previous Findings

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, and Stoner 1997).

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, *et al.* 1996).

Two papers have examined the effects of state-level pollution prevention programs without focusing specifically on pollution prevention planning requirements. Bui (2003) examines the differences in decreases 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 little evidence of a systematic effect of state stringency on the rate of reductions in air releases. 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 waste for fourteen states, seven of which have MBRs and six of which have voluntary pollution prevention programs.[14] She finds that after adjusting for changes in production, states with mandatory programs showed greater progress in reducing toxic releases 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 since 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.

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[14] Voluntary programs differ greatly by state and include technical assistance centers, recognition programs, etc.

This paper builds on previous efforts and analyzes the effect of management-based pollution prevention regulations, accounting for the fact that state programs 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.

4 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.

One potential estimation strategy would be to match identical facilities in states with management-based regulation and without such regulation. If the facilities are truly identical before regulation, then post-regulation differences could reasonably be attributed to the regulation itself. However, there is limited information on which to match facilities across states. Data are not readily available on important indicators such as production levels, age of the equipment, product mix, etc. that would be necessary for such a matching strategy to be successful.

The identification strategy used in this paper is to compare the change in three measures of environmental outcomes—toxic air 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 "differences-in-differences" (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. The difference-in-difference estimator is the sample equivalent to $E[Y_{11} - Y_{10}] - E[Y_{01} - Y_{00}]$, where

Y_{11} is the post-regulation outcome for a plant subject to the regulation,

Y_{10} is the pre-regulation outcome for a plant subject to the regulation,

Y_{01} is the post-regulation outcome for a plant not subject to the regulation, and

Y_{00} is the pre-regulation outcome for a plant not subject to the regulation.

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 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 then never-MBR plants. In other words, plants are allowed to have different levels of environmental performance, but in the absence of regulation, these differences should remain constant over time. In analyzing the results, it will 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" linear regression model:

$$y_{it} = \delta M_{it} + \sum_{t=1988}^{1999} \gamma_t t + c_i + u_{it} \qquad \textbf{(5)}$$

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}.[15] This equation estimates a common non-linear time path[16] 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.[17]

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

[15] 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 et al. (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 this 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. Their results suggest that clustering the standard errors at the state level corrects the precision of the estimates. That is the approach taken here.

[16] One could instead include a linear time trend, but this imposes unnecessary restrictions on the exogenous evolution of environmental performance. The year dummy variables allow for a linear effect if such an effect is present in the data, but does not restrict the time effect to be linear. In this sense, the year dummies are more general and, hence, preferable.

[17] 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 plants 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 McFaddin's 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

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 plants, 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.[18] The regression equation to be estimated is then given by:

$$y_{it} = \delta M_{it} + \sum_{t=1988}^{1999} \gamma_t t + X_{it}\beta + \sum_{t=1988}^{1999} (Z_i * t)\phi_t + c_i + u_{it} \qquad \textbf{(6)}$$

where X_{it} are time-varying covariates, Z_i are time-constant variables, and y_{it}, M_{it}, t, c_i, and, u_{it} 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:

$$y_{it} = \sum_{d=0}^{8} \delta_d M_{id} + \sum_{t=1988}^{1999} \gamma_t t + X_{it}\beta + \sum_{t=1988}^{1999} (Z_i * t)\phi_t + c_i + u_{it} \qquad \textbf{(7)}$$

where t is the current year, T is the year MBR went into effect, and M_{id} is a dummy variable that takes a value of one if t-T=d. All three specifications are employed in this analysis.

5 Data

5.1 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

[18] 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.

the federal Toxics Release Inventory (TRI) program.[19] 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.[20]

5.2 Policy Variable

Data on state-level pollution prevention programs was provided by the National Pollution Prevention Roundtable (NPPR, 1996). Additional information on program details was gathered from state websites and through phone conversations with state pollution prevention employees.[21]

As discussed in Section 3, 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,[22] New Jersey, Oregon, Texas,[23] 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 one 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,[24] and Tennessee. For these states,

[19] 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 (e.g. air, water, land).

[20] 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.

[21] Detailed information on the state programs is available from the author on request.

[22] 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.

[23] 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.

[24] 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

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 EPA. As the name suggests, it contains information on hazardous waste generation reported every two years.[25] 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.[26]

5.3 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 up to four source reduction activities that they engaged in during that reporting year. There are forty-five different source reduction activities to choose from organized into eight broad categories: improved operating practices, inventory control, spill and leak prevention, raw materials modifications,

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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.

[25] 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.

[26] 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 to no longer be considered a 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 a LQG at the time the regulation went into effect. The results are robust to changes in this definition.

process modifications, cleaning and degreasing, surface preparation and finishing, and product modifications. These data are used to construct the second outcome variable that takes a value of one if the plant engaged in any source reduction activities during the year.

The third measure of environmental performance is the number of chemicals reported to the Toxics Release Inventory in a given year. One of the stated goals of the pollution-prevention regulations is to facilitate the elimination of toxics use at the source. Because facilities only report on chemicals they use in quantities greater than the reporting threshold, one measure of toxic use reduction is the number of chemical reports filed by the plant in a given year.[27]

5.4 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 four categories of variables that are included as control variables—facility-specific control variables, variables representing other regulations, political variables, and demographic variables.

5.4.1 Facility-specific Controls

Source reduction opportunities may differ for different chemical product classes. 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. Industry controls at the two-digit SIC code level are interacted with year dummy variables, thereby allowing trends in environmental performance to vary by industry.

Simliarly, 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

[27] This is not a perfect measure of chemical use reduction since the facility may still be using the chemical in some quantity just slightly below the reporting threshold. The researcher cannot distinguish in the data whether a facility eliminates use of a chemical or simply reduces use below the reporting threshold. All the researcher observes is that the facility no longer files a report for a particular chemical.

different for LQGs than for facilities that are not classified as LQGs. A separate trend for LQGs is included to account for these differences.

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 affect the results.

5.4.2 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. There are several reasons to suspect that state environmental stringency differ in ways that are correlated with MBR adoption and also with trend in environmental performance. First, nearly all major environmental statutes are established at the federal level, but 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. I include state-specific trends to account for differences across states that are not a function of MBR. 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 second reason states that adopt MBR might have different regulatory stringency than states that do not adopt MBR is that the nature of pollution in those states may trigger additional federal regulation. 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.[28] Other studies (Henderson, 1996; Becker and Henderson 2000; Greenstone 2002) have found that facilities in non-attainment counties have greater increases in ambient air quality, and it might be expected that facilities in non-attainment counties may be more likely to engage in source reduction activities and have greater reductions in pollution releases. 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 one if the county in which the facility is located was in non-attainment for at least one criteria air pollutant during that year.[29]

5.4.3 Political, Demographic, 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 are relatively constant over time, the state 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. The League of Conservation Voters assigns each federal congressional representative and senator a score based on their voting record on key environmental policies during that congressional session.

Other authors have argued that the public availability of the Toxics Release Inventory data itself may motivate citizens to pressure facilities to improve their environmental performance (Hamilton, 1995; Konar and Cohen, 1997; Khanna *et al*.,

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[28] Greenstone (2003) links TRI chemicals to criteria air pollutants.
[29] Data on attainment status by county for the years 1992-1999 were taken from EPA's Green Book (U.S. EPA, 2003). Attainment status for the years 1988-1992 were graciously provided by Michael Greenstone.

1998; Snyder, 2001). To allow for this possibility, the analysis includes demographic variables from the 1990 Census including: median household income, percentage of the population that is Caucasian, and percentage of the population employed in manufacturing.[30]

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.

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

6 Results

6.1 Toxic Air Releases

Figure 3 provides a graph of the trends in air releases for ever-MBR and never-MBR plants over time. The trends can be informative about whether controlling for covariates is likely to be required to ensure exogeneity of the policy and to get a sense of whether the outcome variable seems to respond in the correct direction when the policy is implemented. The vertical black lines bound the time period in which states enacted MBR. There are two things to notice about the graph. First, the trends in toxic releases do not appear to be parallel prior to the adoption of MBR. In particular, the average releases for ever-MBR plants is rising in the year prior to the first states adoption of the program, while the trend for non-MBR plants is decreasing, implying that we may need to control for other factors to ensure exogeneity. The second thing to notice is that the unadjusted trends do suggest that MBR has had an effect on the level of toxic releases. In fact, from 1991 to 1997 releases in MBR states fell by 46% while releases in non-MBR states fell by 25%.

However, the analysis of trends presented in Figure 3 is not sufficient to establish that MBR has had a causal effect on pollution releases. At a minimum the analysis should account for the precise timing of the adoption and implementation of MBR in

[30] The census data are merged in at the Census Designated Place-level. A Census Designated Place is generally a town or city, thus is a larger designation than a census tract, but smaller than a zip code or county.

different states. The trends presented in Figure 3 would look identical if facilities subject to MBR in 1992 had large decreases in releases in 1992, or if facilities subject to MBR in 1995 had large decreases in releases in 1992. However, only the first of these cases would provide support for MBR as a policy instrument. To adjust for this, one can normalize the year to be equal to one in the year the policy was implemented for any given plant, and then examine the trends for ever-MBR plants around their adoption date.[31] The normalized trend is presented in Figure 4. The normalized trend does suggest that a small increase in the rate of decline of releases occurred in the two year window after the policy was implemented. In the four years prior to regulation, average releases fell by 28%, while in the two years after regulation releases fell by 30%.

The DID estimator provides a powerful combination of the analysis suggested by the two different trend graphs. Using regression analysis we can control for the timing of MBR implementation, but also compare the rate of change of releases among ever-MBR and never-MBR plants. We can also control for covariates to better ensure that the policy variable is exogenous to the trend in releases, and hence, ensure that we are truly measuring the effect of the policy rather than other unobservable differences across plants. The regression results are presented in Table 3.

The simplest DID estimator that can be obtained in the fixed-effect framework is the specification given in equation **(4)**. 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 2. 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 **(5)**.

In specification in 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.

[31] Unfortunately, the normalized trend cannot be used to compare ever-MBR plants and never-MBR plants since never-MBR plants do not have an adoption date that can be used as the benchmark.

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. 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). 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 effects the trend in releases over a longer time period. To allow for this, we can employ the specification in equation **(6)**. The results of this specification are given in column 6. The effect of MBR is negative and statistically significant for the first five years after implementation even when general facility specific time interactions are included. The total effect of MBR over the first five years of implementation is to lower average releases by 163,000 pounds. Taken together the results suggest that MBR has had an effect on toxic chemical releases.

6.2 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 improved 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 subject to regulation.

Table 4 provides regression results for both measures of environmental performance.[32] The results indicate that MBR has had a positive and statistically significant effect on the frequency of source reduction activities, but no discernable effect on the number of chemicals reported.[33]

6.3 Robustness Tests

Results of the regression analysis suggest that MBR has had an effect on environmental performance, particularly on total pounds of chemicals released. However, these results rely on the assumption that the policy variable is exogenous to the trend in total releases. This section contains results from additional specifications 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 5 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.

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 one 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 zero.

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.

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[32] 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.

[33] While the coefficients for the conditional logit used to estimate the source reduction activities model provide the correct sign and statistical significance, they cannot be used to interpret the increase in the probability of source reduction activities due to MBR. Unlike with traditional logit or probit models, there is not easy way to transform the coefficients into their marginal effects on the underlying probability.

Plants in those states that are not subject to MBR 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.[34] 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.[35] If a plant is subject to MBR in 1992 and goes out of business in 1996, we still have five years of post-policy data on this plant and might introduce bias by throwing out these observations. 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 an 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

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[34] The proxy policy takes a value of one 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 one 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 one 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.

[35] 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.

shift.[36] Fortunately, there is no evidence that either of the effects occur. The results for the balanced panel are actually larger in absolute magnitude, with an average decrease of 109,000 pounds, and this result is statistically significant.

6.4 Extensions

The simple model presented in Section 2 indicates that it is theoretically possible for MBR to increase pollution reductions even among profit-maximizing firms. However, this result is not automatic and relies on three conditions: (1) planning and risk reductions are complements, and (2) the government-mandated level of planning effort is higher than the optimal level of planning effort for at least some plants, and (3) some plants choose positive levels of pollution reduction after regulation. The empirical results indicate that, in fact, MBR has lead to decreases in pollution releases controlling for facility, state, economic, and political characteristics. Given that there is an empirical effect, we can return to the model and examine whether the magnitude of this effect behaves in ways that are consistent with the model.

For example, there are several circumstances under which the model would predict a larger effect of MBR. The predicted regulatory effect would be larger if the marginal value of pollution reductions is large, if the degree of complementarity between planning and reductions is large, or if the government-mandated level of planning is substantially greater than the optimal level of planning selected by most plants.

In order to examine whether the magnitude of the policy effect is consistent with these hypotheses, the sample is restricted to chemical manufacturing plants (SIC 28) only. This allows us to capitalize on an additional policy change within the chemical manufacturing industry to test these additional predictions of the theoretical model.

In 1989, the Chemical Manufacturers Association, a trade association representing the largest chemical manufacturing firms, adopted a self-regulatory initiative called Responsible Care. Participation in Responsible Care is required for all CMA members. Responsible Care established six "codes of management practice" designed to improve

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[36] 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.

the industry's image and reduce future liability. One of these codes is the pollution prevention code. On paper, the pollution prevention code is very similar to the requirements of the state management-based pollution prevention regulations and includes: conducting a quantitative inventory of wastes and releases, evaluating the potential impact of these releases on the environment, establishing goals for pollution and risk reduction, and including pollution prevention objectives in the design of new products and processes, among other requirements (CMA, 1993b). Because plants participating in Responsible Care exist in both MBR and non-MBR states we can take advantage of the variation introduced by this additional policy to further test the hypotheses of the model.

A comparison of changes in releases among responsible care (RC) and non-responsible care (non-RC) plants could provide several interesting tests of the predictions of the model.[37] First, RC plants represent a disproportionate share of chemical industry revenue and pollution releases. Only 30% of all plants are owned by firms that participate in Responsible Care, but these plants account for 66% of all pollution releases from this industry. The fact that RC plants are, on average, more polluting might indicate that they have higher expected tort and regulatory liabilities and hence, might have greater marginal values for pollution reduction. Also, RC firms have higher revenues and are more visible than non-RC firms (King and Lenox, 2000). These "deep pockets" may also increase expected tort liabilities and increase the marginal value of pollution reduction. RC plants are also be more likely to have full-time environmental management staff which could lead to greater complementarity between planning effort and pollution reductions. All of these characteristics would suggest that RC plants are likely to have larger reductions in pollution under MBR than non-RC plants.

However, if RC is an effective program, these plants should have been doing much of the planning activities required by MBR *before* the state programs took effect.[38] This would suggest that RC plants would have smaller average reductions in pollution under MBR than non-RC plants. But, the effect of Responsible Care is debatable. King and

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[37] Data on Responsible Care membership by year was taken from periodic progress reports from the CMA (CMA 1992; 1993a; 1994; 1996; 1997). Occasionally only one business unit within a firm is a participant in Responsible Care and plants were assigned based on their business group.

Lenox (2000) find no evidence that Responsible Care had an effect on environmental performance. Thus, a comparison of changes in performance of Responsible Care plants in MBR states also provides a test of the relative efficacy of government regulation versus industry self-regulation.

Figures 5 present trends in releases for Responsible Care plants separately for those plants that are eventually subject to MBR and those that are not. Figure 6 presents the trend only for ever-MBR plants that are also RC-plants, normalized so that year zero is the year before MBR was implemented. Figure 5 suggests that MBR plants did have a greater decline in releases relative to their never-MBR counterparts and Figure 6 suggests that this decline is correlated with the timing of MBR implementation.

Regression results are presented in Table 6. The regressions test for differences in the effect of MBRs for RC and non-RC plants.[39] The first column presents the results for all plants in the chemical manufacturing industry. The effect of MBR is negative and marginally statistically significant, suggesting that MBR lowered average releases from plants in this industry by 150,000 pounds.[40] The second column includes all chemical manufacturing plants but separates the set of plants subject to MBR into two groups—those that are participants in responsible care and those that are not—and estimate the effect of MBR separately for each group. The results from this specification provide strong evidence that effect of MBR in this industry is due to large changes at Responsible Care facilities. The average decrease in releases among Responsible Care facilities is 447,000 pounds and statistically significant while the average change in releases for non-RC plants is actually positive, but not statistically different from zero. The final column restricts the sample to plants that were members of Responsible Care before their state implemented MBR or before 1993 for states that never implement MBR. The estimated effect of MBR on average releases is 368,000 pounds and statistically significant

[39] All specifications control for differences state trends, differences in three-digit SIC code trends, LQG trends, nonattainment status, League of Conservation Voters score, state unemployment rates, and three air regulations that apply to certain plants in this industry.

[40] The average pollution level is higher in the chemical manufacturing industry than in the whole sample. The average pollution releases across all time periods in this industry was 280,000 pounds. For RC plants, the average is 589,000 pounds.

These results provide preliminary support for the hypothesis that plants with larger marginal benefits of pollution reduction and greater complementarity between planning effort and pollution reduction will have larger effects from MBR. The results also cast doubt on the effectiveness of Responsible Care as an industry self-regulatory initiative. If Responsible Care was being fully implemented at member plants then the government-mandated MBR should not have resulted in increased planning effort and, hence, should not have resulted in increased reductions. This finding is consistent with previous empirical studies of the effectiveness of Responsible Care (King and Lenox, 2000).

7 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 and were more likely to engage in source reduction activities. However, no evidence was found to suggest that plants subject to MBR had larger decreases in the number of toxic chemicals reported. These results are robust to several tests of the identifying assumptions.

Furthermore, an examination of the effect of MBR on chemical manufacturing plants reveals that the effect of MBR on total pounds released is larger for plants that are also participants in the Chemical Manufacturers Association's Responsible Care program. This finding is consistent with the predictions of the theoretical model that plants with larger marginal benefits of pollution reduction and greater complementarity between planning effort and pollution reduction will have larger effects from MBR. However, it also implies that Responsible Care itself was not effective. If Responsible Care was fully implemented, then there is little reason to suspect that government-mandated MBRs, which duplicate the requirements of Responsible Care, would have an effect. This result is consistent with previous findings.

This analysis has several policy implications. First, the results suggest that MBR can be a viable alternative to other forms of risk regulation. However, MBR will not be effective in all situations. MBR is more likely to be an effective risk regulatory tool when there is a strong connection between planning effort and risk reductions. Policy makers should consider the likely degree of complementarity between planning and risk reductions when considering MBR as a regulatory tool. This further suggests that MBR is potentially most useful in situations where risk reductions themselves are difficult to measure, but planning effort is easy to measure, and complementarity between planning and reductions exists. These are the cases where direct regulation is hard and MBR is most likely to be effective.

Finally, the results suggest that while government-mandated MBR has had an effect, at least one industry self-regulatory initiative with similar requirements has not been effective at reducing risk indicating that self-regulatory initiatives are not a good substitute for government regulations.

As mentioned previously, knowing that MBR is effective is only the first step in determining whether MBR is a useful alternative to traditional regulatory policy instruments. More research is needed to fully understand the potential for management-based regulation as a regulatory tool. It would be useful to determine whether the structure of management-based regulations (e.g., requiring third party audits) measurably affects the results.[41] More research is also need to determine the relative costs of pollution reductions obtained through MBR so that this policy instrument can be compared to alternatives on cost-effectiveness and efficiency grounds.

[41] Preliminary analysis suggests these effects may be small in the pollution prevention case. Systematically eliminating states from the analysis does not substantively alter the results, indicating that it is not an effect in one or two states that is driving the results.

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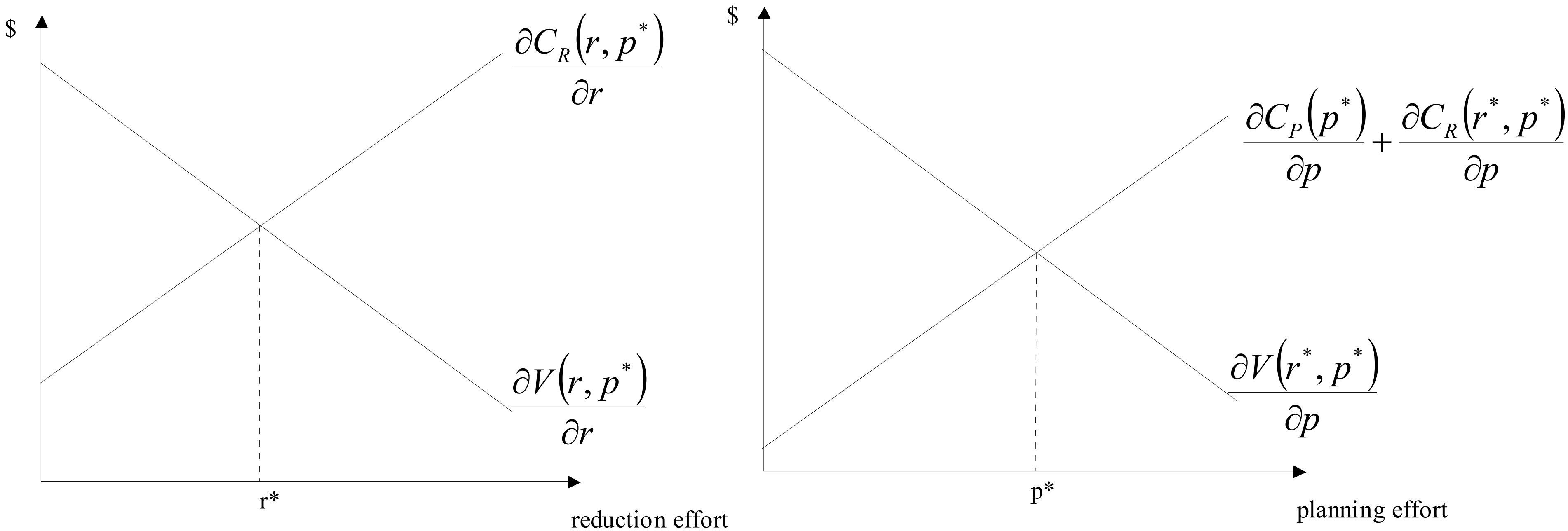

Figure 1: Optimal Reduction and Planning Levels Prior to Regulation

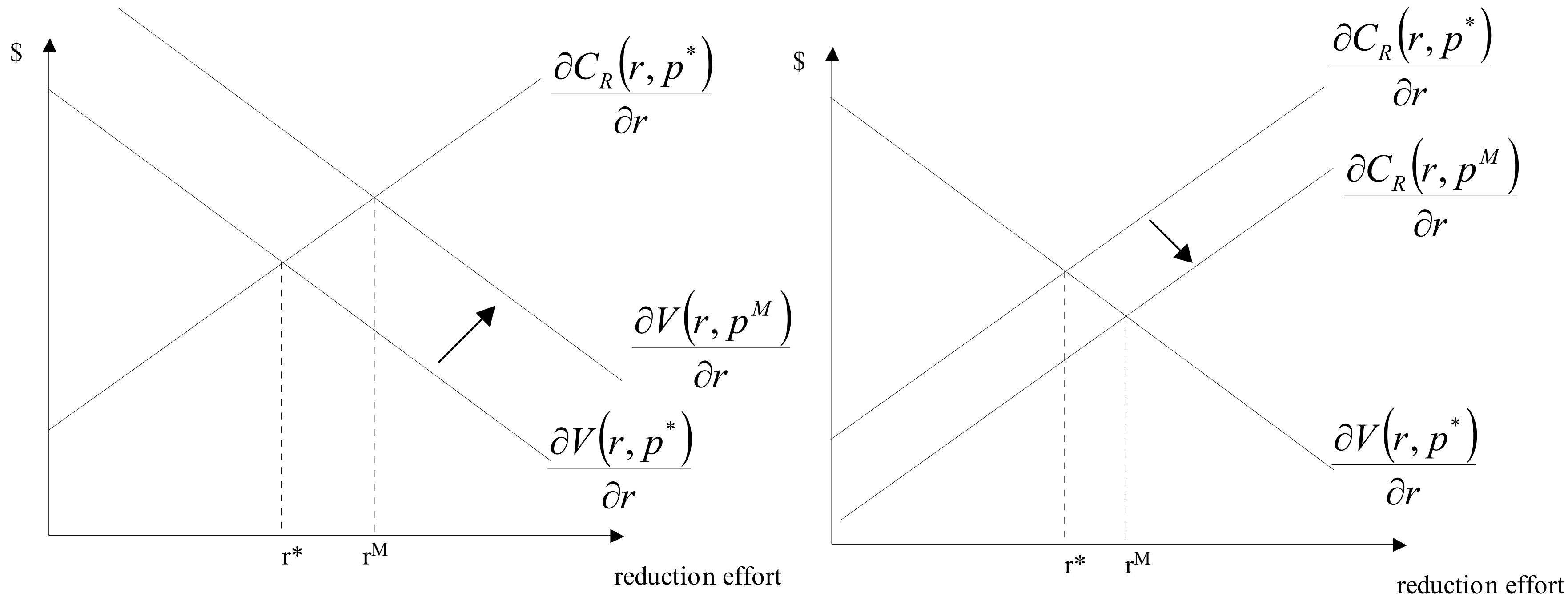

Figure 2: Complementarity of Planning and Reduction Effort Yields Greater Reductions After Regulation

Table 1: Description of State Pollution Prevention Programs						
	Types of Facilities Required to Plan	**Toxic Use Reporting**	**Progress Reports**	**Plan is Public**	**Program Implementation Date**	**Planning Date**
Arizona	TRI, LQGs, Users of more than 10,000 lbs of toxic chemical even in not a TRI reporter, Volunteer	No	Annual	Yes, reviewed by state officials	1991	1992
California	LQGs	No	Every four years	Yes, reviewed by third party auditor	1989	1991
Georgia	LQGs	No	Biennial	No	1990	1992
Maine	LQGs, TRI reporters, and SARA Section 312 filers	No	Biennial	No	1990	1993
Massachusetts	TRI reporters	Yes	Annual	Yes, reviewed by third party auditor	1990	1994
Minnesota	LQGs and TRI filers that have non-zero releases	No	Annual	No	1990	1991 for SIC 35-39, 1992 for all others
Mississippi	LQGs, TRI filers & SQGs can fill out a form in lieu of complete plan	No	Annual	No	1990	1992
New Jersey	TRI filers	Yes	Annual	No	1991	1992
New York	LQGs	No	Annual	Yes, reviewed by state officials	1990	phase in beginning in 1991
Oregon	LQGs, SQGs, TRI filers	Yes	Annual	No	1989	1991
Tennessee	LQGs, SQGs	No	Annual	No		1992 for LQGs, 1994 for SQGs
Texas	LQGs, SQGs, TRI filers	No	Annual	No	1991	phase in beginning in 1993
Vermont	LQGs, SQGs, TRI filers that have releases	Yes	Annual	No	1991	phase in LQGs in 1992, SQGs in 1993, TRI in 1996
Washington	LQGs and TRI filers	No	Annual	No	1988	1992

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)	151	1,668	164	1,768	122	1,639
Source Reduction Activity	0.31	0.46	0.38	0.49	0.29	0.46
Reports	3.36	3.84	3.9	4.78	3.21	3.52
League of Conservation Voters Score	49.6	21.1	54.2	25.6	48.3	19.53
Unemployment rate	5.6%	1.5%	5.8%	1.5%	5.5%	1.5%
Percent White	79.9%	19.1%	78.4%	18.2%	80.3%	19.3%
Percent Manufacturing	10.3%	4.6%	9.4%	3.8%	10.6%	4.8%
Median Household Income	27173	8633	30268	9967	26326	8025
Large Quantity Generator	0.50	0.50	0.70	0.46	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

Figure 3: Trends in Total Pounds of Chemical Releases

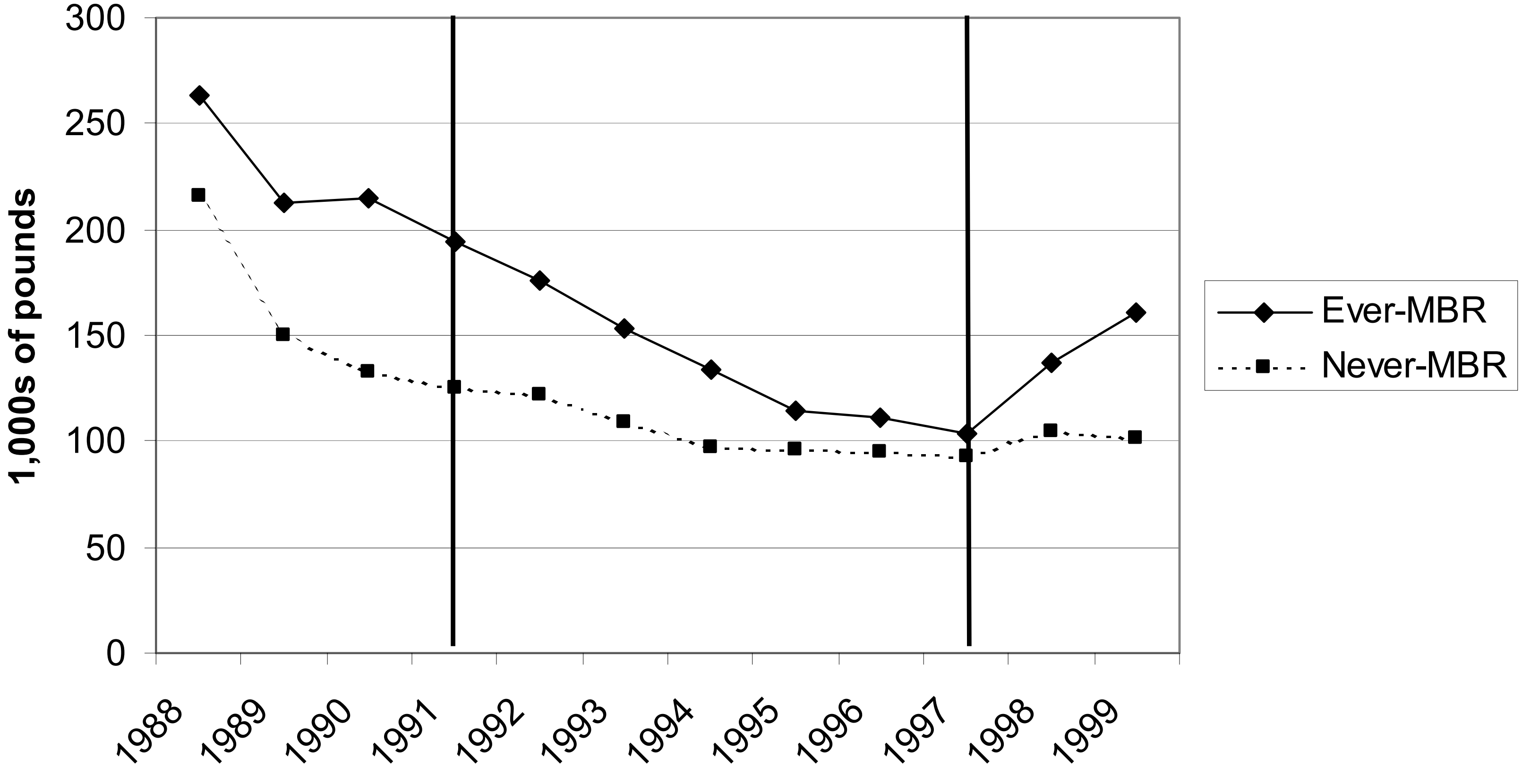

Figure 4: Trends in Pounds of Chemicals Released Normalized by Policy Implementation Date (Year=1 is first year of policy)

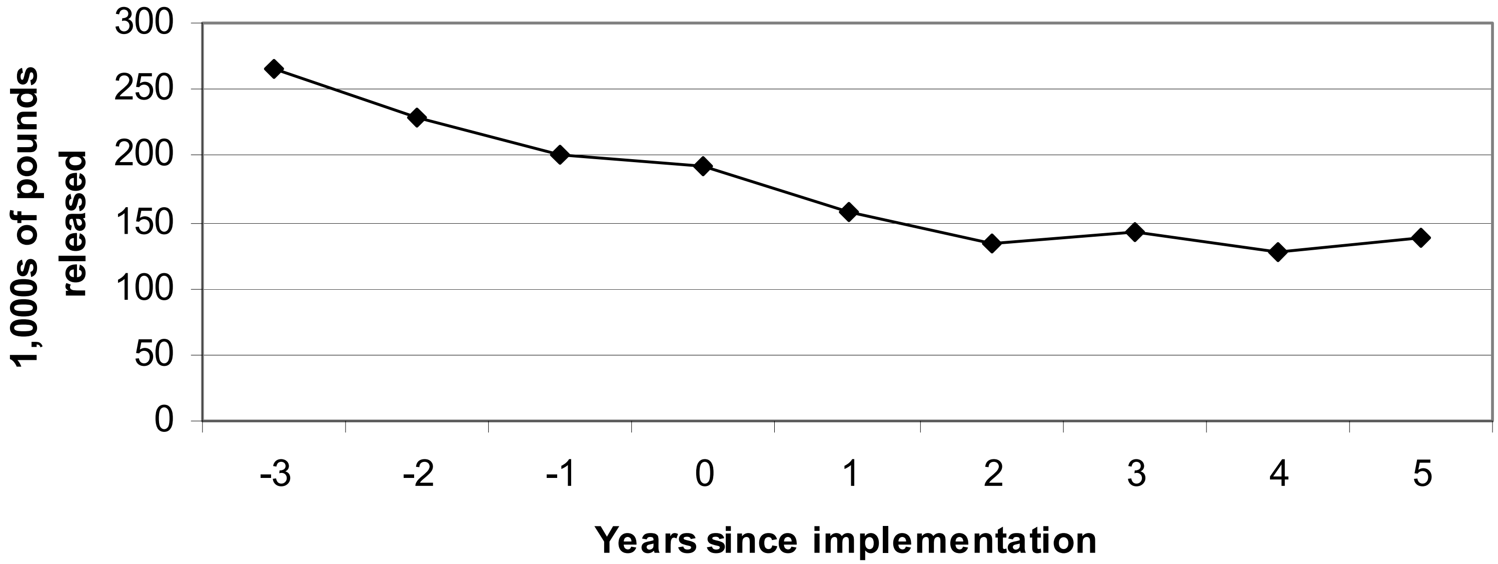

Table 3: Differences-in-Differences Estimates for Total Pounds of Chemicals Released
Standard Errors Clustered By State in Parentheses

	1	2	3	4	5	6
Management-Based Regulation	**-18.5** **(41.7)**	**-78.3** *** **(29.3)**	**-62.2** ** **(30.2)**	**-48.5** **(30.0)**	**-52.4** **(29.4)**	
First Year of MBR Implementation						**-34.8** * **(20.0)**
Second Year of MBR Implementation						**-70.4** ** **(35.6)**
Third Year of MBR Implementation						**-79.3** ** **(40.6)**
Fourth Year of MBR Implementation						**-124.4** ** **(61.1)**
Fifth Year of MBR Implementation						**-143.1** * **(73.4)**
Sixth Year of MBR Implementation						**-162.5** * **(88.7)**
Seventh Year of MBR Implementation						**-137.9** **(109.5)**
Eighth Year of MBR Implementation						**-57.0** **(123.1)**
Ninth Year of MBR Implementation						**-109.8** **(87.2)**
County is in Non-attainment for at least one criteria air pollutant					21.0 (34.0)	
League of Conservation Voters Score					-0.01 (0.03)	
State Unemployment Rate					12.7 (11.8)	
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	0.490
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

Table 4: Differences-in-Differences Estimates for Frequency of Reported Source Reduction Activities and Number of Chemicals Reported

	Source Reduction Activities		Number of Chemicals Reported	
	1	2	3	4
Management-Based Regulation	**0.27** *** **(0.04)**	**0.21** *** **(0.06)**	**-0.13** ** **(0.07)**	**-0.003** **(0.063)**
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 #
Psuedo-R^squared	0.027	0.037	0.881	0.884
Number of observations	89,962	89,962	253,098	253,098
Number of plants	15,803	15,803	35,462	35,462
years	1991-1999	1991-1999	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

Table 5: 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**	**-109.2 ****
	(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

Figure 5: Trends in Releases for Responsible Care Plants

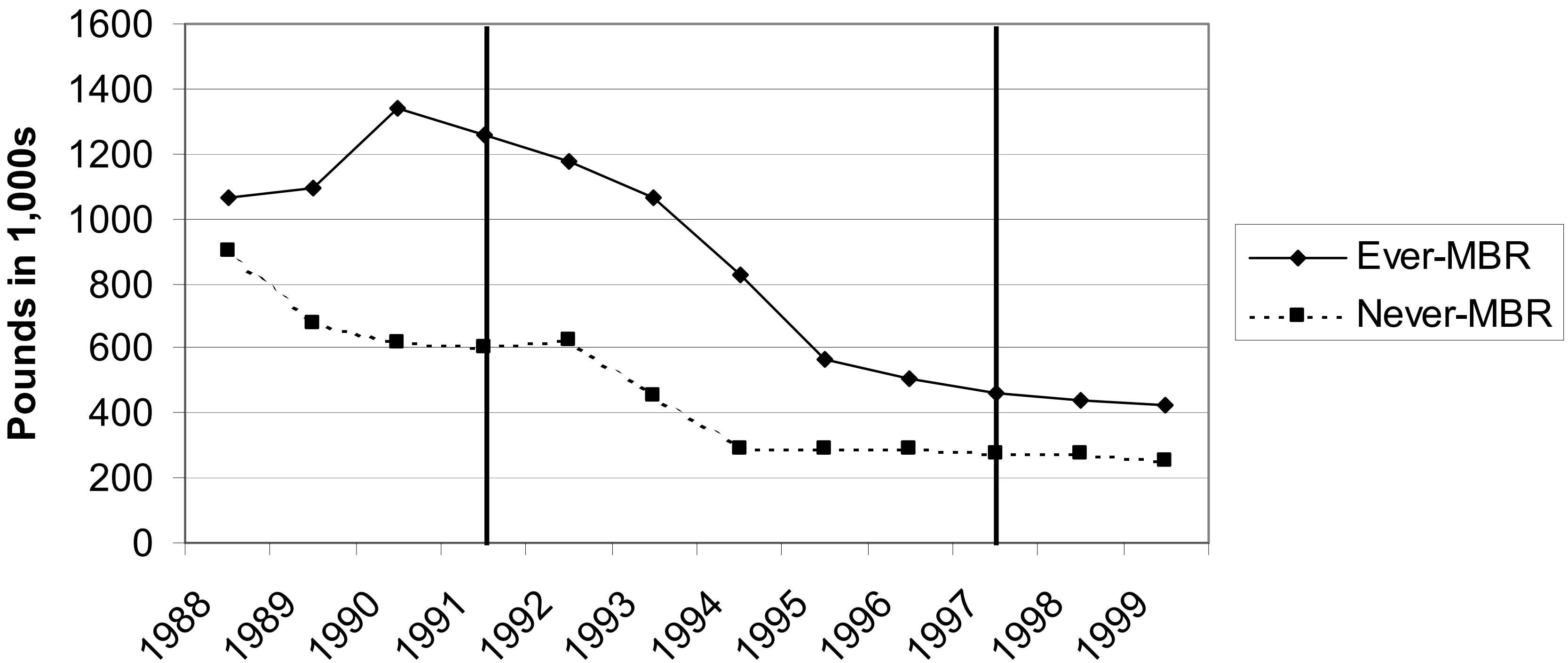

Figure 6: Trends in Pounds of Chemicals Released for Responsible Care Plants Normalized by Policy Implementation Date (Year=1 is first year of policy)

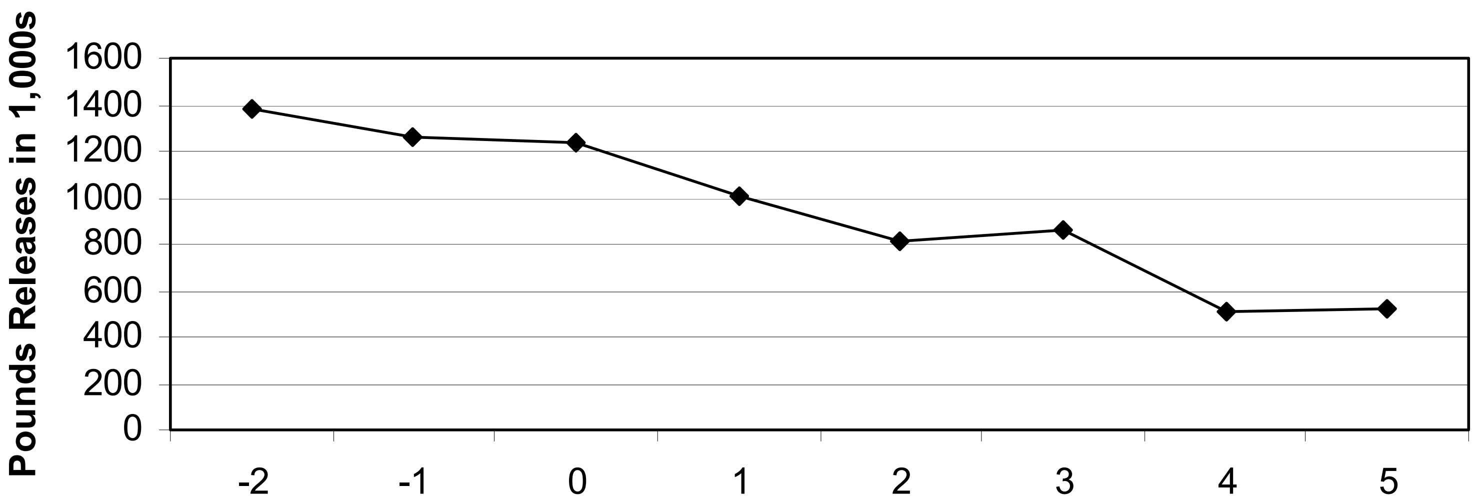

Table 6: Total Pounds of Chemicals Released, Chemical Manufacturing Plants Only
Standard Errors Clustered By State in Parentheses

	1	2	3
Management-Based Regulation	-150.1 * (82.3)		
Management-Based Regulation for Responsible Care Plants		-446.8 ** (211.0)	-368.4 ** (170.1)
Management-Based Regulation for all other plants		4.5 (51.1)	
Adjusted R^squared	0.497	0.497	0.548
Number of observations	41,380	41,380	13,652
Number of plants	4,948	4,948	1,389
years	1988-1999	1988-1999	1988-1999

*** significant at 1% level
** significant at 5% level
* significant at 10% level
All regressions include: state-specific trend, trend for each 3-digit SIC code, trend for LQGs, non-attainment status, league of conservation voters score, state unemployment rate, and three air regulations that apply to plants in this industry.