EVALUATING MANAGEMENT-BASED REGULATION: A VALUABLE TOOL IN THE REGULATORY TOOL BOX?

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Over the last decade, the nature of the risks that government has been asked to control have become more complex, presenting regulators across a variety of policy fields with problems not well-suited to traditional policy instruments. A key example of the effect of this complexity on regulation can be found in the financial sector. Financial regulatory systems that functioned well when investors were primarily large institutions proved insufficient when small individual investors entered the market in larger numbers, presenting financial regulators with new challenges. While imperfect regulation in the financial sector has most recently captivated the nation's attention, nearly all regulatory agencies face increased complexity, uncertainty, and heterogeneity in the sources of risk they are asked to control, whether financial, food and drug safety, workplace safety, or environmental quality. In the face of these challenges, it is not surprising that regulatory agencies have increased experimentation with non-traditional regulatory instruments including information disclosure, voluntary initiatives, industry self-regulation, and management-based regulation. However, there is a dearth of empirical research that evaluates how well these innovative regulatory programs actually perform in reducing risk (Bennear and Coglianese 2005; U.S. Government Accountability Office 1998). Without such evaluation it is difficult to ascertain whether these initiatives should be

continued and expanded, or whether the policy experiment failed to deliver the desired results and should be revised or replaced.

This chapter contributes to the debate by evaluating a regulatory innovation called management-based regulation (MBR). 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 giving the regulated entities flexibility to determine the least costly means to achieve those ends. Management-based regulation neither explicitly imposes the means, nor the ends. Rather what is required is that each regulated entity 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).

MBRs have arisen in at least three policy areas in the United States: food safety, industrial safety, and toxic chemical use and release (Coglianese and Lazer 2003). The first prominent use of management-based regulations in the United States 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. Food processors are required to use a flow chart to evaluate their production process, identify potential sources of contamination, and evaluate and implement alternatives for reducing contamination risk (U.S. Food and Drug Administration 2001; Coglianese and Lazer 2003).

A second use of MBR is in the area of industrial safety. The Environmental Protection Agency requires manufacturers that use certain chemicals to develop risk management plans. These plans should assess the potential for accidents within their plant and evaluate alternatives for reducing or eliminating this risk (Kleindorfer, Feldman, and Lowe 2000; Coglianese and Lazer 2003).

A final example of MBR in the United States is the regulation of toxic chemical use and release. During the 1990s, fourteen states adopted management-based pollution prevention programs. These programs require that plants 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 (Snyder 2004; Coglianese and Lazer 2003).

This chapter examines this last case of management-based regulation: management-based pollution prevention. It focuses on two important sets of questions. First, does MBR actually work? Has the application of MBR to toxic chemical use had an impact on facilities' environmental performance? Is it possible that requiring pollution prevention planning will, by itself, induce private profit-maximizing entities to reduce pollution? Second, assuming MBR does work, under what circumstances does it work better than other regulatory alternatives? Researchers have often compared different policy instruments in terms of their cost-effectiveness (Hahn 1989; Tietenberg 1990; Stavins 2003). Does MBR attain a given level of risk reduction at lower cost than other policy alternatives, where cost includes both the cost of compliance by the regulated entities and the cost of implementation and enforcement by regulators?[2]

To begin, I explore the question of whether MBR works. In the next section, I develop a general model of how MBR may work. I then empirically test whether the use of MBR in state pollution prevention programs led to improved environmental performance by industrial plants. I specifically examine whether plants in states that adopted management-based regulations for pollution prevention during the 1990s experienced greater decreases in reported releases of toxic chemicals. The evidence suggests that plants in these states did experience more rapid decreases in toxic releases, with releases falling by nearly 30 percent more in states with MBR than in states without MBR. Given the evidence that MBR can be an effective regulatory tool, I then turn to the circumstances under which MBR is likely to be more cost-effective than other regulatory instruments. I develop a model that suggests that MBR is likely to be more cost-effective when (1) there is a large degree of heterogeneity in the population of regulated entities, (2) the risk being regulated is not easily measurable, (3) traditional regulations would impose high information burdens on the regulatory agency, and (4) there is some uncertainty with regard to the extent of the risk being regulated. Finally, I offer conclusions and suggestions for future research.

DOES MANAGEMENT-BASED REGULATION WORK?

There are three different categories of MBR (Coglianese and Lazer 2003). The first category requires risk reduction planning, but does not explicitly require implementation of the risk reduction measures identified in the plan. The second category of MBR does not require planning, but does require implementation. The final

category of MBR requires both planning and implementation. This chapter focuses exclusively on the first category— namely, regulation that requires planning but does not explicitly require that firms implement their plans. For regulations in this category, there are two key features of MBR regulations. The first is government-mandated planning for risk reduction. The second is a mandated exchange of information between the regulated entities and the government. In the HAACP program for food safety, the government requires detailed recordkeeping of all food-related safety issues and requires that these records be made available inspectors periodically. In the pollution prevention programs, the states require periodic progress reports on pollution reduction activities. The structure of MBR is illustrated in Figure 1.

Insert Bennear Figure 1 here

Notice that MBR can affect plant behavior in at least two ways. First, MBR might affect the internal decision-making of the plant by revealing opportunities to reduce risk at lower costs or by changing the focus of the key decision-makers within the organization. I discuss the effect of MBR on internal plant decisions in the section below.

Second, the exchange of information between the plant and the regulator allows the regulator to pool information from multiple plants and better ascertain the nature of the risk, the opportunities for reduction, and directions for further regulatory efforts. This information, if used to direct future regulatory efforts or inspection efforts, can also affect the decision-making of the plant. I discuss the effect of the information-sharing component of MBR in a subsequent section of this chapter titled “external interaction

with regulators." Because the focus of this book is on environmental regulation, the remainder of this chapter is couched in terms of MBR as applied to pollution prevention.

MBR and Internal Plant Decision-Making

The classic economic model of plant behavior is one in which the plants have limited resources at their disposal and try to allocate those resources to maximize their expected profit or minimize expected costs. Since plant resources include management resources, particularly management time, one can think of an economic model of MBR beginning with a profit maximizing plant with limited management resources. For simplicity, assume that plants can allocate management resources to investigating pollution prevention opportunities or investigating other productivity-enhancing improvements such as reducing labor or input requirements. Because the plant is profit maximizing, the plant will optimally choose the allocation of management effort across these two areas in a way that maximizes its expected return. Because different plants may have different expectations of the return from allocating management effort toward pollution prevention, the amount of management effort allocated to this cause will vary from plant to plant.

Even in the absence of regulation that mandates such planning, some plants may optimally choose to engage in some or even a lot of pollution prevention planning. These plants see higher expected value from allocating management resources to pollution prevention than to other things. These plants typically expect pollution prevention to enhance profitability, potentially by lowering manufacturing costs or expected regulatory

and tort liabilities (Snyder 2004; Florida and Davison 2001). But not all plants will expect to see value in pollution prevention planning. Or alternatively, they may expect that there would be value in such planning, but they expect there would be more value in devoting their management resources to some other area (Florida and Davison 2001). Thus, prior to the establishment of a management-based regulation there is likely to be a non-homogenous distribution of pollution prevention planning effort across plants. Some plants will already be planning on their own, while others will not be. Among those plants that are engaged in pollution prevention planning, some will have fully developed environmental management systems and others will have less structured planning efforts. Other chapters in this volume discuss in some detail the determinants of these differences in non-regulatory driven environmental management styles (most notably the chapter by Kagan).[3]

Management-based regulations mandate that a plant allocate a certain amount of management resources to pollution prevention planning. The effect of this regulatory mandate on the amount of new planning a plant undertakes will depend on several factors. The first factor is the distribution of pollution prevention planning effort before regulation. If all plants are already "voluntarily" engaged in highly structured and detailed pollution prevention planning, then government regulation mandating planning is unlikely to have significant effects on the actual level of pollution. The second factor that determines the effect of MBR is the stringency of the regulation. If the regulation only requires minimal planning efforts, then plant managers may satisfy the regulatory requirements without actually devoting much effort to looking for pollution prevention opportunities. The final factor to consider is the degree of complementarity between

pollution prevention planning effort and actual reductions in pollution. The definition of complementarity is an economic one, namely that increasing consumption of one good increases the value of consumption of the complementary good. The classic economics example of complementarity is peanut butter and jelly. Since many people like to consume peanut butter and jelly together, increasing the consumption of peanut butter makes the consumption of jelly more valuable. In the context of MBR, complementarity between planning and reductions implies that increasing planning increases the value of risk reductions, either by decreasing the marginal cost or increasing the marginal benefits of these reductions. The greater the degree of complementarity between planning and reductions, the greater the expected effect of MBR will be.

To see how complementarity drives the effectiveness of MBR, consider two cases of risk: (1) risk from a terrorist attack, and (2) risk from a lightening strike. In the case of terrorism risk, investments in planning (or learning) about the sources of risk and ways to reduce these risks is likely to increase dramatically the value of any actual risk reduction activities. For example, after investing in terrorism planning, companies can better allocate resources to activities that are likely to have a greater affect on actual risk levels (perhaps this would involve devoting more money to screening and security or more money to employee training). This is a case where increased risk planning increases the marginal benefits of risk reduction activities. For lightening strikes, however, it is not clear that investing effort to learning about the sources of risk from lightening strikes is likely to have any real effect on the value of activities to reduce risk from these strikes. Lightening strikes are random; even when the weather conditions are right, nobody can predict precisely where one will strike. Investing resources in planning for reduction in

risk from lightening strikes is unlikely to uncover ways to reduce this risk at lower marginal cost or higher marginal benefits. The degree of complementarity between risk reduction planning and risk reductions themselves is likely to be the key determinant of the success of MBR programs.

Combining these three factors one can categorize the effect of MBR at the plant level into four possible cases. In three of these cases, MBR is not likely to be effective at reducing pollution, either because the regulations are weak relative to the amount of pollution prevention planning that is already occurring or because the relationship between pollution prevention planning and cost-savings is weak or because the costs of pollution prevention activities are extremely high or the benefits are extremely low. In the final case however, MBR is likely to be effective. In this case the government planning requirements are strong relative to the amount of planning plants are already doing and there is a stronger complementarity between pollution prevention planning and pollution reductions. Let us examine each of these four cases in more detail.

Four Conceptual Cases of MBR and Pollution Prevention

Case 1: Non-Binding Regulation

If a plant was already engaging in the required level of risk management planning, then the regulation will not require any change in management effort, and hence it should not cause any changes in the plant's environmental performance. For example, if a plant is already ISO 14001 certified, then the plant's environmental management system (EMS) may already include everything the state pollution prevention regulations require. In this case, the regulations are trivial to the plant. They may increase the paperwork burden, but they do not fundamentally change the nature of environmental management

at the plant. If all plants were Case 1 plants, then one would not expect MBR to make a difference in terms of environmental improvements.

If a plant was not previously allocating the amount of management resources to pollution prevention required by the law, one of three results may occur. The discussion of the next three cases illustrates these results.

Case 2: Weak Complementarity between Planning and Reductions

A Case 2 plant is one for which there is not a strong relationship between increased management effort and discovery of lower costs or higher benefits from pollution prevention activities. This might be the case if the toxic chemical use is directly tied to the final output of the plant. For example, a plant the manufacturers vinyl chloride necessarily uses chlorine and either ethylene or acetylene in the production process. All three chemicals are toxic. However, it is not clear how increased management effort will result in the discovery of lower cost or higher benefit measures of reducing toxic chemical use for this plant since these chemicals are fundamental to the production of vinyl chloride. This is a case where there is weak complementarity between management effort and risk reductions. For Case 2 plants one would not expect to see much change in environmental performance as a result of MBR.

Case 3: Strong Complementarity between Planning and Reductions with High Pollution Reduction Costs

Consider a plant that has high costs of pollution reduction such that costs would have to fall substantially before additional pollution reductions would be profitable. Alternatively consider a plant with low private benefits of pollution reduction such that such benefits from decreased tort or regulatory liability would have to increase

substantially before pollution reductions would be profitable. For both of these plants, MBR mandates that the plant allocate more management resources to pollution prevention planning. However, in both cases these additional efforts will only result in pollution reductions if the planning uncovers substantial cost savings or benefits. Thus despite the additional pollution prevention planning effort, the plant may not find it profitable to engage in any additional pollution prevention activities. Absent an unlikely discovery during planning, the plant's environmental performance does not change and the plant is worse off as it allocated management resources away from other potentially profit-enhancing investments. Again, if all plants were Case 3 plants, then one would not expect MBR to result in measurable changes in pollution levels.

Case 4: Strong Complementarity between Planning and Reductions with Lower Pollution Reduction Costs.

In Case 4, consider a plant that was not engaging in the required level of planning before regulation. In contrast to Case 3, this plant has low costs or high private benefits to pollution reduction. In this case, additional management effort directed toward pollution prevention planning may reveal opportunities to lower costs or lower expected regulatory or tort liabilities by engaging in additional pollution prevention activitiesand these cost reductions or benefit increases may be sufficient to make these activities profitable. Thus when the regulation forces the plant to increase investment in pollution prevention planning, the plant chooses to implement pollution prevention activities that it was not implementing in the absence of regulation.

It is precisely these Case 4 plants that most regulators have in mind when they argue for pollution prevention planning as a regulatory instrument. Pollution prevention

for Case 4 plants is often mistakenly labeled “win-win” regulation because the environment is improved and profitability of the plant is enhanced. However, the plant is not necessarily better off from a profit standpoint than it was prior to regulation. In order for the regulation to have helped the plant, it has to be the case that the mandated investment in pollution prevention yielded greater cost savings than would have been obtained if the same management resources had been invested in other areas.

To illustrate, imagine a plant that is allocating all of its management resources to discovering opportunities to enhance product quality. After MBR some of these management resources must be diverted away from quality improvements to pollution prevention. Further imagine that, after completing a pollution prevention plan, the plant discovers ways to reduce pollution by recycling some of its inputs and thereby reducing production costs. The firm is clearly better off right? Unfortunately this is not necessarily true. The key question is: How much would the plant’s profits have increased if the plant had stuck to its original allocation of all management resources to quality improvements? It is entirely possible that the plant’s profits would have increased still further with its original allocation of management resources.[4] Thus, while Case 4 plants show environmental improvements as a result of MBR, MBR is not necessarily a true “win-win” policy.[5] This does not mean that MBR is wasteful, only that it has both benefits (improved environmental performance) and costs (reduction in management resources to pursue other profit-enhancing opportunities) just like any other environmental regulation.

Implications of the Four Cases

Management-based regulations that mandate pollution prevention planning only, and do not also mandate subsequent pollution prevention activities, will not necessarily result in measurable improvements in environmental performance through internal changes at the plant. MBR may be ineffective at reducing pollution if the planning requirements are not stringent relative to the amount of pollution prevention planning that plants are already doing (Case 1). Alternatively, MBR may not be effective if there is a weak relationship between management effort and cost-saving discoveries (Case 2) or if the plants' pollution prevention activities have very high costs or very low benefits (Case 3). Management-based regulations will improve environmental quality through internal changes at the plant only if (a) there is a strong positive relationship between increasing pollution prevention planning effort and increasing cost-savings or benefits from pollution reductions, and (b) some plants are not already engaging in the required amount of management effort.[6] That is, management-based regulations will have an overall net effect of reducing pollution only if there are a sufficient number of Case 4 plants in the regulated population.

External Interaction with Regulators

Management-based regulations may also lead plants to improve their environmental performance through interactions between plant managers and regulators. This may be true even if there are few Case 4 plants. In other words, even if the relationship between planning and reductions is weak or the regulation is non-binding, the information disclosed to regulators through mandated planning might nevertheless have independent effects on facilities' performance.

To see how this information sharing might lead to improved environmental performance, it is helpful to draw from principal-agent theory (Grossman and Hart 1983). In the classic principal-agent model, a principal needs to retain the services of an agent to act on the principal's behalf. The key characteristic of principal-agent relationships is that the principal wants the agent to work towards the principal's objectives, however the agent may not find it in her best interest to work toward the principal's goals. For instance, the principal could be an employer and the agent an employee. The employer wants the employee to work diligently eight hours a day. The agent would prefer to shirk if he can do so without the principal knowing. Similarly, the principal could be a homebuyer and the agent a realtor. The homebuyer wants the realtor to disclose any problems with the home. However, the realtor does not receive a commission unless the house sells, providing an incentive to withhold information that may hinder the ability of the home to sell.[7] One can also apply the principal-agent model to a regulatory setting (Laffont and Tirole 1993). In this case the principal is the regulator and the agent is the regulated entity. The principal wants the agent to reduce pollution (or some other measure of risk), but the agent's profits would be higher if pollution was not controlled.

There is a large literature on contracts that resolve the principal-agent dilemma (Grossman and Hart 1983; Hart and Holmstrom 1987). One segment of this literature focuses on the case of multiple agents. The multiple agent problem is the one most closely related to MBR and is thus worth exploring in more detail.

A classic example of a principal-agent model with multiple agents is a vacuum cleaner dealer that employs several door-to-door sales people. The dealer cannot observe the individual employees' effort, but the dealer observes each employee's sales.

Employee sales are a function of effort and other factors not related to effort, such as the state of the economy, the price of the competition's products, and so forth. Holmstrom (1982) demonstrates that when the factors unrelated to employee effort are common across all employees, then by pooling information on output from multiple agents the principal can actually determine each agent's effort level and reward each employee accordingly.[8] In the vacuum cleaner example, sales may be a function of the general state of the economy, but this factor is common to all sales people in the same geographic area. Thus, by comparing sales for different sales people the dealer can infer which sales people had the highest effort levels.

An analogous model could apply to MBR. Pollution reduction levels are a function of pollution prevention planning effort by the plants, but are also a function of other factors such as the plants' level of production, other regulatory programs, and so forth. The regulator cannot observe the effort that each plant dedicates to pollution reduction, but the regulator mandates that the plants share information on the level of their pollution reductions. By straightforward application of Holmstrom's findings, if the set of factors that affect pollution reduction levels but are unrelated to each plant's effort are common across plants, the regulator can compare reduction levels across plants to infer which plants engaged in the most pollution prevention effort.

To use a simplified example, imagine that pollution levels are only a function of pollution prevention effort and the state of the economy. The regulator cannot observe each plant's pollution prevention effort levels, but since the state of the economy is likely to effect pollution levels similarly at all plants, the regulator simply ranks plants by the magnitude of their pollution levels and this is equivalent to ranking plants based on their

level of pollution prevention effort. Of course, the real world is not this simple. Pollution levels at each plant may be a function of pollution prevention effort and other factors that are common across all plants (such as the state of the economy), but also plant-specific factors that have nothing to do with pollution prevention effort (such as the size of the plant). However, even if Holmstrom's findings do not strictly apply, there is still a possibility that mandating that plants share information about their pollution prevention activities with regulators could lead to a Holmstrom-like result. For example, if most facilities in an industry report rapid decreases in pollution and a few facilities report flat or increasing pollution levels, the regulator may then target these facilities for further investigation. It may turn out that these facilities are fully engaged in pollution prevention planning and their pollution levels are high due to outside factors. But given that the regulator also has limited resources, ranking plants based on their pollution levels can potentially improve regulatory targeting. This kind of ranking can be facilitated by the reporting requirements that are often part of MBR.

Moreover, if information on pollution prevention activities obtained under MBR is used to determine which facilities will face more frequent inspections, then this may actually increase the value to the plant of engaging in more pollution prevention activities. In essence, this regulatory targeting acts to increase the benefits of pollution prevention. If the plant knows that by not reducing pollution it may be targeted for more frequent inspections, then a reduction in this inspection frequency may spur greater pollution reductions. To make this concrete, return to the example of the plant in Case 3. This facility faced either very high costs of pollution reduction or very low benefits of pollution reduction. Just focusing on the internal decision-making component of MBR, it

appeared unlikely the MBR would result in measurable improvements in environmental performance at a plant like that in Case 3. However, if information on pollution levels were to be used to determine regulatory stringency (like inspection frequency), this would increase the private benefits a Case 3 plant would receive from reducing pollution. This increase in private benefits may be enough to induce the plant to engage in reduction activities that would have proven unprofitable based on a purely internal calculation.

In addition to the information MBR provides to regulators, another way in which MBR may result in improved environmental performance is if plants use these regulations strategically to pre-empt more costly regulation . This alternative explanation follows a model developed by Maxwell, Lyon, and Hackett (2000), according to which firms use self-regulation as a strategic tool to pre-empt government regulation. It is costly for consumers to express their desire for more stringent environmental regulation through the political process. They must write letters to their representatives, engage in protests, make phone calls, or just go to the polls and vote. In all of these cases there is a cost of political action (Olson 1971). Plants may be able to pre-empt this action, and thereby avoid any resulting increase in regulatory stringency, by engaging in some clean-up efforts that otherwise would not be in their best interest. By engaging in pollution reduction efforts, plants may placate some of the consumers and reduce their desire to bear the costs of political action. If the existence of management-based regulation generally signals a state's willingness to increase regulatory stringency, then plants in those states may have an incentive to demonstrate greater environmental improvement than plants in states without this regulatory threat. According to this model, the resulting change in environmental performance is not a function of the MBR planning

requirements per se, but rather a function of MBR's signal of the state's willingness to impose regulations.

In at least one state, management-based regulation was itself clearly a pre-emptive regulatory initiative. By the mid-1980s, Massachusetts environmental groups had developed a successful track record of passing state ballot initiatives and credibly threatened to pursue a new initiative that would impose bans on the use of certain toxic chemicals. Faced with the prospect of very costly bans on toxic chemical use, industry initiated a series of negotiating sessions with environmental groups and state legislators to craft a compromise that could substitute for an outright ban. They succeeded in securing agreement on the Massachusetts Toxic Use Reduction Act of 1989, the first state law in the country to include mandatory pollution prevention planning requirements (Gomes 1994).

Empirical Evidence

Either due to internal changes within the firm or changes caused by information sharing with the regulator, MBR may in theory result in changes in environmental performance. Of course, it is ultimately an empirical question whether management-based regulations actually succeed in promoting improvements in environmental quality. Moving from theory to empirical evidence of the effectiveness of MBR is not easy. A straightforward comparison of pollution levels in states with MBR and in states without MBR might be *suggestive* evidence, but it is hardly convincing proof. There may be other differences among states that explain differences in environmental performance. This section discusses how the effects of MBR can be isolated from other potential

drivers of changes in pollution levels. Recent empirical work that strives to isolate the causal effect of MBR suggests that MBR has indeed had a positive effect on pollution levels.

Whether MBR is effective at reducing risk can be assessed empirically by isolating the *causal effect* of management-based regulation on measures of risk reduction, that is, by identifying the change in performance relative to the change that would have occurred if the management-based regulation had not been implemented (Bennear and Coglianese, 2005). In a hypothetical world, one could implement MBR and observe subsequent changes in pollution levels. Then, using a time machine, one could go back in time and keep from implementing MBR, and observe the changes in pollution levels. The difference between these two scenarios would then be the causal effect of MBR on pollution. Of course, we do not have time machines, and this experiment can never be run. The fundamental problem of causal inference is that we cannot observe environmental performance both with and without MBR for the *same* set of facilities at the *same* time. The research challenge is to use observable data to isolate the causal effect of MBR from other explanations of changes in pollution levels. For example, under some circumstances researchers can compare performance of similar facilities in states with MBR and in states without MBR. In other circumstances, they can compare facilities before and after MBR implementation. And of course, they could also utilize both tools, comparing facilities before and after MBR implementation dates in states with and without MBR regulations (Bennear and Coglianese 2005).

Even if methods exist to isolate the causal effect of MBR, there are additional complications that stem from the nature of management-based regulations themselves.

The first complication occurs when the risks regulated by MBR are low-probability risks. This is true, for example, of management-based regulations aimed at pathogen contamination in the food supply and large-scale industrial accidents. In these cases, measuring changes in risk is difficult. Two facilities, one with a more lax risk management plan and one with a rigorous risk management plan, might both experience no incidents in any given period. Yet one still has a greater risk of incidents than the other; it is just that these differences in risk are not measurable as outcomes. In these circumstances, comparing similar facilities across states with and without MBR (and over time) may still not reveal the effect of MBR because these effects are simply not measurable.

An additional difficulty in evaluating the causal effect of MBR is that in regulatory areas such as environmental health and safety, data collection is often built into the regulations themselves. As a result, the researcher only observes data on risk measures for facilities subject to the regulation during years in which the regulation is in effect. For example, researchers have data on toxic releases from the federal Toxic Release Inventory (TRI) program, but only for facilities that are required to report to TRI and only for years in which this regulation has been in effect. Researchers cannot assess the causal effect of the TRI disclosure requirements by comparing releases for facilities that are required to disclose to releases at similar facilities that are not required to disclose. This is because we do not observe releases for facilities that are not required to disclose them under TRI. In general, the marriage of data collection to regulations makes infeasible the use of research designs that compare changes in performance for plants

subject to the regulation with changes at plants not subject to regulation (Bennear and Coglianese, 2005).

Fortunately, state pollution prevention regulations do not suffer from these particular measurement difficulties. During the 1990s, fourteen states adopted management-based pollution prevention laws. These laws targeted reductions in the use and release of *toxic* chemicals. All states focused on toxic chemicals that require reporting under the federal Toxics Release Inventory (TRI) program, and some states also focused on toxic chemicals regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Toxic Substances Control Act (TSCA). These state laws 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. Table 1 provides detailed information on the characteristics of these state laws.[9]

Insert Bennear Table 1 here

In the case of pollution prevention laws, evaluating the causal effect of MBR is feasible. First, the risk that is being regulated is not a low-probability risk. Pollution is an everyday occurrence at manufacturing facilities. Thus, one can *measure* changes in environmental performance from the regulation. Second, because these laws have been adopted in some states but not others, and measures of pollution exist across all states, the researcher can compare environmental outcomes for regulated and non-regulated facilities. Moreover, these comparisons across states can be made both before and after

MBR implementation. The remainder of this section evaluates empirical evidence on the effectiveness of MBR for pollution prevention.

Trends in Toxic Releases

Is there any evidence that MBR has had an effect on pollution levels? Figure 2 provides a graph of the trends in toxic releases for plants that are eventually subject to MBR (MBR plants) and facilities that are never subject to MBR (non-MBR plants).[10] The vertical black lines bound the time period in which states enacted MBR. There are several interesting features of these trends in toxic releases over time. First, releases were lower for MBR states *before* these regulations took effect. This implies that a simple examination of toxic release levels after regulation will overstate the effect of MBR. Some of these differences in toxic release levels existed even prior to MBR implementation and therefore cannot be caused by MBR.

Insert Bennear Figure 2 here

The second interesting feature of the trends in releases over time is the MBR states appear to have an accelerated rate of decrease in toxic releases compared with non-MBR states. This is suggestive of an effect of MBR on environmental performance, but other differences among states may explain differences in the *rate* of decrease in toxic releases, just as other differences among states must explain the difference in pre-regulatory *levels* of releases. It will be important to control for these other potential determinants of the change in release levels in order to isolate the causal effect of MBR.

The third interesting feature of the trends is that releases in MBR states increase dramatically after 1997. This increase is a function of a two plants in Arizona (an MBR state) whose releases increased by an order of magnitude in 1997 and 1998, respectively.

Eliminating these two outliers also eliminates the upward trend in MBR state releases. These facilities are left in to highlight the importance of examining the underlying data rather than simply relying on trends in averages across plants. The TRI data are particularly vulnerable to measurement error because they are self-reported estimates from facilities (Snyder 2004; Graham and Miller 2001).

The trends in MBR and non-MBR releases over time suggest that MBR may have accelerated the rate of decline in toxic chemical releases, but they also provide reasons to be cautious of this interpretation. Differences in release levels prior to regulation suggest that other factors such as differences in industry composition or differences in production levels may explain differences in MBR and non-MBR states. The potential existence of outliers and the extreme effect these can have on average release levels highlights the importance of examining facility-level data rather than relying solely on averages. How does one sort through the data to determine if there is a causal effect of MBR on toxic release levels?

There are two types of empirical evaluations that have been conducted to investigate the degree to which these differences are due to MBR. The first type consists of state-specific program evaluations, which have generally been commissioned by state environmental agencies. The second type compares differences in trends among states with MBR and states without MBR. These comparisons can be done at the aggregate state level or at the facility level. In principle, these comparative studies are better able to assess the causal effect of MBR. The evidence implies that MBR has had a significant causal effect on toxic chemical releases.

State-Specific Studies

At least two states have conducted evaluations of their MBR laws. In a program evaluation conducted in 1997, three years after the management-based regulation went into effect, Massachusetts reported that it found support for the success of its overall toxic pollution prevention legislation. The state evaluated its MBR law by surveying 645 plants, garnering a response rate of 67 percent (434 responses). The study found that the vast majority of plants surveyed (81 percent) intended to implement at least some of the source reduction improvements identified in their mandated pollution prevention plans. 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 pollution prevention law in 1996, four years after its law took effect. Consultants for the State of New Jersey visited 115 plants and analyzed data from 405 planning summaries submitted by the facilities to the state. They found evidence that planning was 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).

While both of these studies provide support for MBR, the focus on a single state makes it difficult to separate the effect of MBR from other features of the state regulatory regime. For example, states often have control over permitting and enforcement for many federal statutes including the Clean Air Act, the Clean Water Act, and the Toxic

Substances Control Act (TSCA). Could differences in how Massachusetts and New Jersey implemented and enforced these other regulations of toxic chemical releases be responsible for some or all of the observed change in facility behavior? The next section discusses comparative empirical studies that were designed to isolate the effects of MBR.

Cross State Comparisons

Tenney (2000) compared the changes in production-related toxic releases and wastes[11] for fourteen states, seven of which had mandatory pollution prevention planning laws and six of which had voluntary pollution prevention programs. She found that after adjusting for changes in production, states with mandatory requirements showed greater progress in reducing toxic releases and hazardous waste than states with voluntary programs. She found that production-related waste (that is, waste levels adjusted by production levels) fell by 22 percent in states with mandatory pollution prevention programs compared to 7 percent in states with voluntary pollution prevention programs. Similarly, she found that releases (again, adjusted for production levels) fell by 51 percent in mandatory pollution prevention states and only by 25 percent in voluntary pollution prevention states.

Unfortunately, the Tenney study was limited by the data available from several states. Moreover, several states selected for that study had pollution prevention planning laws that applied only to a subset of plants that report Toxics Release Inventory data. In particular, California, Georgia, and Tennessee have programs that only require planning for large quantity hazardous waste generators, a subset of all the facilities reporting releases under the TRI program. Large quantity generators of hazardous waste are facilities that generate more than 2,200 pounds of hazardous waste per month. Many

facilities that are required to report releases under TRI are not large quantity generators of hazardous waste. Thus, a comparison of decreases in TRI releases and waste for Georgia with TRI releases and waste for Alabama may understate the effects of MBR because not all TRI facilities in Georgia are covered by the MBR law. The same holds true for the other states whose laws apply only to large quantity generators.

In addition, the Tenney study does not correct for other differences across states that might be affecting facilities' toxic releases or hazardous wastes. Differences in industrial composition, environmental preferences of state residents, or other regulatory or economic characteristics of the state might all partially explain why pollution levels vary across states. To isolate the effects of MBR from these other factors, it is necessary to control for other differences across states.

I have sought to overcome the limitations of the Tenney study by comparing changes in toxic chemical releases at plants subject to toxic pollution prevention planning laws with similar changes at plants not subject to such laws (Snyder 2004). My approach was to use a "differences-in-differences" estimator that recognizes that plants are likely to have different environmental performance levels even in the absence of the state regulations. By using such an estimation strategy, I could control for these differences in order to estimate the precise effects from the management-based regulations. These effects were measured by using regression techniques to compute the difference between (a) the average difference between pre-regulation and post-regulation outcomes for the facilities subject to MBR, and (b) the average difference between pre- and post-regulation outcomes for facilities that were not subject to MBR, *controlling* for other facility and state characteristics that might explain both the level and the trend in toxic releases.

To understand how the effect of MBR is isolated from other factors that can vary across states, imagine two facilities, one that is subject to management-based regulation and the other that is not. Further, imagine that these two facilities do not have identical indicators of environmental performance before the regulation takes effect. This is depicted graphically in Figure 3. Notice that the facility that is eventually subject to MBR has better environmental performance (lower pollution levels) even before the regulation takes effect. It is clear from the figure that labeling the difference in environmental performance after the regulation the causal effect of the regulation would be inaccurate, since some of that difference existed before regulation. The differences-in-differences estimator assumes that in the absence of treatment the rate of change in environmental performance would have been the same between the two facilities, that is, the slope of the lines would have been the same. The causal effect of the regulation is then just the incremental decrease in pollution in the post-regulation period, which is labeled "treatment effect" in Figure 3.

Insert Bennear Figure 3 here

It is possible that the trends are not parallel even in the absence of regulation, that is, plants that are eventually regulated have systematically different trends in environmental performance than plants that are never regulated for reasons other than differences in regulatory stringency. For example, industries may have different rates of technological change. If technological change improves environmental performance, differences in industrial composition among states may lead to differences in trends in toxic releases. To make this explicit, consider two industries: electronics and metal plating. Imagine there is greater technological change in electronics manufacturing than

in metal plating. Further assume that Massachusetts (an MBR state) has many electronics plants and few metal plating plants, while Ohio (a non-MBR state) has few electronics plants and many metal plating plants. Even in the absence of regulatory differences one might expect to see a faster decline in toxic releases in Massachusetts than in Ohio simply because of the differences in industrial composition.

An examination of the trends before 1991 in Figure 2 indicates that, in fact, "MBR" and "non-MBR" plants may have different pre-regulatory trends in total releases. As a result, the differences-in-differences estimator could be biased. To correct for any possible bias and thereby ensure that the measured effect is due to the regulation alone, I controlled for other characteristics that also can affect trends in plants' environmental performance. Specifically, I controlled for industry classification, large quantity generators statues, economic and demographic characteristics, and differences in other regulatory regimes to better isolate the effect of MBR. I found that facilities subject to MBR reduced their total pounds of chemical releases by 60,000 pounds more than comparable facilities not subject to MBR (Snyder 2004). I also found the effect of MBR to be statistically significant for the first six years after adoption of the regulation, providing evidence that MBR has lasting effects on changes in environmental performance (Snyder 2004).

These results suggest that MBR has had a causal effect in terms of improving facilities' environmental performance. They do not, however, explain why MBR has been successful. Is it because increased planning effort changed the internal decision-making of the plant? Or did information sharing between the regulator and the plant lead the plants to improve in order to avoid future regulatory or enforcement actions?

Maxwell, Lyon, and Hackett (2000) have provided some preliminary evidence on this question. Examining 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 compared states with pollution prevention legislation in place by 1991 with states without such legislation. They found no statistically significant effect of state legislation on the change in toxic releases of these 17 chemicals.[12] However, they found greater changes in total releases in that states where residents had higher rates of membership in environmental organizations. Viewing environmental group membership as a proxy for the preferences of the state residents and the potential threat of future environmental regulation, they argued that firms are more likely to reduce emissions voluntarily if the threat of future regulation is high.

Other studies have provided evidence consistent with both the internal decision-making and information sharing explanations for MBR's success. Both New Jersey and Massachusetts found that larger plants were more likely to improve environmental performance as a result of pollution prevention planning (Keenan, Kanner, and Stoner 1997; Natan *et al.*, 1996). Consistent with the internal plant dynamics theory, it might be that larger plants have a greater ability to convert planning into positive action, while smaller plants are subject to the planning burden without having the resources to convert their plans into substantive action. However, it might also be the case that larger plants anticipate that future regulatory or inspection actions will be more likely directed toward them, and hence have greater incentives to engage in voluntary improvements to avoid these future actions. Clearly more research is needed to understand why management-based regulation affects plant performance.

WHEN IS MBR PREFERABLE?

Given the evidence suggesting that pollution prevention planning can be an effective regulatory tool, the next logical question to ask is: When are management-based approaches the preferable regulatory tool? Risk regulators have a growing set of policy instruments available to them, including bans, taxes, tort liability, technology standards, performance standards, tradable permits, information disclosure, industry self-regulation, and management-based regulation (Stavins 2003; Hahn, 1989; Richards 2000). Different sets of these instruments will be appropriate for different types of risk regulation. The challenge for regulators is to determine the conditions under which each type is the appropriate choice.

Determining what is an "appropriate choice" can be based on several criteria against which regulatory instruments can be compared. One can compare instruments' ability to achieve the socially optimal level of pollution control — the efficiency criterion (Helfand, *et al.* 2003; Baumol and Oates 1988). One can compare the instruments in terms of their ability to achieve any given level of risk reduction at the lowest cost — the cost effectiveness criterion (Helfand, et. al 2003; Baumol and Oates 1988). One can also compare instruments on other criteria, such as how equitably risks and risk reductions are distributed. Similarly, one could compare the effect of instruments on the policy process itself, assessing whether the policy instrument promotes public participation or enhances the relationship between government, the public, and industry.

No single regulatory instrument is appropriate for every environmental problem. The characteristics of the pollutants (i.e., uniformly mixed, global or local, acute or chronic exposure), the characteristics of the regulated entities (i.e., competitive market, degree of heterogeneity in the production process, small or large facilities) and the nature of regulatory institutions (i.e., democratic, cooperative or confrontational) can and should affect the choice of policy instrument. Table 2 highlights some of the key characteristics of risks, regulated entities, and regulatory institutions that might affect the suitability of a given policy instrument.

Insert Bennear Table 2 here

In the environmental policy area, researchers have gone to great lengths to ascertain how well different policy instruments perform under varied conditions. The optimal choice of a policy instrument has been shown to depend on, among other things, the heterogeneity of the regulated population (Newell and Stavins 2003), the uniform or non-uniform nature of the pollutant (Hahn 1989), the nature of the uncertainty surrounding the benefits and costs of pollution control (Weitzman 1974), the existence of other distortionary taxes (Goulder 2000), the nature of technological change (Milliman and Prince 1989; Jung, Krutilla, and Boyd 1996), and the irreversibility of damages (Arrow and Fisher 1974).[13]

Where does management-based regulation fit into the mix of regulatory instruments available for risk reduction? Unfortunately, the instrument choice literature has largely ignored management-based regulation. One exception is Coglianese and Lazer (2003), who argue that MBR is best suited for policy situations where the risk itself is difficult to measure and the regulated entities are highly heterogeneous. Let us

examine these two characteristics in more detail and see why MBR might be a preferable regulatory instrument when these characteristics are present. In addition, this section highlights two additional characteristics of the risk and the regulated entities that might make MBR a preferable regulatory alternative compared to other instruments, namely the information burden for regulatory agencies and uncertainty in the nature of the risk being regulated.

Measurability of the Regulated Risk

The first characteristic that might make MBR a preferable regulatory instrument concerns the measurability of the risk being regulated. When crafting environmental regulation, regulators have some discretion in selecting the exact measure of environmental performance that will be targeted. They can choose to measure a facility's performance according to: (1) inputs, such as the sulfur content of coal; (2) releases, such as the pounds of dioxin emitted; (3) concentration, such as measured levels of biological oxygen demand (BOD) in the water; (4) exposure, such as weighted concentrations based on the number and types of people exposed; or (5) risk, such as a weighted measure based on concentration, exposure, and toxicity of the pollutant. In general, these different measures can be arrayed along a spectrum as shown in Figure 4.

Insert Bennear Figure 4 here

The measures further to the left tend to be easier to quantify while the measures further to the right often provide a more accurate assessment of the outcomes of greatest interest to environmental regulators. Yet, most environmental regulation in the United States has targeted inputs and releases, with some regulations focusing on concentration.[14] Few, if any, regulations have specifically set targets for exposure or risk.

The chief reason is that there is a tradeoff between accuracy and measurability. If the environmental outcome needs to be measured for regulation to be enforced, then the regulation needs to target inputs, releases, and concentrations, at least until more reliable measures of exposure and risk can be developed.

As Figure 4 implies, there is a tradeoff between measurement and enforcement cost and the accuracy of the target as a measure of environmental performance. The extent of that tradeoff depends on the specifics of the risk being regulated. In the case of toxic chemical use, risk is a function of the toxicity of the chemical, its concentration, the duration of exposure, and the characteristics of the exposed population (U.S. EPA 2002b). As a result, there is not a simple relationship between risk and a more readily measurable indicator of environmental performance which regulation could target as a proxy for risk. Regulators can choose to target an imperfect, but available, proxy for risk, or they can invest in better measures of risk and target those measures.

Management-based regulations can be thought of as regulations that target one particular type of input called management effort. If three conditions apply, one might argue that targeting the regulation at management effort is a reasonable approach to regulating risk from toxic chemical use: (1) there is a strong relationship between management effort at pollution prevention and risk reduction, (2) management effort can be measured and monitored, and (3) no other measure of risk can be easily measured. This framework dovetails with Coglianese and Lazer's (2003) argument that management-based regulations have appeal in areas of risk regulation where other "performance-based" measures of risk are not available to regulate. However, it adds two additional restrictions, namely that increasing management effort has to have a

measurable and monotonic effect on risk and that management effort has to be either easier to monitor or a stronger signal of risk than other available indicators of environmental performance.

Heterogeneity of Regulated Entities

A second characteristic by which one can classify and compare regulatory instruments is the degree of heterogeneity among regulated entities. The effect of heterogeneity on instrument choice is well studied (Newell and Stavins 2003; Tietenburg 1990). Most of the work on heterogeneity has focused on market-based policy instruments such as pollution taxes and tradable pollution permits. The appeal of market-based instruments on cost-effectiveness grounds is due, in part, to their ability to allocate the distribution of pollution reduction unevenly among regulated entities. When plants have different costs of pollution reduction, uniformity of regulation across plants is costly (Tietenburg 1990). In general, the greater the heterogeneity in the population of regulated entities, the greater the desired degree of non-uniformity in the regulation. Thus, heterogeneity in the population of regulated entities makes market-based policy instruments more attractive. [15]

Similarly, greater heterogeneity may make management-based regulation more attractive. Management-based regulations will also yield non-uniform changes in environmental performance, since each plant develops its own pollution prevention plan and voluntarily decides whether to undertake activities that follow from that plan. Plants with lower costs of pollution reduction are likely to engage in more reduction activities, a distribution of reduction activity that is more cost-effective than requiring all plants to engage in the same type of pollution prevention activity.

Heterogeneity exists in many forms. Typically one thinks of heterogeneity in a cross section of plants — that is, at any given time different plants are using different production technologies, are of different size, and have different pollution control costs. However, it is also important to consider heterogeneity over time, or put differently, the rapidity of technological change in the industry. If the industry is very dynamic, with new production technologies coming on line rapidly, then the regulator will want to avoid locking in a particular technology or even a particular performance standard that might soon be obsolete. One of the advantages of market-based instruments is they provide the correct incentives for plants to continue to adopt pollution-reducing technology (Jaffe, Newell, and Stavins 2003). By encouraging regular updating of the toxics use reduction plan, and thus continued search for new ways of reducing toxics at lower costs, management-based regulations also preserve flexibility over time. Thus, MBR might be considered a more valuable regulatory alternative for industries that are highly dynamic.

Information Burden on the Regulator

In addition to the characteristics of measurability of risk and heterogeneity of regulated entities, MBR might be a preferable regulatory alternative in the face of a third characteristic, namely a heavy information burden required to pass more traditional standards. Along the spectrum in Figure 4, one could imagine implementing both uniform and non-uniform standards. If part of the appeal of market-based instruments is their ability to provide non-uniformity in the distribution of pollution control, thereby lowering pollution control costs, the remainder of their appeal is that they do this with a minimum of information required by the regulator (Stavins 2003, 359). The regulator does not need to know the specific nature of production at each plant, to determine how

much pollution control each plant will undertake. Once the tax level is set or the quantity of permits is determined and allocated, each plant uses its own information on abatement costs to determine the best course of action. Some plants may choose to clean up more and sell permits, others may choose to clean up less and buy permits, but the government does not need to know in advance which plants will do what.

In regulating toxic chemicals, one could imagine developing detailed management plans, technology requirements, or performance standards that are adapted to the specific nature of production, toxics use, substitute availability, and other plant-level characteristics. However, constructing these non-uniform regulations would require a tremendous amount of information on plant-specific characteristics that is generally not available to regulators (Coglianese and Lazer 2003). Management-based regulations try to harness the informational advantage that plants have about their own production process and opportunities for environmental improvement and thereby reduce the informational burden on the regulator.

Uncertainty over the Nature of the Regulated Risk

Finally, the fourth characteristic of settings in which MBR may be a preferable regulatory policy instrument concerns uncertainty over the actual nature of risk being regulated. When there is uncertainty over the benefits of risk reduction, potentially because a chemical is suspected of being toxic, but the degree and nature of its toxicity is debatable, then traditional standards may be viewed as committing to a specific regulatory target without sufficient information to determine whether the target is appropriate. In such a case, the regulator may place a value on preserving the option to learn more about the nature of the risk before committing to a particular regulatory

standard. This concept is related to the literature on irreversible investments and option value (Arrow and Fisher 1974, Pindyck 1991, Hassett and Metcalf 1995). When investment cannot be easily reversed and the benefits or cost of the investment are uncertain, there is value to waiting for the uncertainty to be resolved. For example, retrofitting older homes with more energy efficient insulation and heating systems is largely irreversible. Once the systems have been installed they are costly to remove. The benefits of making older homes more energy efficient is largely a function of the price of heating oil or natural gas, which is uncertain. Thus, there is often value to waiting to learn more about future oil prices before committing money to install the energy efficient systems. Hassett and Metcalf (1995) have shown that this option value can largely explain the low rate of conservation investment that resulted from the energy tax credits.

Option value works in the same way for regulatory agencies. Given that traditional notice-and-comment rulemakings are relatively expensive and difficult to alter, regulators may prefer a less rigid standard when the uncertainty over the nature of the risk being regulated is large. In these circumstances, MBR might provide a reasonable alternative for three reasons. First, the regulator can achieve some changes in behavior by plants, without committing to a specific regulatory standard. Second, the mandatory information-sharing component of MBR helps the regulator learn about the costs and private benefits of risk reduction. And finally, the regulator has time to learn more about the nature of the risk and determine whether future regulatory efforts are required.

Examples of Desirable MBR Use

While all four of these characteristics help explain the circumstances under which MBR might be a more appropriate regulatory instrument, not every problem for which MBR may be considered will necessarily exhibit all four characteristics. Rather different combinations of these characteristics may lead to MBR being a better regulatory instrument than other feasible alternatives. To see how these four characteristics or criteria might be combined in ways that make MBR a more appropriate regulatory alternative, let us examine two different uses of MBR: food safety and pollution prevention.

In the case of food safety, three of the four characteristics are met: measurability, heterogeneity, and information burden. Pathogen contamination of the food supply is a difficult risk to measure. Tests are available for key pathogens, but many require so much time to conduct that the food is on the table before the test results are known. Thus setting a standard, for example that meat not contain more than a certain amount of E. coli, is not enforceable. But this feature alone does not necessarily suggest MBR is the best regulatory instrument for food safety. One could still impose uniform "best practice" standards for food handling and processing. However, it is also the case that there is heterogeneity in the population of food processing facilities that might make infeasible a set of best management practices that function uniformly well across a wide range of facilities. Finally, designing a series of best practice standards that apply differentially to different types of facilities could be done, but would place a large information burden on the regulator.

Notice that in the case of food safety, the uncertainty of the risk was not a key factor. In fact, there is fairly strong evidence linking food contamination to health problems, so in comparison to other risk, there is little uncertainty for food safety. But the combination of immeasurability, heterogeneity in the population of regulated entities, and a high information burden on the regulator is arguably sufficient to justify the use of MBR as a regulatory instrument for food safety.

A different combination of the four characteristics would justify the use of MBR for toxics pollution prevention and control. In the case of toxic pollution, there are measures, albeit imperfect ones, of toxic chemical release levels from each facility. Every year large manufacturing facilities are required to publicly disclose their releases of nearly 600 different toxic chemicals under the federal Toxics Release Inventory program. Thus, toxics regulation could require that facilities not release more than a certain number of pounds or require certain percentage reductions in toxic chemicals. The targets of these regulations would be measurable and enforceable. Given that, why would anyone ever argue that MBR should be use to regulate toxic chemicals?

First, there is again a large degree of heterogeneity in the population of facilities that release toxic chemicals. Therefore, uniform standards are likely to be quite costly for facilities and non-uniform standards place a high information burden on regulators (Stavins 2003; Tietenberg 1990). However, these two conditions are still not sufficient to justify the use of MBR for toxics control. In similar situations for other pollutants, heterogeneity and regulatory information burden have led to the use of market-based regulatory instruments such as tradable pollution permits (Stavins 2003; Tietenberg, 1990). Tradable permits still guarantee an overall level of reduction in pollution, but

attain this reduction at the least cost by allowing facilities with higher costs of pollution control to pay for reductions at facilities with lower costs (Stavins 2003; Tietenberg, 1990).

The argument for MBR in the context of toxics pollution seems to hinge on uncertainty over the nature of the risk. By definition, all toxic chemicals reportable under the TRI program cause either human health or environmental/ecosystem damage at some level (U.S. Code 1986).[16] But the degree of damages, particularly at current levels of exposure, is not clear for at least some of these chemicals. Mercury and arsenic are two recent examples of how uncertainty over the risk posed by a known toxic chemical impaired the ability to set traditional standards. For example, the January 2004 Federal Register notice for a new EPA regulation of mercury releases from utilities stated:

> Exposure to Hg [mercury] and Ni [nickel] at sufficiently high levels is associated with a variety of adverse health effects. The EPA cannot currently quantify whether, and the extent to which, the adverse health effects occur in the populations surrounding these facilities, and the contribution, if any, of the facilities to those problems (US EPA 2004a).

In 1999, the National Research Council provided a scientific assessment of the effects of arsenic in drinking water to aid in EPA's decision on whether or not to lower the standard for arsenic below the established 50 parts per million (ppm) standard. As with mercury, the debate over arsenic standards has not focused on the potential toxicity of the chemical, but rather on the health effects of exposure to this chemical at current levels. The NRC report stated:

> The subcommittee concludes that there is sufficient evidence from human epidemiological studies in Taiwan, Chile, and Argentina that chronic ingestion of inorganic arsenic causes bladder and lung cancer, as well as skin cancer. With minor exceptions, epidemiological studies for cancer are based on populations exposed to arsenic concentrations in drinking water of at least several hundred micrograms per liter. Few data address the degree of cancer risk at lower concentrations of ingested arsenic (National Research Council 1999).

As the mercury and arsenic examples illustrate, uncertainty over the nature of the risk posed by exposure to known toxic chemicals can limit the ability of regulatory agencies to use more traditional environmental standards. Until more is learned about the underlying science of human exposure to these chemicals, specifying regulatory standards for these chemicals may result in standards that prove either too stringent or not stringent enough. While in theory, all regulations can be changed in the presence of new information, it is often costly and politically difficult to do so. MBR provides a way to achieve some reductions in toxic pollution while learning about the costs and benefits of further regulatory action.

The above discussion has focused on theoretical arguments for when MBR might be a viable regulatory alternative. Ideally, one could use empirical evidence to compare the effectiveness of different policy instruments and determine which instrument is most appropriate for a given class of problems. Of course, to date there has been no empirical evaluation of the relative performance of MBR compared to other regulatory policy instruments. This empirical comparison is challenging in large part because different regulatory instruments are often used exclusively in one policy context. Facilities are

usually not simultaneously subject to MBR, market-based instruments, and command-and-control instruments for the same pollutant. Even if they were, isolating the effects of each instrument would be quite challenging. Nonetheless, identification of policy areas where these comparisons can be made empirically should be a high priority for future research.[17]

CONCLUSION

This chapter presents both theoretical and empirical evidence of the effectiveness of management-based regulations with a focus on the use of MBR to control toxic chemical pollution. From a theoretical perspective, the chapter demonstrates that MBR can be effective in two ways. The first is by changing the internal decision-making of the plant. MBR forces plants to allocate management resources toward pollution prevention and as a result some plants discover methods to reduce toxics chemical use or releases at lower costs. The key factors in determining whether MBR will affect the internal decision making of the plant is (1) whether the plant is already engaged in the level of pollution prevention planning required by regulation, and (2) the strength of the connection between increased management effort and discovery of lower cost or higher benefit methods of reducing toxic chemical use and release. If plants are already engaged in the amount of planning that MBR requires, then government regulation is unlikely to result in measurable changes in facility-level pollution. Similarly, if there is a limited relationship between management effort and pollution reductions, then requiring facilities

to devote more management effort to investigating possibilities to reduce chemical use and release will not be fruitful.

The second theoretical pathway through which MBR may be effective is through information sharing between the regulated entities and the regulator. MBR requires plants to share with the regulator the results of their pollution planning efforts. This information sharing can provide the regulator with critical information on both the costs and private benefits of toxic chemical use reductions. It can also allow the regulator to compare performance of plants in the same industry and allocate government resources to inspecting plants that appear to be laggards. The key determinant of the success of information sharing is the degree to which the regulator can make valid comparisons among plants' environmental reports.

Beyond theoretical arguments of why MBR might work, new empirical evidence has emerged showing that plants subject to MBR have experienced greater reductions in toxic chemical releases than they would have in the absence of these regulatory initiatives. The most rigorous study on the topic has found that facilities subject to these regulations reduced toxic chemicals by nearly 60,000 pounds more than comparable facilities not subject to the regulations. This empirical work comparing the relative performance of facilities in states with and without MBR complements prior empirical work that investigated facility responses to specific states' programs. In general, the empirical evidence supports the effectiveness of MBR for toxic chemical reduction.

Given that MBR can be effective, under what circumstances might MBR be a better regulatory instrument than other alternatives? Four characteristics were highlighted including: (1) the measurability of risk, (2) the degree of heterogeneity of the

regulated entities, (3) the degree of information required to promulgate traditional regulations, and (4) the degree of uncertainty surrounding the nature of the risk being regulated. Two examples of the current use of MBR — food safety and pollution prevention — were used to demonstrate how these characteristics might be combined in ways that make MBR an attractive regulatory option. In the case of food safety, the risk of bacterial contamination is not easily measurable in a short enough time frame to affect consumption of contaminated food. This has made binding standards on bacteria levels infeasible as an exclusive basis for regulation. In addition, there is a great deal of heterogeneity among food processing plants thereby limiting the ability to use uniform "best management practice" standards. Finally, the information burden for regulatory agencies to design facility-specific regulations would be extremely high. Given this combination of characteristics of the regulated entities, the risk being regulated, and the regulatory institutions, MBR seems to be a reasonable policy measure to control food contamination.

A different combination of characteristics seems to justify the use of MBR in the pollution prevention context. In the case of pollution prevention, there are measures of pollution outcomes available at the facility level. In this case, traditional performance standards that limit toxic chemical releases or market-based instruments such as tradable permit systems could be used and enforced. The key characteristic of pollution prevention that makes MBR justifiable is that the degree of damages from current levels of exposure to toxic chemicals is uncertain for many of these chemicals. It is difficult to set standards in the absence of good information on the cost and benefits of toxic

chemical control. MBR provides a way to achieve some reductions in toxic pollution while learning about the costs and benefits of further regulatory action.

Given that empirical research has shown that MBR can be a viable regulatory strategy, it deserves to be studied by researchers, and considered by policymakers, as an alternative to other, better recognized policy instruments. In addition, there are circumstances under which MBR may be a superior regulatory instrument compared to other alternatives. Further research will be needed to determine just how appropriate MBR might be in different circumstances, but the evidence from state pollution prevention planning laws does show that MBR has earned a place in the regulator's toolbox.

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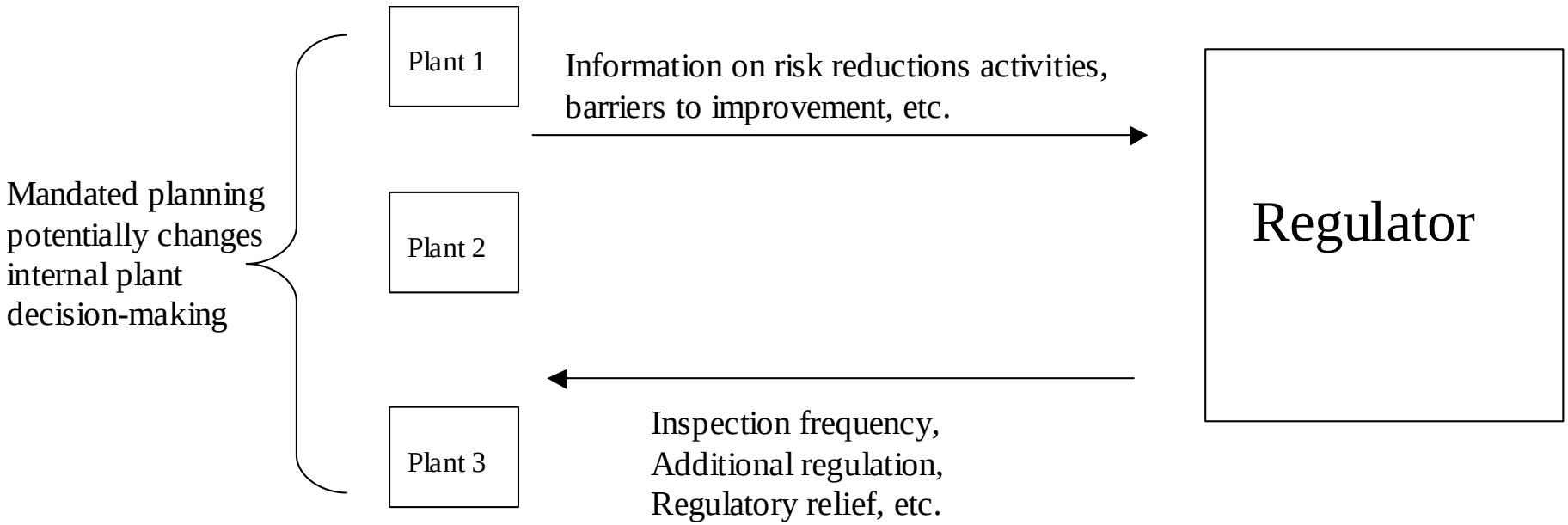
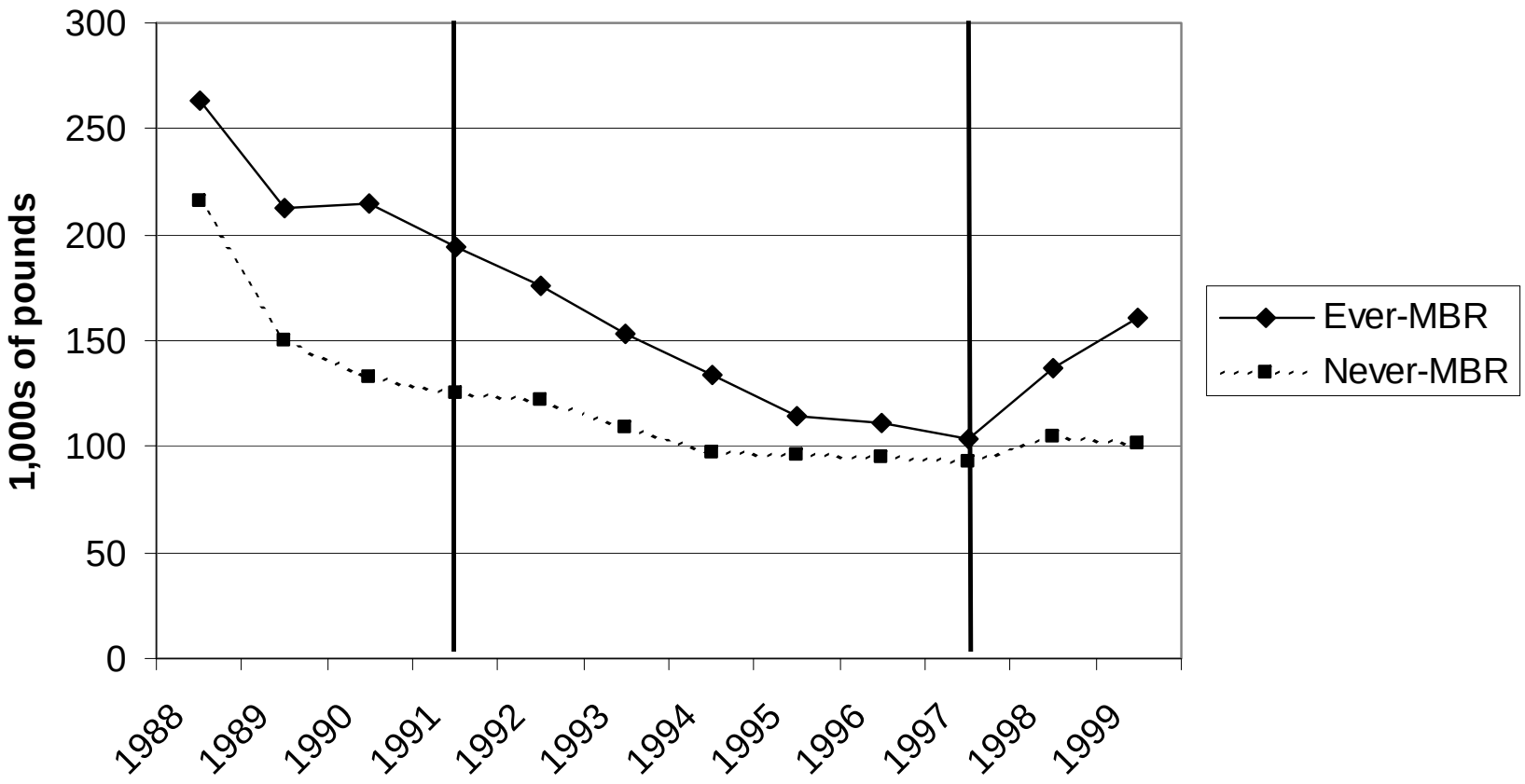
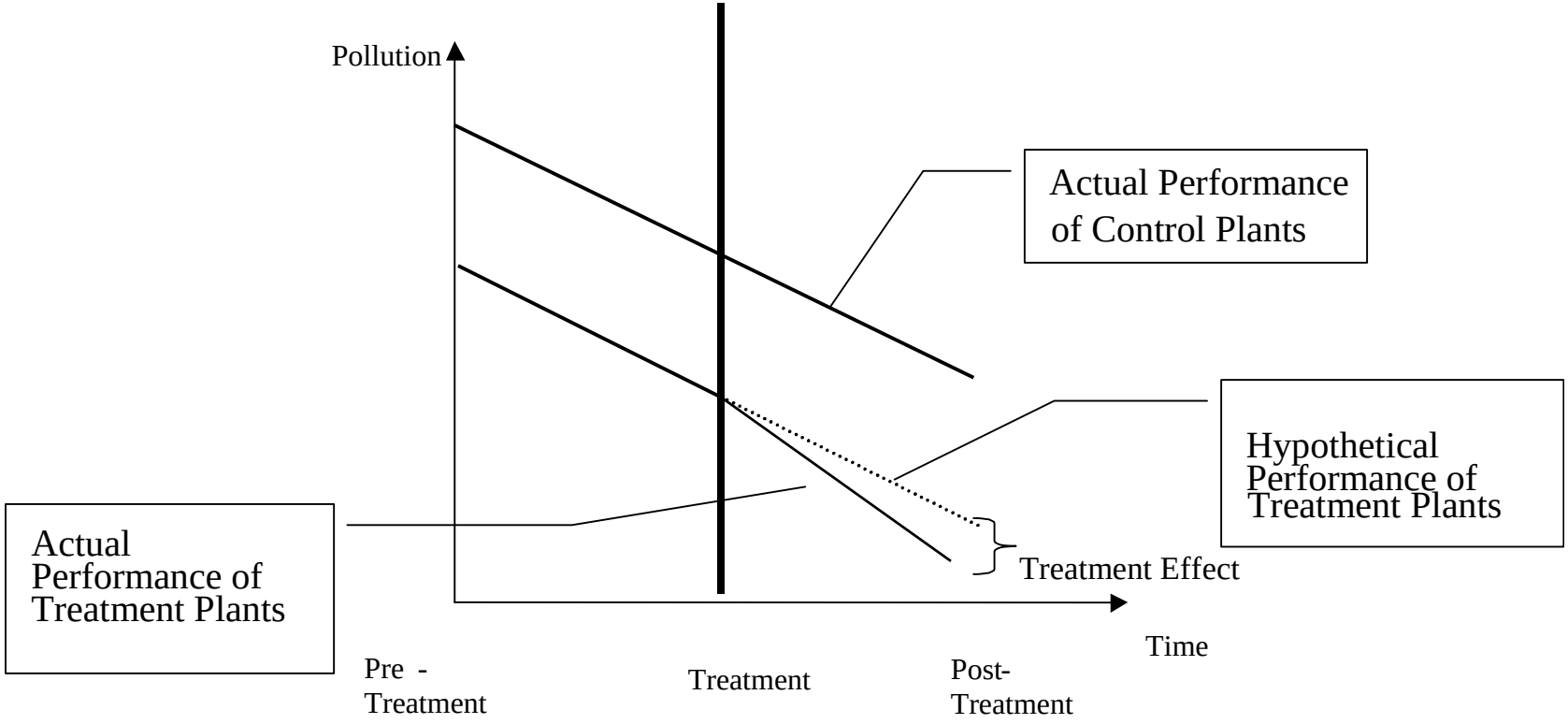


Figure 1: A Diagrammatic Model of MBR

Figure 2: Trends in Total Pounds of Chemical Releases




Pollution
Actual Performance of Control Plants
Hypothetical Performance of Treatment Plants
Actual Performance of Treatment Plants
Treatment Effect
Time
Pre - Treatment
Treatment
Post- Treatment

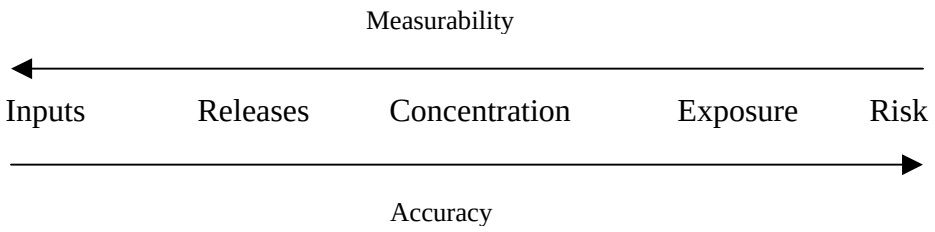


Figure 4: Tradeoffs in Targets for Environmental Regulation

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 reporters LQGs Users of more than 10,000 lbs of a toxic chemical (even in not a TRI reporter) Voluntary Participants	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	TRI reporters LQGs SARA Section 312 Reporters	No	Biennial	No	1990	1993
Massachusetts	TRI reporters	Yes	Annual	Yes, reviewed by third party auditor	1990	1994
Minnesota	TRI reporters with non-zero releases LQGs	No	Annual	No	1990	1991 for SIC 35-39, 1992 for all others
Mississippi	TRI reporters LQGs	No	Annual	No	1990	1992

Table 1 (Continued)

New Jersey	TRI reporters	Yes	Annual	No	1991	1992
New York	LQGs	No	Annual	Yes, reviewed by state officials	1990	Phase in beginning in 1991
Oregon	TRI reporters LQGs SQGs	Yes	Annual	No	1989	1991
Tennessee	LQGs, SQGs	No	Annual	No	1992	1992 for LQGs, 1994 for SQGs
Texas	TRI reporters LQGs SQGs	No	Annual	No	1991	Phase in beginning in 1993
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

Table 2: Key Factors Determining Policy Instrument Choice

Characteristics of Risk	Characteristics of Risk Sources	Characteristics of Policy Institutions
Measurability of risk	Heterogeneity of sources	Democratic
Determinants of risk—location, demographics, affected population	Market structure	Enforcement resources
Level of uncertainty surrounding risk	Dynamic properties of product or market	Existing tax structures
Asymmetry of information about risk	Uncertainty surrounding cost of risk reduction	Centralized or decentralized

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[2] Cost-effectiveness is not the only criteria by which policy instruments should be compared. Other comparisons can also be made including whether the policy results in a more equitable distribution of the costs and benefits or changes the policy process in desirable ways.

[3] Kagan finds that some firms – the "true-believers" – always over comply. Other firms may be strategic over compliers, while still others may only be reluctant compliers. Similarly, these management styles are likely to be highly correlated with the firms' allocation of management effort to pollution prevention.

[4] The plant could be better off with MBR than without MBR if some management resources were idle and those resources were devoted productively toward pollution prevention, or if managers got lucky in its pollution prevention planning, for example, if managers discovered greater-than-anticipated cost savings from pollution reduction.

[5] Porter and van der Linde (1995) argue that regulation might increase competitiveness by focusing firm's attention to improvements in environmental performance that also enhance economic performance, so called "win-win" opportunities. Palmer, Oates, and Portney (1995) provide the neoclassical economics counterpoint for why situations that *ex post* may appear to improve both environmental and economic performance are not necessarily "win-win" *ex ante*.

[6] Snyder (2004) provides a proof of this assertion.

[7] This incentive problem is the primary rationale for regulations that require disclosure of "material facts" by real estate agents.

[8] This is the foundation for relative performance standards—standards that reward or punch based on relative, rather than absolute, performance. For more information on relative performance standards and their use to solve principal-agent problems see Green and Stokey (1983) and Lazear and Rosen (1981).

[9] The information on state pollution prevention laws was obtained from the National Pollution Prevention Roundtable (1996) and through state websites and phone calls with state agencies. Further information on the state laws is available from author upon request.

[10] The measure of toxic releases used is "on-site releases." On-site releases include all releases to air, water, land, and underground injection. They do not include transfers off-site for recovery or storage.

[11] Waste differs from releases in that it includes quantities of chemicals used for energy-recovery, recycled, and treated. Thus waste includes all chemicals that are generated during the production process and are not embedded in the final product.

[12] The programs they evaluate include MBR, but also include other voluntary pollution prevention programs that range from recognition programs, to technical assistance programs, etc. Thus, the fact that they find no evidence that pollution prevention programs had an effect is not a test of whether MBR had an effect.

[13] Helfand, *et al.* (2003) provide an excellent summary of this research, with the exception of research on the effects of instrument choice on rates of technological change, which is summarized in Jaffe, Newell, and Stavins (2003).

[14] Regulations that target inputs include: Maximum Attainable Control Technology standards (MACTs) for hazardous air pollutants (U.S. EPA 2000), the technology mandates embedded in the New Source Review (NSR) (U.S. EPA 2002a), or the lead phase down program for gasoline which targeted the lead content of gasoline (Nichols 1997). Regulations that target emissions include: the SO_2 tradable permit system (Stavins 1998) and the RECLAIM air quality program in Los Angeles (Harrison 1999). A recent attempt to regulate based on concentrations is the Water Quality Trading Policy (U.S. EPA 2004b).

[15] Newell and Stavins (2003) develop a rule of thumb measuring whether industry heterogeneity is sufficient to make market-based instruments preferable to uniform standards.

[16] Specifically chemicals added to the Toxics Release Inventory must be "known to cause or can reasonably be expected to cause in humans—(a) cancer or teratogenic effects or (b) serious or irreversible reproductive dysfunctions, neurological disorders, heritable genetic mutations, or other chronic health effects."

Chemicals may also be added if it "is known to cause or can reasonably be anticipated to cause … a significant adverse effect on the environment …" (U.S. Code 1986).

[17] Keohane (2001) provides an example of the type of empirical analysis that can be done when a policy area is identified that is subject to multiple regulatory instruments. He investigates the adoption of scrubbers at plants subject to tradable permit regulations for sulfur dioxide under the Clean Air Act Amendments of 1990 with plants subject to command-and-control regulations for the same pollutant.