

General Deterrence and the Clean Air Act

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April 28, 2010

Abstract: Decisions to comply with laws may be based on beliefs about the expected penalties for noncompliance, and these beliefs may often be formed by observing the legal sanctions imposed on others (Sah, 1991). I test whether this is true for the enforcement of air pollution regulations in the United States by analyzing plant-level data on emissions of toxic air pollutants from several thousand manufacturing plants and data on regulatory actions to enforce the Clean Air Act. Consistent with this theory being true, large legal sanctions imposed on polluting plants by state governments are associated with reductions in pollution emissions at other plants in the same state. This deterrent response to sanctions of others, known as the general deterrent effect of sanctions, stretches across industrial categories and persists for several years. These results imply that enforcing the Clean Air Act with frequent sanctions that are non-maximal may be efficient (Bebchuk and Kaplow, 1992).

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Acknowledgements: I am grateful to my advisors W. Bentley MacLeod, Janet Currie, and Brendan O’Flaherty for their invaluable advice and constant support. I also thank Mariesa Herrmann, Jamie Kugler, Cecilia Machado, Johannes Schmieder, Justin Svec, Eric Verhoogen, Reed Walker, participants at the Columbia Applied Microeconomics Colloquium, job market candidate talk attendees at CNA Analysis and Solutions and Advanced Analytical Consulting Group, and numerous 2010 American Economic Association Annual Meeting attendees for many helpful comments and suggestions. Finally, I thank Janet Currie for providing the Toxics Release Inventory Data used in this paper to me, and Mariesa Herrman, Johannes Schmieder, and Reed Walker for their work compiling and cleaning this data. I alone am responsible for any errors.

Section 1: Introduction.

Suppose the New York State government issues a large regulatory sanction to a factory in New York that is violating the Clean Air Act, demanding that this factory pay a large fine and take costly steps to reduce air pollution emissions. Will other polluting facilities in New York respond to this action by cutting pollution emissions? Which other facilities will reduce emissions, and what will the size of the response be? In this study, I provide empirical evidence on the answers to these questions by analyzing a panel of data on annual emissions of toxic air pollutants by several thousand manufacturing facilities in all manufacturing industries in the U.S., and the occurrence of regulatory sanctions of Clean Air Act violations.

I find the following. When state governments impose large regulatory sanctions on manufacturing facilities, sanctions that are the results of judicial court enforcement actions rather than administrative enforcement actions, these judicial sanctions are associated with reductions in air pollution emissions of up to 9% at other manufacturing facilities in many industries in the same state. These reductions begin in the year of the sanction and persist for about three years afterwards, although the effects in the year of the sanction are limited to other facilities in the same county, possibly because it takes time for news of the sanction to spread to other counties in the state. Consistent with theory, the reductions are larger in states where judicial sanctions occur more infrequently, and also are larger in counties with more heavily polluted air. The important difference between judicial and administrative sanctions of violations of the Clean Air Act is that judicial sanctions are much more severe and costly sanctions (see Section 3.3 below). Administrative sanctions are associated with smaller reductions in emissions at other facilities in the same county that last for two years, and with smaller reductions in emissions at other facilities in the same state that last for one year.

This study estimates polluting facilities' responses to sanctions of other facilities for the following reasons. Most of the prior literature estimating the effects of actions to enforce environmental regulations has only estimated what are called "specific deterrent" effects, which are the effects of regulatory actions on the inspected or sanctioned facility itself (see Section 2.2 below). It is clear that an inspection, fine or injunction imposed by a regulator on a facility may induce that facility itself to reduce pollution emissions. However, legal scholars and regulatory personnel have long thought that sanctions affect the behavior of facilities other than the sanctioned facilities themselves (EPA, 1992; Reitze, 2005, p. 325; Shimshack, 2007). When managers of polluting facilities are uncertain about the probability of their firms being sanctioned for different types of violations of environmental regulations, and about the severity of the

sanctions, theory states that managers will often estimate the penalties they expect they would receive if they committed violations based largely on information about sanctions of other facilities (Sah, 1991; Shimshack and Ward, 2005). The extent to which responses to sanctions of other facilities, responses known as “general deterrent” effects of sanctions in the literature on enforcing laws, create reductions in pollution emissions in practice is an empirical issue, with important consequences. Bebchuk and Kaplow (1992) show that the optimal enforcement regime for a set of laws can depend on the existence and size of general deterrent effects¹.

Emissions of toxic air pollutants by manufacturing facilities, as reported to the EPA's Toxics Release Inventory (“TRI”), are examined in this study because recent research has estimated that these pollutants are very harmful to human health (Agarwal, Banerghansa and Bui, 2009; Currie and Schmieder, 2009), and because most of the Clean Air Act regulations affect emissions of the toxic chemicals covered by the TRI (Greenstone, 2003; see also Sections 3.1 and 4.1 below). The effects of sanctions on other facilities in the same state are studied because state governments have much authority and responsibility for enforcing the Clean Air Act, so that states have much ability to choose how stringently they will enforce the regulations (see Reitze, 2005, and Section 3.2 below). Variation across states in the timing and frequency of sanctions allows deterrent effects to be estimated using difference-in-differences methods, methods that can control flexibly for changes over time in factors affecting the amount of pollution emitted by facilities that occur at the industry level nationwide.

Compared to the previous literature on general deterrence of pollution enforcement (Earnhart, 2004a,b; Shimshack and Ward, 2005, 2008; Gray and Shadbegian, 2007), which is described below in Section 2.2, my paper makes the following contributions. It is the first paper to examine this topic using a broad panel of data on polluting facilities in all 50 U.S. states and in all manufacturing industries. It uses difference-in-differences identifying variation to estimate general deterrent effects, whereas most of the prior literature has used within-state time series variation or cross-sectional variation. It is the first to distinguish between the general deterrent effects of judicial and administrative sanctions. My paper also examines enforcement of the Clean Air Act, rather than enforcement of the Clean Water Act as in most of the prior literature². It

¹ Bebchuk and Kaplow note that the findings of Becker (1968), which suggest that imposition of maximal punishment with low probability is optimal, are dependent on an implicit assumption that agents accurately observe the probability of being sanctioned. This assumption entails that agents will not respond to sanctions of other agents, as sanctions of others provide no new information about the probability of being sanctioned to agents who are already perfectly informed about this probability. Bebchuk and Kaplow demonstrate that more frequent sanctions that are non-maximal could be optimal when agents are imperfectly informed about this probability.

² Differences in pollution abatement technology may create differences in deterrent effects between air pollution and water pollution. Furthermore, there are differences between the Clean Air Act and Clean Water Act in the amount of

investigates the size of general deterrent effects more thoroughly than in previous studies, along two dimensions: the duration of the effects, and the number of plants that respond to regulatory actions at other plants, measured in terms of geography and legal jurisdictions (whether the plants are in the same county, same state or same set of states overseen by the same regional EPA office) and industrial category (whether the sanctioned plant being in the same or a different industry matters). While the results of the prior literature provide evidence that general deterrence exists, they suggest that most of the responses are brief (lasting only for one year) and that the responses may be fairly limited in “reach”, in that plants only respond to regulatory actions at other plants when the plants are in the same industry and same state as a plant (Earnhart, 2004a,b; Shimshack and Ward, 2005, 2008), or when the plants are in the same state as and in close geographical proximity to a facility (Gray and Shadbegian, 2007)³. My paper provides evidence that responses to regulatory actions at other plants are frequently long-lasting and far-reaching.

The paper proceeds as follows. I first provide additional information on the prior literature on general deterrence, including theories of why actions to enforce environmental regulations might have general deterrent effects. I then provide background information on the Clean Air Act regulations, including how a large amount of responsibility and authority for enforcing the regulations is delegated to U.S. state governments. Next, I describe the data and present the econometric models. The final sections discuss the results and conclusions.

Section 2. Literature Review

2.1. The Theory of General Deterrence⁴.

In the standard law and economics framework modeling decisions to comply with laws, rational utility-maximizing agents weigh the expected penalties for not complying with laws against the expected benefits (Becker, 1968; see also Stigler, 1970; Posner, 1977; Russell, Harrington, and Vaughn, 1986, on environmental regulations specifically; and Polinsky and Shavell, 2000). With environmental regulations, the relevant marginal benefits to polluting firms of not complying with the laws are decreased expenditures on acquiring and operating pollution abatement and control equipment and being able to use cheaper but dirtier raw materials. Firms

responsibility allocated to state governments and in the frequency with which the regulations are violated, which also may create differences in deterrent effects between air and water pollution. Finally, air pollution may pose more of a health risk to humans than water pollution, since exposure to water pollution can be avoided through proper treatment and sourcing of drinking water.

³ Specifically, other facilities within 10 miles of a facility.

⁴ Much of this section of my study draws heavily from the discussion of this issue in Section 4: “Compliance Decisions” in Shimshack and Ward, 2005 (pp. 526-527).

with production facilities upon which the regulators have imposed strict emissions limits will also be able to produce more output by violating the limits⁵. Since firms will necessarily have detailed knowledge of the production processes available to them, and since regulators will need to acquire and disseminate information about the amount of pollution generated by different production processes and levels of output, it is assumed that the benefits of noncompliance are known with certainty by the managers of firms (Shimshack and Ward, 2005, pp. 526-527).

However, models of compliance decisions with laws originating with Sah (1991) posit that the marginal costs of noncompliance are only imperfectly known by agents, and therefore must be estimated. With environmental regulations, the marginal costs of noncompliance are the probabilities of being sanctioned for different types of violations, as well as the severity of the sanctions. In the U.S., state and federal environmental regulators have considerable discretion over whether and how severely different violations of the regulations will be sanctioned; see Section 3.2 below. This creates uncertainty among regulated firms about the costs of noncompliance, since firms do not have perfect information about the preferences and resource constraints of the regulators and other factors that determine how the regulators will respond to violations (Gray and Deily, 1996; Shimshack and Ward, 2005). Specifically, firms may be uncertain about how many violators resource-constrained regulators will be able to sanction. With the Clean Air Act, the EPA has repeatedly stated that it and the state pollution control agencies that enforce the Act generally do not have enough resources to sanction every facility that is known to be violating the Act, and has established procedures for creating priority lists of which violators to sanction first (EPA, 1982, 1984, 1992, 1998). If many other facilities in a jurisdiction such as a state are sanctioned this year, other violators will move up on the priority list and are therefore more likely to be sanctioned in future years if they do not come into compliance before then^{6,7}. Additionally, there may be uncertainty among firms about how personnel at the regulatory agencies will respond to pressure from politicians who favor lax enforcement of the regulations. For instance, Duhigg (2009) describes how enforcement of the Clean Water Act in West Virginia had become quite lax due to pressure on regulators from business-friendly state

⁵ The Clean Air Act regulations require all facilities to keep pollution emissions low relative to output, and many but not all facilities are also subject to strict emissions limits (for example, a certain facility only being allowed to emit 10 tons of a certain type of air pollutant per year). See Section 3.1 below.

⁶ The federal EPA also rarely issues sanctions to violators that it does not classify as “Significant” or “High-Priority” violators, leaving it up to the states as to whether any non-significant violators will be sanctioned. Therefore, sanctions imposed by a state may often signal that the state is able, and willing, to sanction less significant violations.

⁷ When the number of other facilities that are sanctioned this year rises, this may mean that a given facility is less likely to be sanctioned this year rather than more likely, since the regulators have used up their resources for this year sanctioning other violators instead. However, this does still imply that this facility is more likely to be sanctioned in future years. I thank Brendan O’Flaherty for this observation.

politicians. Enforcement of the regulations became stricter when a new lawyer working for the West Virginia Department of Environmental Protection decided to resist political pressure and issue orders forcing mines and plants that were emitting too much pollution to shut down temporarily until they reduced emissions. Reportedly, powerful state legislators then arranged to have a newly-appointed director of the department fire this strict lawyer.

The theory of general deterrence maintains that a primary source of information used in estimating the expected costs of noncompliance is observing whether and how severely other facilities in the same jurisdiction have been sanctioned, as actual actions taken by the regulator signal the willingness and ability of the regulator to impose costly sanctions on any facility in the jurisdiction (see Sah, 1991, pp. 1273-1274; Shimshack and Ward, 2005; Shimshack, 2007). The regulator's actions at a given facility may often provide additional information about the costs of noncompliance that this specific facility faces, but are not the sole source of information on these costs, according to the theory of general deterrence (Sah, pp. 1273-1274). In this theory, rational managers of facilities adjust their beliefs about the costs of noncompliance they face in response to new information about the recent enforcement actions taken by the regulator. Therefore, rational facilities' decisions about how much pollution to emit will often change in response to new information about the regulators' actions at other facilities.

Shimshack and Ward (2005, p. 527) summarize the theory of general deterrence as applied to environmental regulations as follows: "The rational plant chooses to violate when the benefit of doing so exceeds the expected costs. Benefits are known to the plant. Costs are uncertain, but plants form expectations of sanction costs. These expectations are updated based on recent enforcement actions levied against the plant and its neighbors."

2.2. Prior Empirical Work on General Deterrence and Specific Deterrence

The first empirical study of general deterrent effects of actions to enforce environmental regulations was Earnhart (2004a, 2004b). Earnhart analyzes a panel of data spanning 1990 to 1998 on biological oxygen demand wastewater emissions and Clean Water Act monitoring actions (i.e., inspections) and enforcement actions (i.e., sanctions) at 40 major municipal wastewater plants in Kansas. He estimates that sanctions imposed by Federal (as opposed to state) regulators on these plants cause a contemporaneous reduction in emissions from other plants in this sample; lagged general deterrent responses are not examined in these studies. Within-state time-series identifying variation for these studies comes from 6 sanctions occurring in the sample each year in 1997 and 1998, but only 0 or 1 occurring in other years. Earnhart (2004a,b) is also the first empirical study of the deterrent effects of actions to enforce environmental regulations that

includes facility-specific fixed effects in the regression models (2004a, p. 391), which may provide correction for omitted variable bias that is possibly present in prior studies. These prior studies examined specific deterrence, but not general deterrence⁸.

Shimshack and Ward (2005) was the second empirical study of environmental regulations and general deterrence. They analyze data on inspections, non-monetary sanctions (sanctions that do not include fines), and monetary fines of 217 major U.S. pulp and paper mills in 23 different states from 1988 to 1996. This dataset also contains data on each mill's compliance with regulatory limits on the amounts of biological oxygen demand and total suspended solids water pollution it was permitted to emit in each month between 1990 and 1996. Using a difference-in-differences estimation approach, they find that when one mill in a state is fined, all mills in the state, including those that were not fined, are more likely to be in compliance with their emissions limits for 1 to 12 months after the fine. This estimated combined general and specific deterrent effect is no longer present 13-24 months after the fine, suggesting that these plants believe that only very recent fines provide good information on the likelihood of being sanctioned for exceeding emissions limits. This effect is estimated even though the compliance rate in this sample is very high (98.8%). Their study also estimates that inspections and non-monetary sanctions do not have general deterrent effects. Shimshack and Ward (2005) was the first study to differentiate between the deterrent effects of fines and non-monetary sanctions, and their results suggest that only the most severe, infrequent sanctions have general deterrent effects. Shimshack and Ward do not estimate the general deterrent effects of fines of facilities that are not in the pulp and paper mill industry but that emit the same types of water pollutants; however, it is possible that fines of plants in other such industries could affect emissions from pulp and paper mills.

Shimshack and Ward (2008) studies general deterrence using data on 251 major U.S. pulp and paper mills in 27 different states from the years 1990 to 2004. Their 2008 study uses the amount of water pollutants emitted by each mill as dependent variables, instead of compliance status. It estimates that fines of other mills in the same state cause a reduction in emissions that again lasts for 1 to 12 months after the fine, but no longer. Again, a response is estimated even though the compliance rate with emissions limits is over 98% in this sample; the authors explain how it can be rational for facilities that are likely to comply with their emissions limits to aim to

⁸ Again, specific deterrence refers to the effects of regulatory actions on the inspected or sanctioned facility itself. The seminal paper in the empirical literature on specific deterrence is Magat and Viscusi (1990); other notable studies include Gray and Deily (1996), LaPlante and Rilstone (1996), Nadeau (1997) and Keohane, Mansur and Voynov (2009). See Cohen (1999) and Shimshack (2007, Section 3) for excellent reviews of this literature on specific deterrence. The prior empirical studies of general deterrence discussed in this section also study specific deterrence, and find evidence that inspections monitoring facilities' compliance with regulations have specific deterrent effects.

emit much less than their limits due to discharge randomness and discharge jointness (reducing emissions of one type of pollutant tending to reduce emissions of other types of pollutants).

The only other econometric study of general deterrence is Gray and Shadbegian (2007). They analyze a cross-sectional dataset on facilities' Clean Air Act compliance statuses, air pollution emissions, and Clean Air Act monitoring and enforcement activity at 521 plants from all manufacturing industries that are located within 50 miles of 3 major U.S. cities located near state borders, data which spans seven states. They estimate that inspections conducted from 1993-1995 at other plants within a 10 mile radius of a plant cause plants to be more likely to be in compliance in 1997, but only when the inspections are conducted at other plants in the same state. However, they find that inspections at other nearby facilities have no general deterrent effect on particulate matter or sulfur dioxide air pollution emissions in 1996, or on Toxics Release Inventory toxic air pollutant emissions in 1997, and find no effect of sanctions at other plants anywhere in the same state in the current year on either compliance or emissions in the current year.

One can summarize the results of these prior econometric studies as finding evidence that general deterrence exists, but that the responses are generally brief (lasting only for one year), and that the responses may be fairly limited in "reach", in that plants only respond to regulatory actions at other plants when the plants are in the same industry and same state as a plant, or when the plants are in the same state as and in close geographical proximity to a facility. In my study, I explore whether general deterrent effects are often larger in size than these previously estimated effects, in terms of the duration of the effects, and their reach across industrial categories and throughout geographic areas and legal jurisdictions (such as states and counties.) I also provide further exploration of whether emissions of the toxic air pollutants covered by Toxics Release Inventory are ever reduced in response to sanctions and inspections at other facilities, since recent research has found that these air pollutants are particularly harmful to human health (Agarwal, Banerghansa and Bui, 2009; Currie and Schmieder, 2009).

In addition to these econometric studies, a small qualitative literature on general deterrence also exists. Thorton, Gunningham and Kagan (2005), Gunningham, Thorton and Kagan (2005), and State of Oregon Department of Environmental Quality (2004) provide evidence from surveys and interviews of managers of polluting facilities showing that managers are often aware of specific regulatory actions that occurred at other facilities, and often report responding to these actions, although the responses are not always reported as having been taken immediately after news was first obtained of the actions at other facilities (Shimshack, 2007, pp. 15-16). Unlike econometric studies, this qualitative literature provides direct evidence about how firms learn of

regulatory actions at other firms and the reasons why firms might respond to actions at other firms⁹, although it is unable to verify whether managers' self-reported responses are accurate.

Section 3. Background on the Clean Air Act

Section 3.1. Regulations imposed on polluting facilities by the Clean Air Act

Most air pollution control regulations for stationary air pollution sources in the United States are set at the national level by the Clean Air Act and its amendments, as interpreted by the EPA and the Federal courts (Reitze, 2005). The Clean Air Act consists of two basic categories of regulations: the National Ambient Air Quality Standards (“NAAQS”) and the National Emissions Standards for Hazardous Air Pollutants (“NESHAPs”). The NAAQS regulate emissions of six common types of air pollutants that have adverse effects on human health and the environment, known as the “Criteria” air pollutants, by setting thresholds on ambient air concentrations of these pollutants that should not be exceeded by the air in any location in the U.S. Compliance with the NAAQS is measured using ambient air quality monitors, and determining whether an area is complying with the standards is done at the county level. The NAAQS require facilities everywhere in the U.S. to keep air pollution emissions low relative to the amount of output they produce. Facilities in areas with heavily polluted air are also generally subject to strict emissions limits set by the regulators on an individual-facility basis (for example, 100 tons of particulate matter per year for a certain specific facility), and are required to install state-of-the-art pollution abatement equipment (Chay and Greenstone, 2005). Facilities in less polluted areas are still required to limit emissions relative to output (albeit to a lesser extent) so that air pollution levels in their areas stays below the thresholds (Chay and Greenstone, 2005). While the NAAQS were first created by the Clean Air Act of 1970, tightening of some of the standards over time and the difficulty of complying with the standards have meant that in every year from 1970 to the present, many areas of the country have been out of compliance with these standards (Reitze, 2005, Chapter 3; <http://www.epa.gov/air/oaqps/greenbk/phistory.html>, accessed August 22, 2009).

⁹ Thorton, Gunningham and Kagan (2005) present theoretical explanations of why polluting facilities might respond to sanctions and inspections of other facilities that are alternatives to the model of rational self-interested responses presented above in Section 2.1. They argue based on evidence from their surveys and interviews of managers and environmental lawyers that in practice, facilities often respond to regulatory actions at other facilities because the actions “serve as a reminder to busy managers and employees to check on the reliability of existing compliance routines”. They also argue that sanctions of others often serve as a reassurance to altruistic firms that wish to internalize externalities that if they do comply with the regulations, they will not be at a cost disadvantage with firms that violate them, since costly sanctions will be imposed on the violators.

The NESHAPs regulate emissions of 189 toxic chemicals thought to be especially hazardous to human health as they “are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects” (<http://www.epa.gov/ttn/atw/allabout.html>, accessed August 22, 2009.) Prior to the Clean Air Act Amendments (CAAA) of 1990, only seven hazardous substances had been classified as Hazardous Air Pollutants (HAPs) and subject to some emissions regulation, although the scope of these early NESHAPs regulations and activity to enforce them was highly limited (Reitze (2005), pp. 131-132)¹⁰. The CAAA of 1990 classified 182 additional chemicals as HAPs and greatly increased regulation of HAP emissions. Under these amendments, a Maximum Achievable Control Technology (MACT) standard requires all facilities that emit HAPs to keep emissions of them low relative to output through the use of pollution control technology that meets certain regulatory standards. The MACT standards are set at the industry level¹¹. Establishing MACT standards for each industry that is a significant source of HAPs was a long process, however; the first set of MACT standards were promulgated in 1993, and the final set was promulgated in 2004 (Reitze, p. 140). Once a standard for an industry is promulgated, sources within that industry and subject to the standard are given four years to comply with the standard (Reitze, p. 143).

As discussed in Greenstone (2003), facilities can reduce emissions of air pollutants in order to achieve compliance with the CAA regulations not just by installing pollution abatement equipment such as scrubbers and baghouses, but also through the use of cleaner raw materials, such as the use of cleaner coal and iron ore by factories producing steel or iron. Of course, facilities can also reduce pollution emissions by reducing the amount of output they produce¹². Sometimes, they can also reduce emissions through better maintenance and operation of existing pollution abatement equipment¹³.

In this study, I estimate the general deterrent effects of actions to enforce the Clean Air Act. Enforcement of the CAA is a natural setting in which to estimate general deterrent effects because uncertainty about the expected costs of violating the CAA regulations is likely to be high (as explained above in Section 2.1, general deterrence is unlikely to be important when there is

¹⁰ This lack of regulatory activity was caused by the text of the original CAA of 1970 appearing to require that the EPA set emissions standards so that there would be no health risk whatsoever to humans from exposure to HAPs, regardless of the costs of compliance (Reitze, p. 133). It was clearly infeasible for the EPA to enforce such standards.

¹¹ These standards are based primarily on the technology used by the best-performing sources in an industrial category, although the EPA may implement a stricter standard than this based on consideration of abatement costs and health impacts (Reitze, p. 442).

¹² Perhaps by shifting production to other facilities owned by the same company that are in different states that are being less strict about enforcing pollution regulations. See Gray and Shadbegian (2002).

¹³ See, for example, the BP Texas City Clean Air Act Settlement of 2009, in which an oil refinery was required to maintain its equipment better (<http://www.epa.gov/compliance/resources/cases/civil/caa/bptexas.html>.)

little uncertainty about the expected costs of breaking a law.) It is likely that there is much uncertainty about these costs because the CAA regulations are often violated by firms and because very many violations of the CAA go unsanctioned, and fewer still are sanctioned severely. If almost all violations of the regulations were severely sanctioned in practice, there would be little uncertainty about the costs of violating the regulations. Various sources indicate that the percentage of polluting facilities known to be violating the CAA regulations at most points in time since the 1970's is over 10% (Russell, 1990; EPA's AIRS Facility Subsystem data, March 2008 release, author's own calculations)¹⁴, which is much higher than the rates at which different types of sanctions are imposed on facilities regulated by the Clean Air Act; see Section 4.3 below. In the EPA's periodically updated Policies on Timely and Appropriate Response to Significant Violators (EPA, 1982, 1984, 1992, 1998), the EPA itself has repeatedly stated that both Federal and state regulators will generally not have sufficient resources to sanction every known violator of the Clean Air Act, even if they wished they could sanction every violator¹⁵.

Section 3.2. The roles of the states and the EPA in Clean Air Act enforcement

Although air pollution regulations in the U.S. are set at the national level, responsibility for enforcing the regulations is shared by the federal EPA and state governments, and state governments have substantial authority and responsibility for enforcing these regulations in practice (Hutchinson and Kennedy, 2008; Helland, 1998b,c; Konisky, 2007, 2009a,b; Konisky and Woods, forthcoming; Portney, 2000; Potoski and Woods, 2001; Reitze, 2005; Traub and Sigman, 2007; EPA, 1982, 1984, 1992, 1998). States provide much of the funding and resources for enforcing the Clean Air Act, and states conduct the majority of the inspections of facilities that monitor their compliance with the CAA as well as the majority of the sanctions of violations of the CAA (see next section). Since the enactment of the Clean Air Act of 1970, the EPA has required each state government to develop a State Implementation Plan ("SIP") for the enforcement of the National Ambient Air Quality Standards within the state (Reitze, 2005, Ch. 3; Traub and Sigman, 2007, p. 4). The SIP program gives the states great flexibility in the methods they may require

¹⁴ These rates likely represent lower bounds on the true rate of noncompliance, given that regulators are probably unable to detect every violation that is committed (Heyes, 2000). Heyes notes that "a 1979 report by the General Accounting Office estimated that only 3% of sources designated fully-compliant with air pollution limits were actually compliant." Incidentally, these estimates of the rate of noncompliance with the Clean Air Act greatly exceed the estimated monthly rate of noncompliance with the Clean Water Act amongst major pulp and paper mills, the largest source of conventional water pollutants in the U.S., reported in Shimshack and Ward (2005, 2008). The reported rate of Clean Water Act noncompliance in their sample of pulp and paper mills is less than 2%.

¹⁵ These policies on responding to Significant Violators provide guidelines to state and EPA personnel on which violators of CAA regulations to give priority to, in terms of sanctioning them before other violators, when there are insufficient resources to sanction every violator in a state into complying with the CAA in a timely manner.

polluters to use to reduce emissions, and the categories of pollution sources they may require to reduce emissions, in order to achieve attainment of the standards (Reitze, pp. 59-60). The rationale behind the creation of the SIP program in 1970 was “the premise that air pollution is a localized phenomenon that is best handled as a state program with minimum federal involvement” (Reitze, p. 126). Although the CAA states that the federal EPA Administrator is supposed to promulgate a Federal Implementation Plan (“FIP”) for any state that has not submitted an adequate SIP for the current time period, in practice, the EPA lacks the money and staff to implement an adequate FIP covering anything more than a small sub-region of a state, the probability that the EPA will promulgate a FIP is small, and FIPs have not played a major role in air quality planning (Reitze, Ch. 3, pp. 66, 126.) For instance, as of 1995 California had yet to submit a SIP that the EPA deemed to be adequate for the South Coast of California, yet no FIP was developed and implemented for the South Coast between 1970 and 1995 (p. 66). Federal EPA personnel may step in to sanction a violation of a SIP (or one of the National Emissions Standards for Hazardous Air Pollutants) if a state has not done so, or if the state and the EPA agree that they would prefer that the EPA impose the sanction rather than the state, as both state governments and the EPA have the authority to sanction any violation of the CAA. However, the EPA sanctioning a violator itself when the state does not sanction the violator is far from automatic, and the EPA does not have the resources to sanction every violation itself (Reitze, pp. 118-123; EPA, 1982, 1984, 1992, 1998). The EPA Policies on Timely and Appropriate Response to Significant Violators discussed in the previous section also state that the EPA will rarely sanction Clean Air Act violators that do not meet the EPA’s criteria for categorization as “significant”. Whether or not non-significant violators are sanctioned is therefore almost entirely up to the states. Overall, Reitze’s assessment of the State Implementation Plan process is that “most of the effort to enforce the CAA is at the state level, which results in uneven enforcement” and that “requirements of the CAA are not always adequately enforced” (p. 125)¹⁶.

Variation in EPA activity to enforce the Clean Air Act may occur at the industry level nationwide and at the regional office level, in addition to the state level. At the industry level, the EPA establishes “National Priority Lists” of industries that it is targeting for sanctions at the current time (<http://www.epa.gov/compliance/civil/caa/caaenfpriority.html>, accessed October 6, 2009). These lists change over time, and frequently attempt to impose sanctions on every major facility in the industry that is violating the Clean Air Act (see, for example, the Petroleum

¹⁶ Becker and Henderson (2000) note that the CAA gives the EPA the authority to withhold federal grants for things such as highways and to impose moratoria on new plant construction in states that fail to enforce the CAA adequately. However, Duhigg (2009) observes that the EPA has frequently declined to exercise this authority in practice.

Refinery Priority initiated in 2000¹⁷). The EPA also divides the country up into ten EPA Regions, each covering between four and eight states and territories, which have their own Regional Administrators and budgets and oversee enforcement within their assigned states and territories (<http://www.epa.gov/epahome/where.htm>, accessed October 6, 2009).

Section 3.3. Categories of Clean Air Act enforcement actions

State and EPA regulators can take three basic types of actions to enforce the CAA: inspections, administrative sanctions, and judicial sanctions. Inspections are actions that monitor facilities' compliance with the Clean Air Act regulations, and include such activities as reviews of facility records, operating logs, and required reports, assessments of pollution control equipment and production process operating conditions and parameters, and "stack" tests measuring pollution emissions at a facility (EPA, 2009). Under the CAA, states are responsible for conducting most of the inspections, and states conducted 96.6% of the inspections done between 1978 and 2007 (EPA's AIRS Facility Subsystem data, author's own calculations).

Administrative sanctions are compliance orders issued directly to violating facilities by the EPA and state regulators, and order the violator to come into compliance by taking specified steps to reduce pollution emissions according to a specified time schedule¹⁸. States also issue most (93.7% between 1978 and 2007) of the administrative sanctions.

Judicial sanctions are lawsuits to enforce pollution regulations that are filed in either state or Federal court, and ultimately lead to orders called "court consent decrees" that are issued to facilities by the courts¹⁹. These decrees will be enforced by either state or Federal law

¹⁷ <http://www.epa.gov/compliance/resources/cases/civil/caa/oil/index.html>, accessed October 6, 2009.

¹⁸ The official name for this type of action is an "Administrative Compliance Order". Administrative Penalty Orders imposing fines of no more than \$200,000 on violating facilities also exist. However, data on administrative penalty orders issued by state governments is not available in the AIRS Facility Subsystem dataset on enforcement actions that is used in this study, so I do not estimate the deterrent effects of this type of sanction. It is likely that many if not most administrative compliance orders will be accompanied by administrative fines, however, so data on administrative compliance orders should serve as a proxy for both types of administrative sanctions. Furthermore, \$200,000 should be quite small in comparison to the revenues generated by facilities large enough to have to report pollution emissions to the TRI, the dataset on emissions used in this paper, so that the deterrent effects of administrative fines are expected to be negligible.

¹⁹ The EPA rarely loses these lawsuits; Helland (2001) reports that between 1977 and 1996, 94.5% of judicial enforcement actions pursued by EPA personnel in Federal courts resulted in settlements in which the prosecuted facilities agreed to reduce pollution emissions and/or pay fines, and that the EPA still won 28.6% of those actions that went to trial. Data on the success rate of lawsuits filed by state pollution control agencies in state courts is not available, but it is expected that their success rates should be similar to those of the EPA. Miller (1997, Table 1) also reports that the average duration of a lawsuit to enforce a pollution regulation that is filed in Federal court, from the filing of the claim until settlement or verdict, was 1.62 years for claims terminating between 1972 and 1997. The standard deviation of the duration was 2.20 years. Claims are to be referred by the regulators to the federal

enforcement agencies (although these agencies do not enforce administrative sanctions). Like administrative sanctions, judicial sanctions mandate that a facility take specified steps to reduce pollution emissions according to a specified time schedule. However, unlike administrative sanctions, judicial sanctions frequently impose large monetary fines on polluting facilities, fines that are intended to punish them for their violations and to deter future violations at that and other facilities (EPA, 1992)²⁰. EPA policy on choosing between sanctioning a violator of the CAA administratively or judicially states that “there are statutory limits on the use of administrative remedies” and that “long-term, court-supervised injunctive relief is available only in the judicial forum” (EPA, 1991). Long-term court-supervised injunctive relief is to be sought when it seems probable that a violator will not obey an administrative order in light of that violator’s past and current behavior, and also when “the violator will be required to perform complex or capital-intensive compliance activities, since these situations present an increased likelihood for disputes over satisfactory performance and for missed compliance deadlines” (EPA, 1991). Furthermore, administrative sanctions may not be used to address violations that began more than a year prior to initiation of the administrative sanction, and monetary sanctions penalizing violators with fines of over \$200,000 can be obtained only with judicial sanctions (EPA, 1991). In practice, both state and EPA judicial sanctions frequently impose fines of over \$500,000 and of over \$1,000,000²¹, with \$8,752,154 and \$2,529,257 being the largest fines imposed between 1985 and 2000 in EPA and state judicial sanctions, respectively (EPA AIRS Facility Subsystem Data, author’s own calculations. These fines are measured in 2008 dollars to adjust for inflation). Therefore, judicial sanctions are almost always more severe than administrative sanctions.

Lawsuits to impose judicial sanctions are filed in State court when the state regulators take the lead in pursuing the sanction and in Federal District court when the EPA takes the lead. Unlike inspections and administrative sanctions, only 50.1% of the judicial sanctions that concluded between 1978 and 2007 were actions taken by states (AIRS Facility Subsystem data).

Section 4. Data

4.1. Toxics Release Inventory (TRI) Data on Facilities’ Pollution Emissions

Department of Justice or the state attorney general for prosecution within 150 days after a violation is discovered (EPA, 1982, 1984, 1992).

²⁰ Not every judicial sanction imposes a fine; many just require the facilities to reduce pollution emissions. According to the data on CAA sanctions used in this study, 62.87% and 44.63% respectively of EPA and state judicial sanctions of major manufacturing facilities that occurred between 1985 and 2000 imposed fines, and the rest did not.

²¹ See, also, the examples of large fines given in the summary of recent major EPA Clean Air Act sanctions at <http://cfpub.epa.gov/compliance/cases/index.cfm?templatePage=12&ID=1>, accessed November 15, 2009.

The data used in this paper on the amount of air pollution emitted by individual facilities each year come from the Environmental Protection Agency's (EPA's) Toxics Release Inventory ("TRI"). The TRI was created as part of the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986. Since 1987, manufacturing facilities that have 10 or more full time employees or the equivalent and that "manufactured" or "processed" more than 25,000 pounds or "otherwise used" more than 10,000 pounds of a chemical on the TRI reportable chemicals list during a calendar year have been required to report, on an annual basis, the amounts of every chemical exceeding this threshold that the facility emitted²². Thus, the TRI is a dataset at the facility-chemical-year level. The TRI contains separate records for each reported chemical on the number of pounds of that chemical that are released into the air, water, and land. It also contains detailed geographic information on the reporting facility, as well as the industry the facility belongs to and the parent company that owns the facility. The EPA's Risk-Screening Environmental Indicators (RSEI), a computer-based screening tool developed by the EPA for analyzing health risks from exposure to chemicals covered by the TRI, provides numeric toxicity weights for the chemicals in the TRI data.

Hundreds of different toxic chemicals are on the TRI list each year, although over the years more chemicals have been added to the reportable chemicals list, and a few chemicals have also been de-listed. For consistency over time, only releases of the 344 chemicals that are on the TRI list each year from 1988 to 1999 are included in the pollution emission variables used in this paper²³. In 2000, the reporting thresholds for many chemicals on the TRI list, specifically dioxin, dioxin-like compounds, and numerous other Persistently Bioaccumulative Toxins (PBTs), were lowered from 25,000 pounds manufactured or processed or 10,000 pounds otherwise used to be either 0.1 grams, 10 pounds, or 100 pounds depending on the chemical. As a further step for maintaining consistency over time in the construction of the facility-level pollution emissions variables, TRI data from 2000 and later are not used in this paper. As a final step, while facilities in several industries other than manufacturing, such as mining and oil- and coal-combusting electrical utilities, have been required to report to the TRI starting in 1998, only manufacturing facilities are included in the data used in this paper.

Emissions of almost all of the chemicals on the TRI list are regulated by either the National Ambient Air Quality Standards (NAAQS), the National Emissions Standards for Hazardous Air Pollutants (NESHAPs), or both. Since most of the chemicals on the TRI list are

²² Precise definitions of "manufactured", "processed" and "otherwise used" are given in several EPA documents, including the codebooks to the public data releases of the different years of the TRI data.

²³ Data from 1987 is not used in this paper since data from the first year of the TRI may be of low quality.

classified as the Criteria Air Pollutants Particulate Matter or Lead, or as Volatile Organic Compounds, which are a necessary ingredient in the formation of the Criteria Air Pollutant Ozone (Greenstone, 2003; Bui, 2005), enforcement of the NAAQS regulations will generally reduce emissions of the air pollutants covered by the TRI. Emissions of the 189 air pollutants that are classified as Hazardous Air Pollutants are reported to the TRI as well (<http://www.epa.gov/ttn/atw/allabout.html>, accessed August 22, 2009.)

Data on pollution emissions in the TRI are generally not based on actual monitoring of pollution releases at the reporting facilities. Instead, emissions are estimated using engineering pollution production functions that take into account the quantity and type of inputs used in the production process at a facility, the nature of the production process used, and the installed pollution abatement devices, such as scrubbers and baghouses (Greenstone, 2003, p. 443). Data on air pollutant emissions released from smokestacks (“stack emissions”) are more likely to be based on monitoring data from a facility than data on “fugitive emissions” are, however (de Marchi and Hamilton, 2006, p. 60). Fugitive emissions are releases that escape into the air from the plant at ground level (e.g., leaks).

Since the TRI data are computed in this way and since the data are self-reported, it is possible that facilities might strategically underreport toxic pollutant emissions to the TRI - or strategically increase the extent of underreporting - in response to regulatory activity. However, there are many reasons to think that changes in emissions levels that are reported to the TRI are, for the most part, accurate and honest reports, so that the possibility of misreporting is unlikely to create much bias in estimates of the deterrent effects of regulatory actions. First, intentional underreporting of pollution emissions is a federal crime, so that employees of a company who participate in underreporting that company’s emissions to the TRI can be imprisoned and personally fined (Reitze, 2005, p. 309; Shimshack and Ward, 2005, p. 524). In contrast, violating the NAAQS or NESHAPs limits on the amount of air pollution that may be emitted results in only the company, not its employees personally, being penalized²⁴. Second, de Marchi and Hamilton (2006) compare reductions from 1988-1990 to 1998-2000 in ambient air quality monitoring measurements in the U.S. of five of the most common chemicals on the TRI list to reported reductions in air emissions of those same chemicals in the TRI. For each of the five chemicals, the reduction in air emissions is accompanied by a similar reduction in measured ambient air

²⁴ Furthermore, emitting high amounts of the pollutants on the TRI chemicals list is not a violation of any environmental regulation in and of itself. See Section 3.1 above. While strict emissions limits for the six Criteria Air Pollutants governed by the NAAQS may be imposed on facilities, the amount of TRI chemicals released does not directly correspond to the amount of any Criteria Air Pollutant that is released.

concentrations of the same chemical (p. 63, Table 1). This is consistent with fairly accurate reporting of emissions to the TRI.

Regulators may also audit facilities to investigate whether they took actions to reduce emissions (installing abatement equipment, etc.) that are consistent with the amount of emissions reductions they report to the TRI. The results of an actual audit study that investigated this issue support this statement and the accuracy of the TRI data. Natan and Miller (1998) examine reductions in reported toxic releases in the early years of the TRI data using an audit of plants with large changes in reported toxic releases. They found that changes in plant operations and production levels explained over 90 percent of the reductions in releases²⁵. In addition, to the extent that underreporting of emissions to the TRI is possible, facilities have incentives to underreport to as large a degree as is possible regardless of how much Clean Air Act enforcement activity is being done in that facility's jurisdiction. This is because local residents and real estate owners, environmental groups, potential consumers of that company's products, and potential investors in the facility's parent company also may care about the amount of pollution it releases. Hamilton (1995) shows that a company's stock price is adversely affected by higher levels of reported TRI emissions. Chay and Greenstone (2005) provide evidence that air pollution reduces the price of local homes. Furthermore, at least until 1998, the Federal EPA, rather than state pollution control agencies, was responsible for efforts to assure accuracy of reporting to the TRI²⁶. Thus, differences across states and time in the amount of regulatory activity to reduce air pollution emissions should be uncorrelated with changes in regulatory oversight of TRI reporting.

4.2. AIRS Facility Subsystem (AFS) Data on Monitoring and Enforcement Actions

Data used in this paper on actions taken by state governments' pollution control agencies and by the federal Environmental Protection Agency to monitor compliance with and sanction violations of the Clean Air Act comes from the EPA's Aerometric Information Retrieval System ("AIRS") Facility Subsystem ("AFS"). Since 1978, the EPA has recorded its monitoring and enforcement activities in the AFS database, and has also collected data on the monitoring and enforcement activities of all of the states. The EPA intends for the AFS to contain data on the

²⁵ Similarly, LaPlante and Rilstone (1996) and Shimshack and Ward (2005) use the presence of inspectors at pulp and paper mills to test the accuracy of self-reported data on water pollution emissions from these plants, under the assumption that releases are reported accurately when an inspector is present. They fail to reject the accuracy of self-reporting. See Shimshack and Ward pp. 524-525, 537-538.

²⁶ http://www.epa.gov/tri/stateprograms/state_programs.htm, accessed August 24, 2009. This EPA website does not say whether state agencies acquired more responsibility for overseeing the accuracy of TRI reporting after 1998.

universe of CAA monitoring and enforcement actions²⁷. Studies and random audits conducted by the EPA to investigate whether data are being entered accurately into the AFS indicate that the data are of high quality, particularly for sanctions, although data on inspections are sometimes missing from the AFS²⁸. Like the TRI, the AFS contains detailed geographic information on the facilities that are regulated by the Clean Air Act, as well as the industries to which they belong (as classified by Standard Industrial Classification (“SIC”) codes).

The AFS contains data on inspections, administrative sanctions, and judicial sanctions, differentiates between these three types of actions, and identifies the specific facility inspected or sanctioned by each regulatory action. It also has data on the size of the fines assessed by judicial sanctions, although it may often report that many of the fines are much smaller than they actually were²⁹. In this paper, the deterrent effects of actions against other facilities that are “Federally Reportable”, according to data on facilities’ classification status in the AFS, are studied. “Federally Reportable” means that actual or potential pollution emissions at a facility fall above certain thresholds³⁰. This focus on actions at Federally Reportable facilities is done for two reasons. One, Federally Reportable facilities are larger sources of pollution that should be quite similar to the types of facilities that are required to report pollution emissions to the TRI. Two, monitoring and enforcement actions at larger facilities may be better recorded than actions against smaller facilities. See http://www.epa-echo.gov/echo/about_data.html#random_audits and Footnote 27 above.

While the TRI and AFS are separate datasets, each with its own distinct set of unique identifier numbers for the facilities in the data, the EPA’s Facility Registry System (“FRS”) data provides a crosswalk between the TRI and AFS ID numbers, so that the two datasets can be

²⁷ There are two exceptions to this: data on inspections of and notices of violations sent to facilities that are not “Federally Reportable” do not have to be entered in to the AFS. See http://www.epa-echo.gov/echo/data_entry_requirements_table.html. See the next paragraph below for the definition of “Federally Reportable”. Data on inspections of and notices of violations sent to facilities that are not Federally Reportable are not used in this paper.

²⁸ See http://www.epa-echo.gov/echo/about_data.html#data_quality and http://www.epa-echo.gov/echo/about_data.html#random_audits, accessed August 22, 2009.

²⁹ The codebook for the AFS data states that data on fines is measured in thousands of dollars. However, an inspection of the data indicates that this is clearly not the case for many fines, as values of over 1,000,000 and even 10,000,000 are entered for the variable for fine amount. This suggests that fines in excess of \$1 billion have been used to enforce the Clean Air Act, but this is clearly not what has actually been done. In working with the data on fine amount, I have assumed that all entries for the fine variable are measured in dollars rather than thousands of dollars, even though this may not be the case for every fine. As such, it is possible that there is substantial, albeit unavoidable, measurement error in the variables on fine amounts I have constructed.

³⁰ See the AIRS Facility Subsystem Business Rules Compendium (<http://www.epa.gov/compliance/resources/policies/data/systems/air/afsbusinessrulescompendium.pdf> , accessed August 22nd, 2009), p. 6, for a statement of these thresholds.

merged at the facility-year level. Only 75.9% of the AFS ID numbers used in the AFS are present in the FRS crosswalk, however, primarily since many facilities that are permanently closed, according to AFS data on each facility's current operating status³¹, are not covered by the FRS crosswalk. However, data from the AFS and TRI for over 1,200 facilities that do not have their AFS ID numbers listed in the FRS crosswalk were linked and merged together using data on facilities' geographic location and industrial category, for facilities that are uniquely identified by geographic and industrial category variables that are elements of both the AFS and TRI datasets. The number of facilities reporting air pollution emissions to the TRI that were matched to facility-level data from the AFS varies from year to year; the lowest yearly match percentage is 58.69% in 1989, and this percentage increases steadily after 1989, reaching a high of 71.54% in 1999.

4.3. Data on Control Variables

The regressions in this study include several state-year and county-year level control variables. The following demographic variables are included as controls, and are measured at both the state-year and county-year level: percent of the state and county population that is African-American, percent of the population that are races other than African-American or White, percent of the population that is age 4 or younger, and the percent of the population that is age 65 and older. Data on the number of persons in different demographic groups and the total population within states and counties comes from the U.S. National Institutes of Health, 2008 and the U.S. Bureau of the Census, 2009. Data on the percentages of the population who are young children and who are elderly are included since these population groups may suffer more from exposure to pollutants than other demographic groups. Data on the percentages of the population who are African-American and other races is included because of possible race-based disparities in exposure to pollution (Konisky, 2009a,b). Although the most direct effect of these demographic factors on polluters are their influence on whether violations of the Clean Air Act will be sanctioned, they may also affect polluters through community pressure, citizen suits, and similar channels (Gray and Shadbegian, 2004; Shimshack and Ward, 2005, p. 529). These variables are measured at both the state-year and county-year level since much of the pollution emitted in a county is often carried by the wind to other counties (Reitze, 2005, pp. 96-111). The ratio of employed persons to working age adults in the county, the unemployment rate in the state, and county and state real per capita income are included as controls as well³². Data on these variables

³¹ as of 2008, the year the AFS data used in this study was released

³² Data on counties' unemployment rates is not available prior to 1990, and is thought to be less well measured than the number of persons employed in counties and county population.

comes from the U.S. Bureau of Economic Analysis, 2009 and the U.S. Bureau of Labor Statistics, 2009. These variables measure the current condition of the local economy in order to control for shocks to demand for the output of polluting firms in the county and state. Controlling for these variables at both the county and state levels is necessary since residents of one county may commute to work in other counties. Wealthier areas and areas with lower unemployment may also put more pressure on local firms to reduce emissions. Finally, variables for whether the facility is in a county that is out of attainment with the National Ambient Air Quality Standards for Ozone and Particulate Matter are included as controls, as this may affect regulatory pressure faced by a facility independently of whether it and other facilities are being inspected and sanctioned. Data on county attainment status comes from the EPA's Green Book (2009).

Table 1 gives summary statistics for the control, emissions, and enforcement activity variables. All values are for facility-year level observations, and are for facilities that report air pollution emissions to the TRI for 8 or more years between 1988 and 1999. Note that if the ten states in which judicial sanctions occur most frequently are dropped from the sample, then a Federal judicial sanction occurs during the year in only 17.5% of the observations, and a State judicial action occurs during the year in only 17.0% of the observations. This demonstrates that judicial sanctions occur infrequently in most states, and further illustrates the extent of variation across states in the amount and frequency of enforcement activity.

Section 5. Econometric Models

As shown by Table 1, there is considerable variation in the amount of activity to monitor compliance with the Clean Air Act and to sanction violations of the Clean Air Act across facilities in different U.S. states, counties and EPA Regions during different years. The empirical model used in this study uses this source of identifying variation to estimate the deterrent effects of actions to enforce the Clean Air Act in a difference-in-differences framework.

My primary econometric model is the following:

$$\begin{aligned}
 (1) \ln(\text{EMISSIONS})_{iscrt} &= a + B_1 \sum_{n=0}^3 \text{ENFORCEMENT_OTHERS}_{iscrt-n} \\
 &+ B_2 \sum_{n=0}^3 \text{ENFORCEMENT_SELF}_{iscrt-n} + B_3 \text{XVAR}_{sct} + B_4 \text{FACILITY}_{iscr} \\
 &+ B_5 * \text{INDUSTRY} * \text{YEAR}_t + \varepsilon_{iscrt},
 \end{aligned}$$

where i, s, c, r and t denote facilities, states, counties, EPA Regions and years, respectively. EMISSIONS denotes a measure of the amount of air pollution emitted by a facility, measured in

pounds released. The different measures of air pollution emissions I use are defined in the next paragraph. Taking the natural logarithm of EMISSIONS means that the effects of the right hand side variables can be interpreted as percentage changes or as elasticities, and also prevents outliers from overly influencing the estimates³³. ENFORCEMENT_OTHERS is a variable or vector of variables measuring the amount of regulatory activity conducted at other facilities in the same jurisdiction as facility i during a year. Below in this section, I describe the different variants of ENFORCEMENT_OTHERS that are included in different regressions in this study, and discuss why multiple lags of ENFORCEMENT_OTHERS are included in the regressions. ENFORCEMENT_SELF is a vector of variables for the occurrence of inspections and sanctions at facility i itself. XVAR is a vector of the state and county-level control variables described above in Section 4.3. FACILITY_{iscr} are facility-specific fixed effects, which control for time-invariant unobservables at that facility, as well as in the state and county where the facility is located. Finally, INDUSTRY _{i} *YEAR _{t} are industry fixed effects interacted with year fixed effects³⁴. These interaction terms control for changes over time within industries in demand for output, changes in input prices, changes in the environmental cleanliness of available production technology, and environmental regulation enforcement activity against that industry at the national level. ε_{iscrt} , the error term, is the shock to facility i 's level of pollution emissions in year t .

For EMISSIONS, I examine stack emissions (emissions of air pollutants from smokestacks) separately from fugitive emissions (emissions that escape from the plant at ground level, i.e., leaks). This is done because stack emissions may be measured more accurately in the TRI than fugitive emissions, while fugitive emissions may have worse effects on human health, at least for residents of the county or city in which the facility is located; see Section 4.1 above. Also, it may be more or less difficult for facilities to reduce stack emissions than to reduce fugitive emissions; for instance, stack emissions can be reduced by installing scrubbers and other such abatement and control devices in smokestacks (Greenstone, 2003), which may be easier to do than actions reducing fugitive emissions. However, it may often be relatively easy for facilities to reduce fugitive emissions by converting them into stack emissions; converting fugitive into stack may help facilities comply with the Clean Air Act National Ambient Air Quality Standards by sending the pollution they emit downwind to far away areas, keeping it out of the areas in which they are located (see Reitze, 2005, pp. 97-98 for a discussion of the use of tall smokestacks in response to CAA regulations and the controversies surrounding this issue). The measures of stack

³³ Table 1 shows that there is great variance across facilities in the amount of pollution they emit.

³⁴ For the industry fixed effects, I define the industry a facility is in by 2-digit Standard Industrial Classification codes.

and fugitive emissions are calculated as the sum of pounds of all TRI chemicals released by a facility during a year, both raw (without toxicity weights) and weighted by the EPA's numeric estimates of the toxicity of each chemical (see Section 4.1 above).

ENFORCEMENT_OTHERS is a variable or vector of variables measuring the amount of regulatory activity conducted at other facilities in the same state, county, and/or EPA Region as facility *i* during a year. In the primary regressions for this study, ENFORCEMENT_OTHERS includes variables for judicial sanctions of other facilities, but not variables for inspections and administrative sanctions of other facilities. This is because I expect, in light of the results of prior studies of general deterrence discussed in Section 2.2, only the largest, most visible sanctions to have general deterrent effects. Variables for inspections and administrative sanctions of other facilities are included in some regressions, however, to test whether this is true. In the regressions, I distinguish between judicial sanctions imposed by state pollution control agencies and judicial sanctions imposed by the federal EPA, as EPA sanctions may provide a stronger or weaker signal of the strictness with which the Clean Air Act will be enforced within a state in the future than state sanctions do; reasons why this may be the case are stated in Section 6 below. In most regressions, an indicator variable for whether at least one judicial sanction was imposed on another facility in a year is used to measure the extent of judicial enforcement activity in an area. This is done since most of the time, if any judicial sanctions of a given type occur in a state or county in a year, only one occurs, and it is rare for more than two to occur (AFS data, author's own calculations). The natural log of one plus the number of judicial sanctions of other facilities, $\ln(1 + \# \text{ of judicial sanctions of others})$, is used in some regressions instead of indicator variables. Since zero state and zero EPA judicial sanctions occur in most states in most years, 1 is added to the number of judicial sanctions to avoid taking logs of zeros; importantly, $\ln(1 + \# \text{ judicial sanctions of others})$ is a transformation of the number of judicial sanctions that equals 0 when the number of judicial sanctions is equal to 0. Also, including the log in the regression is similar to including the log of the rate of judicial sanctions per facility, since $\ln [(\text{Number of Actions}) / (\text{Number of Facilities})] = \ln(\text{Number of Actions}) - \ln(\text{Number of Facilities})$, and the log of the average number of facilities operating in a state, county or EPA Region between 1988 and 1999 that are similar to the facilities that report to the TRI is measured by the facility-specific fixed effects. Unfortunately, the EPA does not provide data on the number of Federally Reportable manufacturing facilities regulated by the Clean Air Act that are active in each state and EPA Region in each year (AIRS Facility Subsystem Data; Konisky, 2007, 2009a, b; Konisky and Woods, forthcoming), so including rates of regulatory actions per facility in the regressions explicitly is not possible. When measures of

the amount of inspections and administrative sanctions at other facilities in the jurisdiction are included in the regressions, the log of 1 plus the number of inspections and the log of 1 plus the number of administrative sanctions are used³⁵. Since inspections and administrative sanctions occur frequently (see Table 1), taking the log of these variables is desirable so that the variables proxy for the rate of these actions at facilities in the jurisdiction. I study the general deterrent effects of inspections and administrative sanctions conducted by the states, rather than the EPA, since the states conduct the vast majority of these actions (see Section 3.3 above).

Lags of ENFORCEMENT_OTHERS are included in the regressions for a number of reasons. First, firms may need time to respond to actions at other facilities, since many actions to reduce pollution emissions, such as installing new pollution abatement and control equipment, cannot be done quickly. It also may take time before firms even learn of actions at other facilities. Second, the duration of general deterrent effects is of interest, as this is one measure of the size of these effects. Third, taking lags helps to alleviate possible reverse causality bias in the estimates of the general deterrent effects. While the average shock to pollution emissions in state s in year t across all facilities in the state may cause the regulator to issue more sanctions and conduct more inspections in year t or in future years, it is much less likely that the average shock in year t influenced regulator actions in past years. The lead of ENFORCEMENT_OTHERS, $ENFORCEMENT_OTHERS_{ist+1}$, is included in some regressions since with judicial sanctions, firms may obtain news that a judicial sanction has been filed against another facility before this action is actually concluded and a court consent decree against the facility is obtained³⁶, or in case firms otherwise anticipate and respond to what the regulators will do next year.

ENFORCEMENT_SELF is a vector that contains the following variables: an indicator for whether facility i was inspected during a year, an indicator for whether an administrative sanction was imposed on facility i during a year, and indicators for whether state and EPA judicial sanctions were imposed on facility i during a year. For the estimates obtained by using econometric model (1), the estimates of the specific deterrent effects of actions probably suffer from greater reverse causality bias than the general deterrent effects estimates, because actions at a specific facility may be determined by shocks to pollution emissions at this specific facility, and

³⁵ While there are relatively few states and counties where zero inspections or zero administrative sanctions occur during a year, 1 is still added to the number of these actions when taking the log to avoid taking logs of zeros.

³⁶ Footnote 8 above provides evidence that the average duration of a judicial action, from filing of the claim until the claim is settled or resolved at trial, is approximately 1.62 years. The EPA does not publicize cases before the cases have concluded, however, at least as far as I am aware: see <http://cfpub.epa.gov/compliance/cases/> (accessed September 4, 2009).

not just by the average shock to pollution emissions across all facilities in the area. The average shock across the state or county is only somewhat correlated with the specific-facility shock.

The standard errors on the estimates are clustered by state, since the variation in regulatory activity at other facilities occurs mainly at the state-year level (Bertrand, Duflo and Mullainathan, 2004). Clustering at the state level allows for arbitrary forms of serial correlation and heteroscedasticity at the state level in the error terms.

Finally, there are two different samples of plants that I use in different regressions. In most regressions I include only plants that report emissions to the TRI for 9 or more out of the 12 years of emissions data (1988-1999) in my sample. In others I only include plants that report for 4 or more of these 12 years. The former is my preferred sample, and is used in the regressions shown in Tables 2 through 12 unless otherwise specified; plants that report emissions for 9 or more years emit more pollution annually, on average, than plants that report for between 4 and 8 of these years, and are likely to be bigger plants, plants that would have difficulty reducing use of the chemicals on the TRI list to below the threshold use level that determines whether they need to report to the TRI (see Section 4.1 above for a discussion of these reporting thresholds). Using plants that report for 9 or more years helps avoid potential sample selection bias.

Section 6. Results and Interpretation

As a first step at estimating whether facilities that emit toxic air pollutants respond to sanctions of other facilities, Figures 1 and 2 plot means of residuals and confidence intervals for these means for residuals from regressions of the log of the measure of stack emissions constructed without toxicity weights on all of the right-hand side variables in equation (1), except for ENFORCEMENT_OTHERS. On the x-axis of these graphs is the number of years after 1 or more state pollution control agency judicial sanctions of other facilities in the same state occur. The graphs show that the mean of these residuals is significantly below zero for a few years following the occurrence of a sanction, suggesting that many facilities may be responding to these sanctions of other facilities by reducing pollution emissions. As shown in Figure 2, the reductions in emissions are even larger when the 10 states in which judicial sanctions occur most frequently are dropped from the sample³⁷. This is consistent with the theory of general deterrence presented in Sah (1991), as the occurrence of a sanction should create a larger change in beliefs about the expected penalties for violating a law when few sanctions occurred in the recent past. Figures 1

³⁷ The frequency with which judicial sanctions occur is measured by the number of years between 1984 and 2000 in which one or more state or EPA judicial sanctions occur.

and 2 show the main results of this study, and the inferences that can be drawn from the figures will be confirmed by the regression results.

Estimates of equation (1) that employ several different variants of the vector ENFORCEMENT_OTHERS are shown in Tables 2 through 12. Since I have estimated that regulatory actions have stronger general deterrent effects on stack emissions not weighted by toxicity than on toxicity-weighted stack emissions or on fugitive emissions, most of these tables, specifically Tables 2 through 10 but not 11 and 12, show estimates from regressions using the log of non-weighted stack emissions as the dependent variable. Additional tables of results for additional regressions using the other dependent variables are available from the author upon request.

The regressions in Table 2 include indicator variables for whether one or more judicial sanctions occurred at another manufacturing facility or facilities in the same state. These variables differentiate between judicial sanctions imposed by state governments' pollution control agencies and those imposed by the federal EPA. Three of these regressions also include variables for inspections and sanctions of a facility itself, which may be correlated with sanctions at other facilities. They show that judicial sanctions issued by state governments are associated with reductions in stack emissions from other plants in the state that last from one to three years after the sanction, although results are stronger for years 2 and 3 than for year 1. That a general deterrent effect of these sanctions is estimated in regressions including facilities in all manufacturing facilities in the sample strongly suggests that facilities in multiple industries are responding to the sanctions, rather than just facilities in the same industry as the sanctioned plant; the number of plants reporting to the TRI in each state consists of plants from a wide variety of industries, and rarely are more than 20% of the plants in a state in the same 2-digit SIC code. These regressions do not estimate that inspections and sanctions have specific deterrent effects, although regulatory actions at a plant itself are likely to be endogenous, and it is difficult to obtain precise estimates of the specific deterrent effects of judicial sanctions since they occur very infrequently (see Table 1). However, that the coefficients on many of the variables for inspections at a facility itself are positive and significant shows that facilities that emit more air pollution are more likely to be inspected, particularly in the current and following years. This suggests that regulators are good at detecting which facilities are likely to be violating the Clean Air Act³⁸. Some of the lags of these inspections are positive and significant; this could reflect facilities that are inspected, but that are not sanctioned and that do not observe sanctions of others, believing that

³⁸ Since ambient air quality monitors measure air pollution levels in most U.S. counties, this may be unsurprising.

the regulators find current air pollution levels to be acceptable and deciding to emit more air pollution in response.

The duration of the estimated general deterrent effects is worth discussing. This response does not lead to a permanent reduction in emissions at facilities, as there is no significant association between state judicial sanctions of others and stack emissions four years after the sanctions occur. As discussed above in Section 3.1, facilities can reduce air pollution emissions either by installing new pollution abatement and control equipment, using cleaner raw materials, reducing output, or through better maintenance and operation of existing pollution abatement equipment. It is clear that the last three of these things can produce a temporary decrease in pollution emissions. However, if pollution abatement equipment that a facility was eventually going to install is installed sooner than it would have been, a temporary decrease in pollution will also occur. Regulators often discuss the issue of facilities taking a long time to obey orders to come into compliance with regulations and falling behind on the schedules accompanying such orders (see EPA, 1992, and Nadeau, 1997).

It is perhaps surprising that judicial sanctions imposed by the EPA do not appear to have general deterrent effects within states. However, there are a number of explanations for this. First, firms may be less uncertain about the probability of being sanctioned by the EPA than they are about the probability of being sanctioned by the state, since the EPA's willingness and ability to enforce the regulations may be well-established, and its targeting strategy for issuing sanctions may be quite predictable. The EPA's policies on targeting what it classifies as "Significant Violators" for sanctions indicate that the EPA targets the sanctions it is able to issue to what it considers to be the worst violators, leaving whether other violators will be sanctioned up to the states (see Sections 2.1 and 3.2 above). Facilities in the TRI data that are sanctioned by the EPA with judicial sanctions have emissions levels in the year of the sanction that are nearly twice as high on average as those who receive state judicial sanctions³⁹, suggesting that the EPA prefers to take the lead on issuing judicial sanctions to the largest violating polluters itself. Secondly, whether or not the EPA imposed a judicial sanction on a facility in the state will often be driven by the EPA's National Priority lists of particular industries it is targeting for enforcement at the current time, rather than a concern about overall air pollution levels in that state. It is interesting to note that the coefficients on the variables for state judicial sanctions of other facilities change very little when variables for EPA judicial sanctions are omitted from the regression, indicating that the occurrence of an EPA judicial sanction within a state is almost uncorrelated with the

³⁹ The averages are 219761.9 pounds and 121503.3 pounds respectively for stack emissions, and 113603.7 pounds and 62590.51 pounds for fugitive emissions.

occurrence of a state judicial sanction. If the EPA frequently stepped in to sanction violators itself when it felt that a state had become too lax about enforcement, or often issued sanctions at the request of strict states, then there would be a correlation between these two types of sanctions.

The last two columns of Table 2 omit industry times year fixed effects interactions and facility-specific fixed effects from the regressions, respectively. This is done for comparison with prior research on general deterrence and environmental regulations, as much of this research was unable to control for either year fixed effects or facility fixed effects due to the use of data from a single state or a single year (see Section 2.2 above). Interestingly, omitting industry times year fixed effects interactions or facility-specific fixed effects causes the general deterrent effects of state judicial sanctions to be overestimated, rather than underestimated, as would be the case if these fixed effects alleviated reverse causality bias. Facility-specific fixed effects do a great deal to alleviate reverse causality bias in estimates of the specific deterrent effects of sanctions and inspections, however.

Tables 3, 4 and 5 present a series of robustness checks to the estimates of the effects of judicial sanctions shown in Table 2. Table 3 presents estimates of regressions that only include facilities in the 40 states in which judicial sanctions occur most infrequently in the sample. This sample drops facilities in large states with many polluting facilities from the sample, as these states are ones in which the number or rate of judicial sanctions, rather than just a regulator display of willingness and ability to impose any judicial sanctions and news that a high-profile event has just occurred, may matter. Also, as previously explained, theory predicts that the occurrence of a sanction should create a larger change in beliefs about the expected penalties for violating a law when few sanctions occurred in the recent past (Sah, 1991). In Table 3, the estimates of the general deterrent effects of state judicial sanctions are larger in size and generally stronger in significance than in Table 2. This likely reflects that facilities in the states that have been dropped from the sample are aware that they are under relatively constant threat of receiving a judicial sanction, as high levels of pollution resulting from having very many manufacturing plants concentrated in a single state should often lead to constant, predictable regulatory pressure.

In Table 4, facilities from all 50 states are back in the sample, but the variables for state and EPA judicial sanctions of other facilities are interacted with indicators for whether or not facility i is in a county that is out of attainment with the Clean Air Act National Ambient Air Quality Standards for Ozone, Particulate Matter, or both⁴⁰. Facilities in counties that are out of

⁴⁰ The standards for Ozone and Particulate Matter are the National Ambient Air Quality Standards that are most frequently violated by U.S. counties. Also, most of the chemicals in the TRI air emissions data qualify as either Particulate Matter, chemicals that contribute to the formation of Ozone, or both; see Section 4.1.

attainment are more likely to be out of compliance with the Clean Air Act, and consequently have a greater incentive to reduce emissions. The results in Table 4 show that the reduction in emissions associated with state judicial sanctions of other facilities is primarily concentrated among facilities in counties that are out of attainment, consistent with the theoretical prediction that these facilities are more likely to respond to sanctions of others. While there is still a negative, significant association between state judicial sanctions of others two years ago and emissions in counties that are in attainment, facilities in these counties are still required to limit pollution emissions so that their counties stay in compliance with the standards (see Section 3.1).

In Table 5, facilities from all 50 states are again included in the sample, but the log of one plus the number of judicial sanctions occurring at other facilities in the state, $\ln(1 + \text{number of judicial sanctions of others})$, is included in ENFORCEMENT_OTHERS, rather than indicators for one or more judicial sanction occurring. Results for state judicial sanctions of other facilities two and three years ago are the same in sign and significance as those in Table 2. In the last two columns of Table 5, the variables for EPA judicial sanctions of other facilities are equal to the log of one plus the number of judicial sanctions of other plants in the same EPA Region, rather than just in the same state, to explore whether general deterrence exists at the EPA Region level. However, the coefficients on the Region variables are still not statistically significant, which again may reflect that the behavior of the EPA Regions' personnel is fairly predictable, rather than uncertain.

The estimates shown in Table 6 are from regressions in which the variables in ENFORCEMENT_OTHERS differentiate between the occurrence of 1 or more state judicial sanctions against other facilities in the same county and state judicial sanctions of other facilities anywhere in the same state. Sanctions of others in the same county this year and one year ago as well as sanctions of others anywhere in the same state two and three years ago have statistically significant, negative associations with stack emissions (although the results for same county are only marginally significant). It appears that the general deterrent response to these sanctions begins in the same county as a plant, and then spreads throughout the state as news about the occurrence of the sanctions spreads to other parts of the state.

The estimates in Table 7 provide direct evidence that facilities frequently respond to sanctions of plants in other industries. The estimates are from regressions that include plants in a single industry rather than those in all manufacturing industries in the sample, and in which the variables in ENFORCEMENT_OTHERS differentiate between the occurrence of 1 or more judicial sanctions of other facilities in the same state and same industry, and the occurrence of judicial sanctions of other facilities in the same state and in any manufacturing industry (including

the same industry). The regressions shown in the first two columns of Table 7 use a sample of plants from the Pulp and Paper Industry (Standard Industrial Classification (“SIC”) Code Group 26), while those in the second two columns use plants from the Industrial and Commercial Machinery Industry (SIC Code 35)⁴¹. Most of the lags of the variables for state judicial sanctions of other facilities in the same state and in any industry are negative and significant, while those for sanctions of others in the same industry have no systematic association with emissions and are generally not significant. General deterrent effects do not appear to be stronger when the sanction is against another plant in the same industry. This is not unexpected, as sanctions against plants in other industries still provide information about the regulator’s ability and preferences, and since the types of air pollutants emitted by any given facility (for example, particulate matter) are generally emitted by facilities in numerous other industries (Greenstone, 2002).

The regressions shown in Table 8 include variables for the size of the fines imposed on other facilities in the same state in ENFORCEMENT_OTHERS, along with variables indicating whether any judicial sanctions occurred. The variables for the size of the fines are the log of 1 plus the size of the largest fine assessed in a judicial sanction of another facility in the state, and the log of 1 plus the average size of the fines over all judicial sanctions of others occurring in the state. Interestingly, there are no statistically significant relationships between the fine variables and emissions (and this is also true in regressions not shown in Table 8 that include variables for the size of the fines assessed in EPA judicial sanctions of other facilities in the same EPA Region)⁴². However, larger fines not having larger general deterrent effects is actually consistent with the evidence presented in Thorton, Gunningham and Kagan (2005) and Gunningham, Thorton, and Kagan (2005), who interviewed managers of polluting facilities and found that they were frequently aware of sanctions of other facilities and the nature of the infractions that triggered them, but were often unaware of the size of the fines. Also, the size of the fines assessed in judicial sanctions is typically only a small fraction of the costs of the steps to reduce emissions required by the sanction, so a fine’s size may be an imperfect measure of a sanction’s severity⁴³. Finally, there may be substantial measurement error in the data on fines; see Footnote 29 above.

⁴¹ Regressions analogous to those in Table 7 were run using samples of plants from a few other industries besides these two, such as Chemicals and Allied Products (SIC Code Group 28) and Petroleum Refining (SIC 29). However, few of the associations between judicial sanctions of other facilities and air pollution emissions were statistically significant for these industries, perhaps due to low sample size and conservative standard errors.

⁴² When variables for both the average size and largest of the fines were included in the regressions simultaneously, the first lags of these variables had marginally significant coefficients that were almost equal in size but opposite in sign, indicating that the average and maximum fine in a state-year cell are highly collinear.

⁴³ See for, example, the EPA judicial sanctions to enforce the Clean Air Act summarized at <http://cfpub.epa.gov/compliance/cases/index.cfm?templatePage=12&ID=1> (accessed October 11, 2009). The size of the fines is also only somewhat correlated with the costs of the steps to reduce emissions.

The regressions shown in Table 9 estimate the general deterrent effects of inspections and administrative sanctions conducted in the same county and in the same state. While the coefficients and standard errors on the variables measuring specific deterrence are omitted from the table to conserve space, they are very similar to those shown in Table 2. Since a large number of inspections and administrative sanctions occur in most states and counties, the log of one plus the number of inspections and the log of one plus the number of administrative sanctions of others are included in ENFORCEMENT_OTHERS as substitutes for the rates of these enforcement actions; see Section 5 above. No evidence that inspections have general deterrent effects is found, as the coefficients on the inspections variables are often positive and significant, rather than negative and significant. The coefficients on the variables for inspections of other facilities this year indicate reverse causality: high levels of pollution this year cause there to be more inspections this year. Since monitoring of ambient concentrations of air pollution occurs in most US counties, this is not surprising, and is consistent with regulators being effective at detecting many violations of the Clean Air Act. The second and third lags of inspections of other facilities in the same state being positive and significant may appear puzzling at first, however. What can explain this, though, is facilities believing that many additional inspections occurring without a similar increase in the number of sanctions indicates that the probability of being sanctioned for a violation is relatively low. It is also the case that the regulators will conduct additional inspections when they believe that many plants in the state are being modified to expand production, to check if the modified plants are complying with the Clean Air Act's New Source Performance Standards⁴⁴. This could also create a positive association between inspections in the past and emissions this year. In any case, this positive association between lagged inspections in the state and emissions at a facility is small in size despite being statistically significant. The results for inspections do suggest that increases in the probability of being sanctioned, rather than increases in the probability of being caught violating a regulation, are more effective (on the margin) for enforcing compliance with the Clean Air Act.

The results in Table 9 provide evidence that administrative sanctions have general deterrent effects. Their effects, however, are brief, occurring only during the year of the sanctions as opposed to for approximately four years afterwards as with the effects of state judicial sanctions. These results contrast somewhat with those in Shimshack and Ward (2005), who estimate that only the most severe, high-profile sanctions have general deterrent effects (see Section 2.2), although I do estimate that the more severe sanctions have larger effects.

⁴⁴ The New Source Performance Standards require new and nontrivially modified plants to install and maintain up-to-date pollution abatement equipment, in order to keep emissions low relative to output.

The regressions for Table 10 include in the sample plants that report stack emissions to the TRI for 4 or more years between 1988 and 1999, rather than only those that report stack emissions for 9 or more years. The variables in ENFORCEMENT_OTHERS in these regressions are the same as in Table 2. The results are very similar in sign and significance to those in Table 2, particularly for the second and third lag of the variable for 1 or more state judicial sanctions of other facilities. This obtains despite their being greater potential for sample selection bias in the sample of plants reporting for 4 or more years, since plants reporting for fewer years may have intentionally used less than the reporting threshold use level of each chemical on the TRI list in some years in order to avoid having to report emissions to the TRI (see Sections 4.1 and 5 above).

The regressions shown in Table 11 estimate the effects of judicial sanctions of other facilities in the same state on the other dependent variables, instead of stack emissions not weighted by toxicity. The variables in ENFORCEMENT_OTHERS in these regressions are the same as in Table 2. The first two columns show the results for the measure of fugitive emissions constructed without toxicity weights, the third and fourth column show the results for toxicity-weighted stack emissions, and the fifth and sixth columns show the results for toxicity-weighted fugitive emissions. In this table, the coefficients on the variables for 1 or more judicial sanctions of other facilities are occasionally negative and marginally significant, but primarily insignificant. The lack of a relationship between sanctions of other facilities and fugitive emissions may be caused by fugitive emissions being more difficult to control and reduce than stack emissions (or that most facilities in the sample had already reduced fugitive emissions to a low level prior to the beginning of the sample period). The lack of relationship with toxicity-weighted emissions can be explained by observing that very few of the Clean Air Act's National Emissions Standards for Hazardous Air Pollutants, which are the regulations governing emissions of the most toxic air pollutants on a specific, individual chemical basis, had been established and made enforceable prior to the late 1990's (see Section 3.1 above). A consequence of this is that it may have been difficult for air pollution regulators in the United States to mandate reductions in emissions of the most toxic chemicals throughout most of the 1988-1999 time period covered by the emissions data I use⁴⁵.

Table 12 shows the estimated general deterrent effects of inspections and administrative sanctions of other facilities in the same county and in the same state on fugitive emissions, since these estimates are of interest. While there is little relationship between inspections of other facilities and fugitive emissions, administrative sanctions of other facilities in the same county and

⁴⁵ Scientific knowledge on the toxicity of the hundreds of different chemicals on the TRI list might also have been rather limited during much of this time period.

same state are associated with lower levels of fugitive emissions, as they were in Table 9 for stack emissions. The estimated effect of administrative sanctions in the same county on fugitive emissions is larger than for stack, as sanctions occurring last year as well as this year are associated with statistically significant reductions in fugitive emissions, and the coefficients are larger. Since fugitive emissions are primarily a health risk for those in the local area of the facilities emitting them, it is possible that regulators tend to address excessive amounts of fugitive emissions in an area by issuing many administrative sanctions to local facilities. Judicial sanctions may be reserved primarily for addressing concerns about the amount of pollution being released from tall smokestacks and being spread by the wind over many areas of a state (although concerns about stack emissions may still be frequently addressed with administrative sanctions instead.)

Section 7. Conclusion.

Prior empirical work on the enforcement of environmental regulations has estimated that polluting facilities reduce emissions for one year in response to regulatory sanctions of other facilities in the same industry and same state (Earnhart, 2004a,b; Shimshack and Ward, 2005, 2008). Prior empirical work has also estimated that inspections to search for violations of environmental regulations at other facilities in the same state and within 10 miles of a facility in past years have general deterrent effects (Gray and Shadbegian, 2007). Analyzing a larger and more comprehensive dataset on pollution emissions, sanctions and inspections than those used in these prior studies, a dataset that enables me to explore the size of general deterrent effects more fully, I find evidence that the general deterrent effects of sanctions are often much larger than the effects estimated by this prior literature. Judicial sanctions, the most severe, infrequent category of sanctions of Clean Air Act violations, are associated with reductions in toxic air pollution emissions from other facilities in the same state and in many different industries that last for up to four years when the sanctions are imposed by state governments' pollution control agencies. A number of findings support the view that these estimates reflect a causal deterrent effect of the sanctions on emissions from facilities other than the sanctioned plant. First, these sanctions have a larger effect in states where they occur less frequently, consist with theory predicting that they should cause a larger change in beliefs about the expected penalties for noncompliance in these states (Sah, 1991). Second, the association with reduced air pollution emissions is stronger at facilities in counties whose air quality does not meet the Clean Air Act's National Ambient Air Quality Standards. Facilities in these counties are more likely to be out of compliance with the Clean Air Act, and therefore have more incentive to reduce emissions. Finally, the estimated

response starts in the same county as the sanctioned plant and then spreads to other counties in the state. Assuming that it takes time for news about the occurrence of sanctions to spread throughout a state, this is consistent with what one would expect.

Administrative sanctions, the less severe category of sanctions of Clean Air Act violations, are also associated with reductions in emissions from facilities other than the sanctioned facilities. Specifically, they are associated with emissions reductions at other facilities in the same county, elsewhere in the same state, and in many industries. However, these associations are of shorter duration and smaller size than those between the occurrence of judicial sanctions and reduced emissions.

My results have the following policy implications. First, state governments interested in reducing air pollution emissions should strongly consider making more frequent use of judicial sanctions, as these sanctions have large general deterrent effects. Second, since the results indicate that general deterrent effects sometimes operate at the county level, targeting sanctions to counties with a large number of polluting facilities will often be efficient. Third, the results suggest that any targeting of specific industries by state pollution control agencies that occurs does not have the undesirable consequence of encouraging facilities in other, non-targeted industries to emit more pollution. Instead, demonstrating an ability and willingness to impose severe sanctions by imposing them on one or more plants in a single industry can motivate plants in many industries to reduce emissions. While Shimshack (2007, p. 30) has recommended to the EPA that it consider distributing enforcement and compliance alerts describing its enforcement activities to firms that are industry-specific, rather than aggregated as is current practice⁴⁶, my results suggest that this is unnecessary, at least for enforcement actions taken by state governments' pollution control agencies.

Finally, my results allow me to comment on whether economic theories of decisions to comply with laws should assume that the decision makers are perfectly informed about the probability of being sanctioned for violating the laws, as assumed in Becker (1968), or whether they are imperfectly informed about this probability, as assumed in Sah (1991). If agents are perfectly informed, this entails that they will not respond to sanctions of other agents, since the sanctions do not provide any new information about the probability of being sanctioned. I find that polluting facilities respond to regulatory sanctions issued by state governments to other facilities in the same state, but not to regulatory sanctions issued by the federal Environmental Protection Agency. It appears that firms are uncertain about the probability of being sanctioned by state governments, but that they are reasonably close to being perfectly informed about the

⁴⁶ See <http://www.epa.gov/compliance/resources/newsletters/civil/enfalert/index.html>.

probability of being sanctioned by the EPA, since the EPA's willingness and ability to enforce the regulations may be well-established, and its targeting strategy for issuing sanctions may be quite predictable. Therefore, my results suggest that whether agents are perfectly informed about the probability of being sanctioned for violating laws depends on context and the behavior of the law enforcer itself. Some regulators, like the federal EPA, are able to behave in such a way that the agents they regulate can accurately anticipate their actions. This issue of perfect information has practical implications for the design of systems to enforce laws. Bebchuk and Kaplow (1992) show that Becker's (1968) finding that it is efficient to enforce a law using maximally large sanctions and a low probability of being sanctioned may not hold if this assumption of perfect information does not hold, and that it is more difficult to determine the efficient system for enforcing regulations under imperfect information. As such, it is reassuring to find evidence that law enforcers may be able to create an enforcement environment in which agents are perfectly informed.

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Table 1: Summary Statistics

Variable	Mean	Standard Deviation
Stack Air Pollution Emissions, Pounds	117154.20	982426.40
Fugitive Air Pollution Emissions, Pounds	43156.24	162513.90
1 or more State Judicial Sanctions, Other Facilities in State	0.319	0.466
1 or more EPA Judicial Sanctions, Other Facilities in State	0.339	0.473
Number of Administrative Sanctions, Others in State	22.61	36.74
Number of Inspections, Others in State	426.74	368.00
Average Size of Fines, State Judicial Sanctions, Others in State (\$2008) ¹	55326.76	235932.60
Average Size of Fines, EPA Judicial Sanctions, Others in State	174739.90	597320.20
Largest of Fines, State Judicial Sanctions, Others in State	72761.06	284022.80
Largest of Fines, EPA Judicial Sanctions, Others in State	241787.70	755750.00
1 or more State Judicial Sanctions, Other Facilities in County	0.026	0.158
Number of Administrative Sanctions, Others in County	1.18	3.72
Number of Inspections, Others in County	24.00	47.94
Number of EPA Judicial Sanctions, Other Facilities in EPA Region	2.91	3.44
Regulatory Actions at Facility Itself, within the current year:		
Inspected	0.42	0.49
Administrative Sanction Imposed	0.029	0.167
State Judicial Sanction Imposed	0.0014	0.0372
EPA Judicial Sanction Imposed	0.0012	0.0343
State-Year Level Controls:		
Unemployment Rate	5.44	1.42
Real per Capita Personal Income (\$2008)	31992.61	4443.90
Percent African-American	13.27	8.06
Percent Other Minority	2.62	2.54
Percent Age 4 and Under	7.21	0.59
Percent Age 65 and Over	12.81	1.63
County-Year Level Controls:		
Employment-to-Population Ratio	76.52	19.84
Real per Capita Personal Income (\$2008)	31011.47	6782.61
Percent African-American	12.57	13.42
Percent Other Minority	2.28	2.98
Percent Age 4 and Under	7.17	0.89
Percent Age 65 and Over	13.00	3.04
County Out of Attainment with Ozone Standard	0.41	0.49
County Out of Attainment with Particulate Matter Standard	0.19	0.39

Note: All values are for facility-year level observations, and are for facilities that report air pollution emissions to the TRI for 8 or more years between 1988 and 1999. The measures of stack and fugitive emissions are not constructed with toxicity weights. The variables for the occurrence of 1 or more judicial sanctions at other facilities and for the occurrence of regulatory actions at the unit of observation facility itself are indicator variables.

¹ The data on fines may often report that many of the fines are much smaller than they actually were; see Section 4.2.

Figure 1: Residuals from Regression of Log of Stack Emissions on Controls

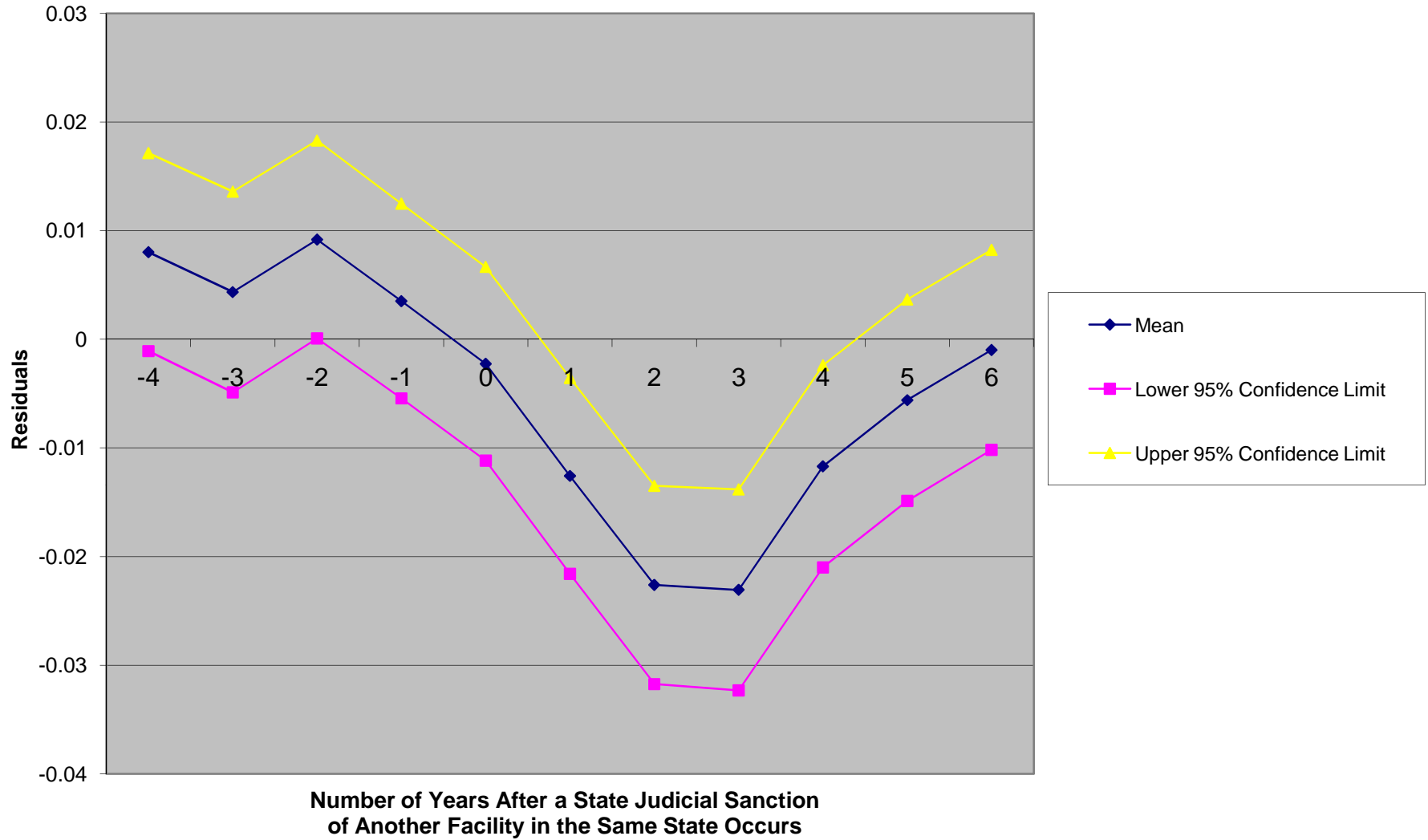


Figure 2: Residuals from Regression of Log of Stack Emissions on Controls
Regression uses data from the 40 states in which judicial sanctions occur most infrequently

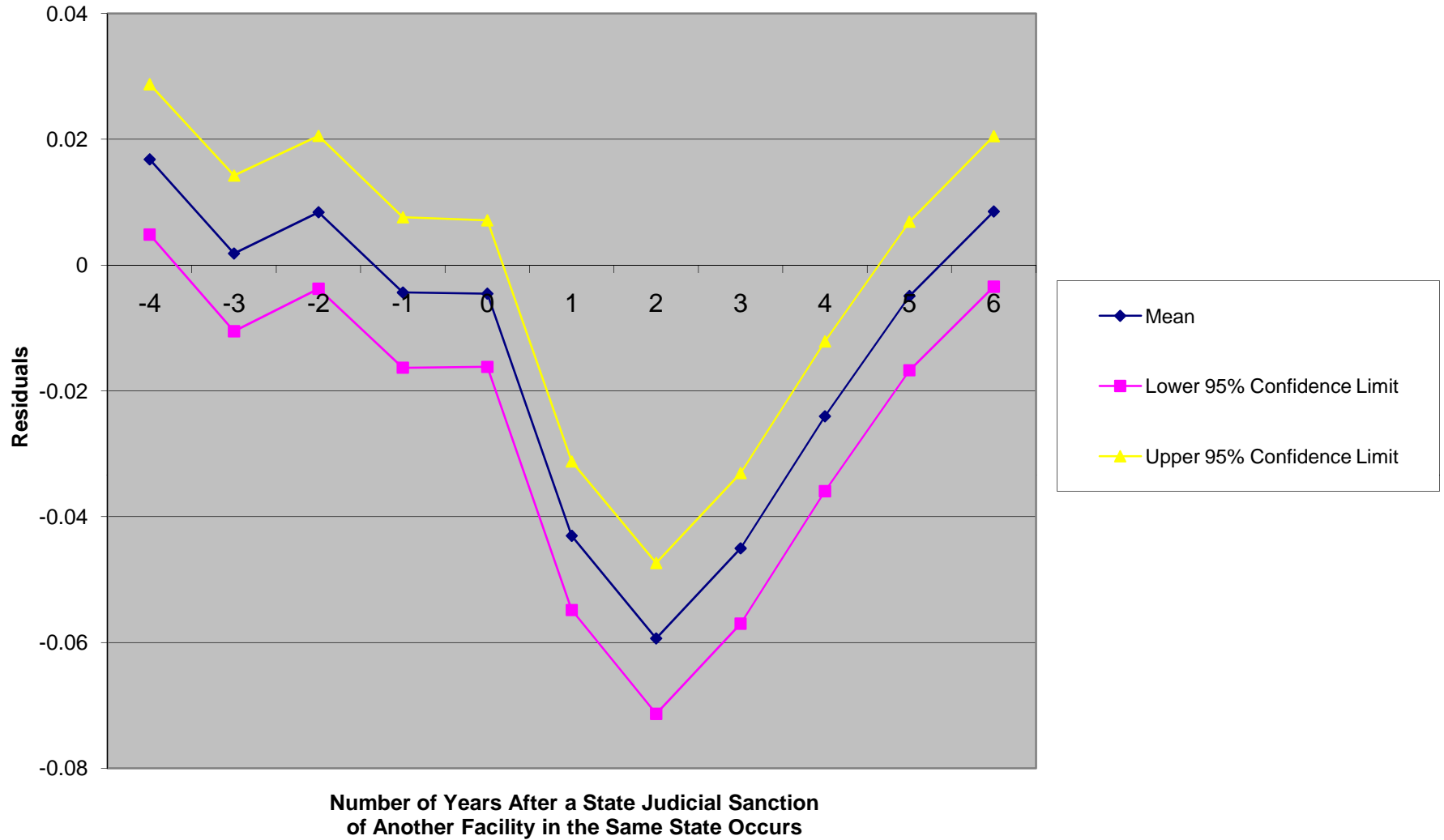


Table 2: Regression Results: Effects of Judicial Sanctions of Other Facilities in the Same State on Stack Emissions (log of pounds emitted)

State Judicial Sanctions of 1 or More Other Facilities in the Same State Next Year					0.014 [0.016]		
This Year	0.000 [0.018]	0.001 [0.018]	0.004 [0.017]	0.004 [0.017]	0.003 [0.016]	-0.022 [0.023]	-0.074 [0.059]
1 Year Ago	-0.028 [0.017]	-0.029+ [0.017]	-0.022 [0.016]	-0.024 [0.016]	-0.026+ [0.016]	-0.035+ [0.020]	-0.061 [0.045]
2 Years Ago	-0.051** [0.018]	-0.051** [0.019]	-0.048** [0.018]	-0.048* [0.018]	-0.046** [0.016]	-0.058** [0.021]	-0.070* [0.034]
3 Years Ago	-0.047** [0.016]	-0.048** [0.016]	-0.045** [0.016]	-0.046** [0.016]	-0.045** [0.014]	-0.077** [0.028]	-0.081+ [0.047]
4 Years Ago					-0.014 [0.021]		
EPA Judicial Sanctions of 1 or More Other Facilities in the Same State Next Year					-0.023 [0.018]		
This Year		-0.015 [0.013]		-0.016 [0.013]	-0.021 [0.014]	-0.036 [0.030]	-0.004 [0.052]
1 Year Ago		-0.003 [0.014]		-0.006 [0.013]	-0.007 [0.013]	-0.012 [0.023]	0.027 [0.053]
2 Years Ago		-0.009 [0.015]		-0.010 [0.015]	-0.011 [0.014]	-0.024 [0.026]	0.016 [0.046]
3 Years Ago		-0.016 [0.023]		-0.018 [0.021]	-0.020 [0.021]	-0.003 [0.036]	-0.01 [0.043]
4 Years Ago					0.013 [0.011]		
Actions at this Specific Facility Itself:							
Inspected Next Year					0.121** [0.017]		
Inspected This Year			0.081** [0.016]	0.081** [0.016]	0.068** [0.014]	0.062** [0.018]	0.444** [0.050]
Inspected 1 Year Ago			0.046** [0.015]	0.047** [0.015]	0.036* [0.015]	0.029 [0.019]	0.345** [0.033]
Inspected 2 Years Ago			0.031* [0.013]	0.031* [0.013]	0.028* [0.013]	0.009 [0.016]	0.306** [0.033]
Inspected 3 Years Ago			0.015 [0.017]	0.015 [0.016]	0.016 [0.015]	-0.006 [0.020]	0.302** [0.049]
Inspected 4 Years Ago					0.012 [0.018]		
Administrative Sanction Next Year					0.038 [0.040]		
Administrative Sanction This Year			0.027 [0.028]	0.028 [0.029]	0.021 [0.029]	0.027 [0.030]	0.468** [0.078]
Administrative Sanction 1 Year Ago			-0.012 [0.033]	-0.012 [0.034]	-0.013 [0.035]	-0.002 [0.037]	0.361** [0.075]
Administrative Sanction 2 Years Ago			0.007 [0.032]	0.008 [0.032]	0.008 [0.033]	0.011 [0.035]	0.325** [0.073]
Administrative Sanction 3 Years Ago			-0.008 [0.042]	-0.008 [0.042]	-0.009 [0.044]	0.001 [0.048]	0.329** [0.073]
Administrative Sanction 4 Years Ago					-0.028 [0.035]		
EPA Judicial Sanction Next Year					0.112 [0.108]		
EPA Judicial Sanction This Year			0.138 [0.147]	0.141 [0.148]	0.151 [0.160]	0.178 [0.143]	1.049** [0.155]
EPA Judicial Sanction 1 Year Ago			0.152 [0.189]	0.155 [0.190]	0.182 [0.203]	0.214 [0.195]	1.042** [0.153]
EPA Judicial Sanction 2 Years Ago			0.060 [0.216]	0.063 [0.217]	0.074 [0.228]	0.132 [0.210]	0.868** [0.203]
EPA Judicial Sanction 3 Years Ago			0.187 [0.112]	0.189 [0.113]	0.198 [0.124]	0.236+ [0.129]	0.960** [0.158]
EPA Judicial Sanction 4 Years Ago					0.015 [0.057]		
State Judicial Sanction Next Year					0.321** [0.094]		
State Judicial Sanction This Year			0.088 [0.125]	0.090 [0.126]	0.134 [0.129]	0.109 [0.125]	0.687** [0.224]
State Judicial Sanction 1 Year Ago			-0.051 [0.143]	-0.051 [0.143]	-0.004 [0.153]	-0.038 [0.137]	0.599** [0.221]
State Judicial Sanction 2 Years Ago			-0.010 [0.139]	-0.009 [0.139]	0.037 [0.151]	0.031 [0.136]	0.468+ [0.264]
State Judicial Sanction 3 Years Ago			0.055 [0.155]	0.056 [0.155]	0.096 [0.172]	0.077 [0.162]	0.440* [0.168]
State Judicial Sanction 4 Years Ago					0.113 [0.156]		
Econometric Specification Includes Facility-Specific Fixed Effects?	Y	Y	Y	Y	Y	Y	N
Econometric Specification Includes Industry * Year Fixed Effects?	Y	Y	Y	Y	Y	N	Y
Observations	73213	73213	73213	73213	73213	73213	73213
R-squared	0.82	0.82	0.82	0.82	0.82	0.81	0.17
Number of Facilities	6,482	6,482	6,482	6,482	6,482	6,482	6,482

Notes: Standard errors in brackets. They are clustered at the state level. A + indicates statistical significance at 10%;

* significance at 5%; ** significance at 1%.

All regressions include facility fixed effects and year fixed effect times industry fixed effect interactions (unless otherwise specified), and the following county-year level control variables: employment to population ratio, real per capita income, percentage of the county population who are African-American, percentage who are Other Minority, percentage who are age 4 or younger, percentage who are age 65 or older, and indicators for whether the facility is in a county that is in attainment of the Clean Air Act National Ambient Air Quality Standards for Ozone and Particulate Matter. The following state-year level control variables are also included: unemployment rate, real per capita income, percentage of the state population who are African-American, percentage who are Other Minority, percentage who are age 4 or younger, and percentage who are age 65 or older. The sample consists of facilities that report stack emissions to the TRI for 9 or more years between 1988 and 1999.

Table 3: Regression Results: Effects of Judicial Sanctions of Other Facilities in the Same State on Stack Emissions (log of pounds emitted)
 Regressions use the Sample of Plants in the 40 States where Judicial Sanctions Occur Most Infrequently, Rather than All 50 States

State Judicial Sanctions of 1 or More Other Facilities in the Same State Next Year					0.001 [0.036]
This Year	0.002 [0.042]	0.004 [0.041]	0.005 [0.040]	0.006 [0.039]	0.008 [0.035]
1 Year Ago	-0.062+ [0.031]	-0.057+ [0.029]	-0.059+ [0.030]	-0.055+ [0.029]	-0.062* [0.026]
2 Years Ago	-0.090** [0.028]	-0.087** [0.028]	-0.090** [0.027]	-0.087** [0.027]	-0.087** [0.027]
3 Years Ago	-0.065+ [0.033]	-0.062+ [0.033]	-0.068* [0.032]	-0.065* [0.032]	-0.065* [0.029]
4 Years Ago					-0.037 [0.034]
EPA Judicial Sanctions of 1 or More Other Facilities in the Same State Next Year					-0.018 [0.029]
This Year		-0.016 [0.022]		-0.015 [0.022]	-0.014 [0.023]
1 Year Ago		-0.031 [0.022]		-0.030 [0.022]	-0.025 [0.020]
2 Years Ago		-0.001 [0.021]		0.000 [0.020]	-0.003 [0.020]
3 Years Ago		-0.035 [0.023]		-0.034 [0.022]	-0.029 [0.022]
4 Years Ago					0.003 [0.021]
Actions at this Specific Facility Itself:					
Inspected Next Year					0.099** [0.025]
Inspected This Year			0.066* [0.025]	0.065* [0.025]	0.055* [0.022]
Inspected 1 Year Ago			0.049* [0.023]	0.049* [0.023]	0.038 [0.023]
Inspected 2 Years Ago			0.036+ [0.019]	0.035+ [0.019]	0.034+ [0.019]
Inspected 3 Years Ago			0.010 [0.023]	0.009 [0.023]	0.013 [0.021]
Inspected 4 Years Ago					0.002 [0.029]
Administrative Sanction Next Year					0.084 [0.055]
Administrative Sanction This Year			0.062 [0.038]	0.062 [0.038]	0.056 [0.039]
Administrative Sanction 1 Year Ago			0.008 [0.039]	0.008 [0.039]	0.007 [0.039]
Administrative Sanction 2 Years Ago			-0.001 [0.042]	0.000 [0.042]	0.004 [0.044]
Administrative Sanction 3 Years Ago			-0.038 [0.055]	-0.037 [0.055]	-0.032 [0.057]
Administrative Sanction 4 Years Ago					-0.007 [0.052]
EPA Judicial Sanction Next Year					0.235 [0.144]
EPA Judicial Sanction This Year			0.126 [0.165]	0.133 [0.165]	0.174 [0.182]
EPA Judicial Sanction 1 Year Ago			0.179 [0.178]	0.188 [0.181]	0.247 [0.196]
EPA Judicial Sanction 2 Years Ago			0.031 [0.239]	0.037 [0.242]	0.077 [0.258]
EPA Judicial Sanction 3 Years Ago			0.307 [0.203]	0.324 [0.210]	0.366 [0.225]
EPA Judicial Sanction 4 Years Ago					0.213 [0.170]
State Judicial Sanction Next Year					0.316* [0.136]
State Judicial Sanction This Year			0.096 [0.171]	0.098 [0.171]	0.142 [0.176]
State Judicial Sanction 1 Year Ago			-0.146 [0.235]	-0.145 [0.235]	-0.102 [0.243]
State Judicial Sanction 2 Years Ago			-0.130 [0.217]	-0.133 [0.216]	-0.092 [0.237]
State Judicial Sanction 3 Years Ago			0.040 [0.190]	0.042 [0.190]	0.069 [0.190]
State Judicial Sanction 4 Years Ago					0.113 [0.260]
Observations	41570	41570	41570	41570	41570
R-squared	0.83	0.83	0.83	0.83	0.83
Number of Facilities	3,673	3,673	3,673	3,673	3,673

Notes: Econometric model, control variables, and standard errors are as described in Table 2. The sample consists of all manufacturing plants in the 40 states in which judicial sanctions occur most infrequently that report stack emissions to the TRI for 9 or more years between 1988 and 1999.

Table 4: Regression Results: Effects of Judicial Sanctions of Other Facilities in the Same State on Stack Emissions (log of pounds emitted)
 Estimated Response Allowed to Vary Based on Whether Air Quality in the County the Facility is in Meets National Ambient Air Quality Standards

State Judicial Sanction, Other Facility in the Same State Response of Facilities in Counties Out of Attainment with National Ambient Air Quality Standards		
This Year	-0.025 [0.022]	-0.023 [0.020]
1 Year Ago	-0.045* [0.019]	-0.039* [0.018]
2 Years Ago	-0.049+ [0.027]	-0.050+ [0.026]
3 Years Ago	-0.071** [0.022]	-0.071** [0.022]
State Judicial Sanction, Other Facility in the Same State Response of Facilities in Counties In Attainment with National Ambient Air Quality Standards		
This Year	0.025 [0.023]	0.032 [0.022]
1 Year Ago	-0.016 [0.023]	-0.011 [0.023]
2 Years Ago	-0.061* [0.023]	-0.055* [0.023]
3 Years Ago	-0.027 [0.020]	-0.027 [0.021]
EPA Judicial Sanction, Other Facility in the Same State Response of Facilities in Counties Out of Attainment with National Ambient Air Quality Standards		
This Year	0.011 [0.015]	0.009 [0.016]
1 Year Ago	0.016 [0.019]	0.012 [0.018]
2 Years Ago	-0.021 [0.021]	-0.025 [0.021]
3 Years Ago	-0.016 [0.020]	-0.022 [0.019]
EPA Judicial Sanction, Other Facility in the Same State Response of Facilities in Counties In Attainment with National Ambient Air Quality Standards		
This Year	-0.033 [0.020]	-0.033+ [0.018]
1 Year Ago	-0.027 [0.024]	-0.026 [0.022]
2 Years Ago	0.001 [0.020]	0.002 [0.019]
3 Years Ago	-0.010 [0.030]	-0.008 [0.029]
Variables for Inspections and Sanctions of this Specific Facility Itself:	N	Y
Observations	73213	73213
R-squared	0.82	0.82
Number of Facilities	6,482	6,482

Notes: see Table 2.

Table 5: Regression Results: Effects of Judicial Sanctions of Other Facilities on Stack Emissions (log of pounds emitted)
Effects of Number of Judicial Sanctions of Other Facilities, in the Same State and in the Same EPA Region

Log of Number of State Judicial Sanctions (plus 1), Other Facilities in the Same State					
This Year	-0.018 [0.019]	-0.016 [0.019]	-0.011 [0.018]	-0.017 [0.019]	-0.014 [0.018]
1 Year Ago	-0.026 [0.016]	-0.027 [0.017]	-0.022 [0.016]	-0.027+ [0.016]	-0.021 [0.015]
2 Years Ago	-0.045** [0.015]	-0.045** [0.015]	-0.042** [0.015]	-0.046** [0.015]	-0.043** [0.015]
3 Years Ago	-0.039** [0.013]	-0.040** [0.012]	-0.038** [0.013]	-0.039** [0.012]	-0.038** [0.013]
Log of Number of EPA Judicial Sanctions (plus 1), Other Facilities in the Same State					
This Year		-0.011 [0.010]	-0.011 [0.009]		
1 Year Ago		0.005 [0.012]	0.004 [0.011]		
2 Years Ago		0.004 [0.012]	0.003 [0.011]		
3 Years Ago		-0.006 [0.019]	-0.012 [0.019]		
Log of Number of EPA Judicial Sanctions (plus 1), Other Facilities in the Same EPA Region					
This Year				-0.003 [0.008]	-0.003 [0.008]
1 Year Ago				0.002 [0.013]	0.002 [0.013]
2 Years Ago				0.010 [0.010]	0.007 [0.010]
3 Years Ago				-0.010 [0.016]	-0.016 [0.015]
Actions at this Specific Facility Itself:					
Inspected This Year			0.081** [0.016]		0.081** [0.016]
Inspected 1 Year Ago			0.045** [0.015]		0.046** [0.016]
Inspected 2 Years Ago			0.031* [0.013]		0.031* [0.013]
Inspected 3 Years Ago			0.015 [0.017]		0.015 [0.017]
Administrative Sanction This Year			0.028 [0.029]		0.028 [0.028]
Administrative Sanction 1 Year Ago			-0.011 [0.034]		-0.011 [0.034]
Administrative Sanction 2 Years Ago			0.007 [0.033]		0.006 [0.033]
Administrative Sanction 3 Years Ago			-0.009 [0.043]		-0.010 [0.043]
EPA Judicial Sanction This Year			0.143 [0.148]		0.140 [0.148]
EPA Judicial Sanction 1 Year Ago			0.154 [0.190]		0.156 [0.191]
EPA Judicial Sanction 2 Years Ago			0.062 [0.218]		0.061 [0.217]
EPA Judicial Sanction 3 Years Ago			0.190+ [0.113]		0.190+ [0.113]
State Judicial Sanction This Year			0.095 [0.126]		0.096 [0.125]
State Judicial Sanction 1 Year Ago			-0.042 [0.147]		-0.040 [0.147]
State Judicial Sanction 2 Years Ago			0.002 [0.143]		0.002 [0.143]
State Judicial Sanction 3 Years Ago			0.066 [0.162]		0.066 [0.162]
Observations	73213	73213	73213	73213	73213
R-squared	0.82	0.82	0.82	0.82	0.82
Number of Facilities	6,482	6,482	6,482	6,482	6,482

Notes: See Table 2.

Table 6: Regression Results: Effects of Judicial Sanctions of Other Facilities on Stack Emissions (log of pounds emitted)
 Effects of Sanctions of Other Facilities in the Same County Compared to Effects of Sanctions of Others Anywhere in the Same State

State Judicial Sanctions of 1 or More Other Facilities in the Same County		
This Year	-0.072+ [0.036]	-0.067+ [0.036]
1 Year Ago	-0.074+ [0.037]	-0.068+ [0.036]
2 Years Ago	0.006 [0.044]	0.005 [0.043]
3 Years Ago	-0.024 [0.046]	-0.027 [0.046]
State Judicial Sanctions of 1 or More Other Facilities in the Same State		
This Year	0.007 [0.018]	0.010 [0.017]
1 Year Ago	-0.023 [0.018]	-0.018 [0.017]
2 Years Ago	-0.051** [0.018]	-0.048** [0.017]
3 Years Ago	-0.046** [0.014]	-0.043** [0.015]
Variables for Inspections and Sanctions of this Specific Facility Itself:	N	Y
Variables for EPA Judicial Sanctions of 1 or More Other Facilities in the Same State	Y	Y
Observations	73213	73213
R-squared	0.82	0.82
Number of Facilities	6,482	6,482

Notes: see Table 2.

Table 7: Regression Results: Effects of Judicial Sanctions of Other Facilities in the Same State on Stack Emissions (log of pounds emitted)
 Regressions use Samples of Plants from a Single Industry, and Estimate Effects of Sanctions of Others in the Same vs. Any Industry

Industry:	Pulp and Paper (SIC 26)	Pulp and Paper (SIC 26)	Industrial and Commercial Machinery (SIC 35)	Industrial and Commercial Machinery (SIC 35)
State Judicial Sanctions of 1 or More Other Facilities in Any Manufacturing Industry in the Same State				
This Year	0.078 [0.114]	0.066 [0.115]	0.007 [0.066]	0.030 [0.067]
1 Year Ago	-0.124+ [0.071]	-0.145+ [0.074]	-0.118 [0.071]	-0.124 [0.074]
2 Years Ago	-0.197** [0.068]	-0.192** [0.070]	-0.180* [0.072]	-0.193* [0.073]
3 Years Ago	-0.173* [0.080]	-0.152* [0.073]	-0.249** [0.067]	-0.263** [0.063]
EPA Judicial Sanctions of 1 or More Other Facilities in Any Manufacturing Industry in the Same State				
This Year		0.097 [0.090]		-0.053 [0.097]
1 Year Ago		0.112 [0.120]		0.022 [0.117]
2 Years Ago		0.152 [0.117]		0.044 [0.129]
3 Years Ago		-0.006 [0.122]		0.040 [0.108]
State Judicial Sanctions of 1 or More Other Facilities in the Same Industry and Same State				
This Year	-0.204+ [0.106]	-0.168 [0.100]	-0.160 [0.322]	-0.152 [0.329]
1 Year Ago	-0.101 [0.110]	-0.124 [0.108]	0.185* [0.091]	0.209* [0.088]
2 Years Ago	0.116 [0.082]	0.068 [0.072]	-0.161 [0.151]	-0.113 [0.187]
3 Years Ago	0.330** [0.115]	0.312* [0.122]	-0.270 [0.261]	-0.344 [0.284]
EPA Judicial Sanctions of 1 or More Other Facilities in the Same Industry and Same State				
This Year		-0.081 [0.133]		0.000 [0.000]
1 Year Ago		0.217 [0.140]		0.000 [0.000]
2 Years Ago		0.139 [0.176]		-0.322+ [0.168]
3 Years Ago		0.106 [0.152]		-0.011 [0.131]
Variables for Inspections and Sanctions of this Specific Facility Itself:	Y	Y	Y	Y
Observations	3361	3361	3651	3651
R-squared	0.78	0.78	0.76	0.76
Number of Facilities	293	293	328	328

Notes: Regressions include facility-specific fixed effects and year fixed effects. Other control variables are as described in Table 2. Standard errors are clustered at the state level.

Table 8: Regression Results: Effects of Judicial Sanctions of Other Facilities in the Same State on Stack Emissions (log of pounds emitted)
Effects of Size of Fines Assessed as well as Effects of Any Judicial Sanctions Being Imposed

Log of Average Size of Fine assessed by State
Judicial Sanctions, Other Facilities in Same State

This Year	0.131 [0.213]	0.144 [0.200]
1 Year Ago	0.045 [0.218]	0.107 [0.209]
2 Years Ago	-0.239 [0.314]	-0.148 [0.287]
3 Years Ago	-0.099 [0.235]	0.016 [0.206]

Log of Average Size of Fine assessed by EPA
Judicial Sanctions, Other Facilities in Same State

This Year	0.147 [0.308]	0.168 [0.278]
1 Year Ago	0.150 [0.214]	0.160 [0.200]
2 Years Ago	0.168 [0.202]	0.148 [0.191]
3 Years Ago	0.042 [0.285]	0.015 [0.267]

Log of Largest of the Fines assessed by State
Judicial Sanctions, Other Facilities in Same State

This Year	0.098 [0.214]	0.111 [0.201]
1 Year Ago	0.002 [0.214]	0.065 [0.204]
2 Years Ago	-0.254 [0.307]	-0.166 [0.284]
3 Years Ago	-0.083 [0.218]	0.026 [0.194]

Log of Largest of the Fines assessed by EPA
Judicial Sanctions, Other Facilities in Same State

This Year	0.143 [0.296]	0.165 [0.268]
1 Year Ago	0.156 [0.208]	0.168 [0.194]
2 Years Ago	0.170 [0.190]	0.152 [0.180]
3 Years Ago	0.043 [0.281]	0.016 [0.264]

Variables for State Judicial Sanctions of 1 or More Other Facilities in the Same State

Y Y Y Y

Variables for EPA Judicial Sanctions of 1 or More Other Facilities in the Same State

Y Y Y Y

Variables for Inspections and Sanctions of this Specific Facility Itself:

N Y N Y

Observations	73213	73213	73213	73213
R-squared	0.82	0.82	0.82	0.82
Number of Facilities	6,482	6,482	6,482	6,482

Notes: See Table 2. Coefficients and standard errors on variables for fines of other facilities are multiplied by 100. Variables for size of fines at other facilities are the log of 1 plus the measure of the size of the fines, to avoid taking the log of zero.

Table 9: Regression Results: Effects of Inspections, Administrative Sanctions, and Judicial Sanctions of Other Facilities on Stack Emissions (log of pounds emitted)

Log of Number of Inspections (plus 1), Other Facilities in the Same County				
This Year	0.041** [0.012]	0.029* [0.012]		
1 Year Ago	0.011 [0.012]	0.003 [0.011]		
2 Years Ago	0.022+ [0.011]	0.017 [0.011]		
3 Years Ago	-0.009 [0.018]	-0.011 [0.019]		
Log of Number of Inspections (plus 1), Other Facilities in the Same State				
This Year			0.026+ [0.013]	0.015 [0.012]
1 Year Ago			0.010 [0.010]	0.004 [0.011]
2 Years Ago			0.036** [0.013]	0.032* [0.013]
3 Years Ago			0.029+ [0.015]	0.029+ [0.015]
Log of Number of Administrative Sanctions (plus 1), Other Facilities in the Same County				
This Year	-0.033** [0.011]	-0.032** [0.011]		
1 Year Ago	0.002 [0.015]	0.002 [0.015]		
2 Years Ago	0.012 [0.015]	0.012 [0.015]		
3 Years Ago	0.021 [0.013]	0.021 [0.014]		
Log of Number of Administrative Sanctions (plus 1), Other Facilities in the Same State				
This Year			-0.025* [0.010]	-0.025* [0.010]
1 Year Ago			-0.011 [0.008]	-0.011 [0.008]
2 Years Ago			-0.006 [0.008]	-0.007 [0.009]
3 Years Ago			0.004 [0.009]	0.001 [0.010]
State Judicial Sanctions of 1 or More Other Facilities in the Same State				
This Year	0.005 [0.017]	0.006 [0.017]	-0.001 [0.017]	-0.001 [0.017]
1 Year Ago	-0.023 [0.016]	-0.021 [0.016]	-0.020 [0.016]	-0.020 [0.016]
2 Years Ago	-0.046* [0.018]	-0.046* [0.018]	-0.043* [0.017]	-0.043* [0.017]
3 Years Ago	-0.048** [0.016]	-0.047** [0.016]	-0.044** [0.014]	-0.044** [0.015]
Variables for Inspections and Sanctions of this Specific Facility Itself:	N	Y	N	Y
Variables for EPA Judicial Sanctions of 1 or More Other Facilities in the Same State	Y	Y	Y	Y
Observations	73213	73213	73213	73213
R-squared	0.82	0.82	0.82	0.82
Number of Facilities	6,482	6,482	6,482	6,482

Notes: see Table 2.

Table 10: Regression Results: Effects of Judicial Sanctions of Other Facilities in the Same State on Stack Emissions (log of pounds emitted)
 Regressions use sample of plants that report stack emissions to the TRI for 4 or more years between 1988 and 1999, rather than 9 or more

State Judicial Sanctions of 1 or More Other Facilities in the Same State					
Next Year					0.022 [0.014]
This Year	0.007 [0.017]	0.008 [0.017]	0.010 [0.016]	0.011 [0.016]	0.009 [0.016]
1 Year Ago	-0.024 [0.016]	-0.024 [0.016]	-0.019 [0.015]	-0.019 [0.015]	-0.023 [0.015]
2 Years Ago	-0.044** [0.016]	-0.044** [0.016]	-0.042** [0.015]	-0.042** [0.016]	-0.039** [0.014]
3 Years Ago	-0.054** [0.015]	-0.055** [0.015]	-0.052** [0.014]	-0.052** [0.015]	-0.051** [0.012]
4 Years Ago					-0.014 [0.018]
EPA Judicial Sanctions of 1 or More Other Facilities in the Same State					
Next Year					-0.015 [0.017]
This Year		-0.007 [0.012]		-0.008 [0.013]	-0.012 [0.014]
1 Year Ago		0.002 [0.015]		0.001 [0.015]	0.001 [0.015]
2 Years Ago		0.004 [0.019]		0.003 [0.019]	0.003 [0.019]
3 Years Ago		0.001 [0.023]		-0.001 [0.022]	-0.004 [0.022]
4 Years Ago					0.015 [0.013]
Actions at this Specific Facility Itself:					
Inspected Next Year					0.104** [0.017]
Inspected This Year			0.065** [0.016]	0.065** [0.016]	0.056** [0.014]
Inspected 1 Year Ago			0.053** [0.014]	0.053** [0.014]	0.045** [0.014]
Inspected 2 Years Ago			0.036** [0.012]	0.036** [0.012]	0.034** [0.012]
Inspected 3 Years Ago			0.021 [0.016]	0.021 [0.016]	0.022 [0.015]
Inspected 4 Years Ago					0.019 [0.019]
Administrative Sanction Next Year					
Administrative Sanction This Year			0.030 [0.027]	0.030 [0.027]	0.053 [0.027]
Administrative Sanction 1 Year Ago			0.011 [0.037]	0.011 [0.037]	0.010 [0.038]
Administrative Sanction 2 Years Ago			-0.006 [0.031]	-0.005 [0.031]	-0.004 [0.032]
Administrative Sanction 3 Years Ago			-0.019 [0.032]	-0.018 [0.033]	-0.019 [0.035]
Administrative Sanction 4 Years Ago					-0.018 [0.031]
EPA Judicial Sanction Next Year					
EPA Judicial Sanction This Year			0.155 [0.144]	0.155 [0.145]	0.068 [0.115]
EPA Judicial Sanction 1 Year Ago			0.162 [0.167]	0.162 [0.168]	0.162 [0.178]
EPA Judicial Sanction 2 Years Ago			0.112 [0.200]	0.113 [0.202]	0.115 [0.208]
EPA Judicial Sanction 3 Years Ago			0.211* [0.098]	0.211* [0.100]	0.216* [0.107]
EPA Judicial Sanction 4 Years Ago					0.028 [0.062]
State Judicial Sanction Next Year					
State Judicial Sanction This Year			0.216 [0.143]	0.216 [0.144]	0.327** [0.084]
State Judicial Sanction 1 Year Ago			0.052 [0.168]	0.052 [0.168]	0.258+ [0.148]
State Judicial Sanction 2 Years Ago			0.049 [0.153]	0.049 [0.153]	0.092 [0.171]
State Judicial Sanction 3 Years Ago			0.069 [0.144]	0.069 [0.145]	0.091 [0.159]
State Judicial Sanction 4 Years Ago					0.105 [0.163]
					0.046 [0.151]
Observations	97967	97967	97967	97967	97967
R-squared	0.83	0.83	0.83	0.83	0.83
Number of Facilities	10,704	10,704	10,704	10,704	10,704

Notes: See table 2. The sample used in these regressions consists of facilities that report stack emissions to the TRI for 4 or more years between 1988 and 1999.

Table 11: Regression Results: Effects of Judicial Sanctions of Other Facilities in the Same State on Other Dependent Variables

Dependent Variable:	Fugitive Emissions (Log of Pounds Emitted)		Stack Emissions, Toxicity Weighted (Log of Pounds Emitted)		Fugitive Emissions, Toxicity Weighted (Log of Pounds Emitted)	
State Judicial Sanctions of 1 or More Other Facilities in the Same State						
This Year	0.016 [0.024]	0.017 [0.023]	0.005 [0.026]	0.007 [0.025]	-0.026 [0.019]	-0.025 [0.019]
1 Year Ago	-0.022 [0.018]	-0.019 [0.018]	-0.012 [0.025]	-0.009 [0.025]	-0.027 [0.017]	-0.025 [0.018]
2 Years Ago	-0.042+ [0.022]	-0.041+ [0.022]	-0.029 [0.023]	-0.027 [0.023]	-0.020 [0.025]	-0.020 [0.026]
3 Years Ago	-0.023 [0.018]	-0.023 [0.018]	-0.036+ [0.019]	-0.034+ [0.020]	-0.030 [0.018]	-0.031+ [0.018]
EPA Judicial Sanctions of 1 or More Other Facilities in the Same State						
This Year	-0.011 [0.015]	-0.012 [0.015]	0.028 [0.021]	0.025 [0.021]	0.013 [0.018]	0.011 [0.019]
1 Year Ago	-0.013 [0.022]	-0.016 [0.021]	0.021 [0.026]	0.018 [0.027]	-0.010 [0.017]	-0.012 [0.016]
2 Years Ago	-0.016 [0.024]	-0.018 [0.023]	0.005 [0.022]	0.004 [0.023]	-0.022 [0.020]	-0.024 [0.019]
3 Years Ago	-0.012 [0.025]	-0.014 [0.023]	0.018 [0.028]	0.016 [0.028]	-0.018 [0.022]	-0.020 [0.020]
Actions at this Specific Facility Itself:						
Inspected This Year		0.065** [0.021]		0.060* [0.023]		0.061* [0.024]
Inspected 1 Year Ago		0.039+ [0.022]		0.033 [0.027]		0.031 [0.029]
Inspected 2 Years Ago		0.030 [0.024]		0.004 [0.027]		-0.011 [0.031]
Inspected 3 Years Ago		-0.015 [0.018]		-0.003 [0.023]		-0.027 [0.031]
Administrative Sanction This Year		0.019 [0.042]		0.078 [0.056]		0.034 [0.050]
Administrative Sanction 1 Year Ago		-0.009 [0.046]		0.050 [0.051]		0.076 [0.049]
Administrative Sanction 2 Years Ago		-0.043 [0.056]		0.053 [0.062]		-0.023 [0.044]
Administrative Sanction 3 Years Ago		-0.073 [0.049]		0.042 [0.084]		-0.042 [0.045]
EPA Judicial Sanction This Year		0.037 [0.136]		0.167 [0.225]		0.389+ [0.206]
EPA Judicial Sanction 1 Year Ago		-0.092 [0.187]		0.362* [0.180]		0.195 [0.216]
EPA Judicial Sanction 2 Years Ago		0.205 [0.193]		0.022 [0.156]		0.585** [0.164]
EPA Judicial Sanction 3 Years Ago		0.009 [0.122]		0.066 [0.155]		0.307 [0.217]
State Judicial Sanction This Year		0.048 [0.115]		0.300 [0.194]		0.113 [0.196]
State Judicial Sanction 1 Year Ago		0.177 [0.149]		0.054 [0.208]		0.129 [0.147]
State Judicial Sanction 2 Years Ago		0.231 [0.179]		-0.026 [0.161]		0.208 [0.151]
State Judicial Sanction 3 Years Ago		0.180 [0.171]		-0.215 [0.185]		0.168 [0.213]
Observations	69080	69080	71749	71749	70143	70143
R-squared	0.78	0.78	0.72	0.72	0.67	0.67
Number of Facilities	6,403	6,403	6,482	6,482	6,403	6,403

See Table 2. The sample used in the Fugitive Emissions regressions consists of facilities that report fugitive emissions to the TRI for 9 or more years between 1988 and 1999. The sample used in the Stack Emissions regressions consists of facilities that report stack emissions to the TRI for 9 or more years between 1988 and 1999.

Table 12: Regression Results: Effects of Inspections, Administrative Sanctions, and Judicial Sanctions of Other Facilities on Fugitive Emissions (log of pounds emitted)

Log of Number of Inspections (plus 1), Other Facilities in the Same County				
This Year	0.028+	0.018		
	[0.014]	[0.016]		
1 Year Ago	-0.002	-0.010		
	[0.009]	[0.011]		
2 Years Ago	0.007	0.003		
	[0.010]	[0.012]		
3 Years Ago	0.001	0.003		
	[0.014]	[0.014]		
Log of Number of Inspections (plus 1), Other Facilities in the Same State				
This Year			0.023	0.014
			[0.015]	[0.014]
1 Year Ago			-0.013	-0.019
			[0.012]	[0.013]
2 Years Ago			0.023+	0.020
			[0.014]	[0.014]
3 Years Ago			0.026	0.030
			[0.018]	[0.019]
Log of Number of Administrative Sanctions (plus 1), Other Facilities in the Same County				
This Year	-0.044**	-0.044**		
	[0.014]	[0.014]		
1 Year Ago	-0.038*	-0.038*		
	[0.015]	[0.015]		
2 Years Ago	-0.021	-0.020		
	[0.014]	[0.013]		
3 Years Ago	0.007	0.009		
	[0.015]	[0.014]		
Log of Number of Administrative Sanctions (plus 1), Other Facilities in the Same State				
This Year			-0.017	-0.017
			[0.011]	[0.011]
1 Year Ago			-0.026*	-0.025*
			[0.010]	[0.010]
2 Years Ago			0.001	0.001
			[0.011]	[0.011]
3 Years Ago			-0.002	-0.003
			[0.009]	[0.009]
State Judicial Sanctions of 1 or More Other Facilities in the Same State				
This Year	0.013	0.013	0.009	0.009
	[0.023]	[0.023]	[0.023]	[0.023]
1 Year Ago	-0.021	-0.021	-0.024	-0.024
	[0.018]	[0.017]	[0.019]	[0.018]
2 Years Ago	-0.042+	-0.043+	-0.040+	-0.041+
	[0.022]	[0.022]	[0.023]	[0.023]
3 Years Ago	-0.026	-0.027	-0.021	-0.022
	[0.018]	[0.018]	[0.020]	[0.020]
Variables for Inspections and Sanctions of this Specific Facility Itself:	N	Y	N	Y
Variables for EPA Judicial Sanctions of 1 or More Other Facilities in the Same State	Y	Y	Y	Y
Observations	69080	69080	69080	69080
R-squared	0.78	0.78	0.78	0.78
Number of Facilities	6,403	6,403	6,403	6,403

See Table 2. The sample used in the Fugitive Emissions regressions consists of facilities that report fugitive emissions to the TRI for 9 or more years between 1988 and 1999.