Environmental Management Responses to Punishment: Specific Deterrence and Certainty versus Severity of Punishment

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Abstract: According to the standard model of enforcement, both the certainty of punishment and the severity of punishment influence deterrence. Discerning the separate effects of these two components on behavior, however, is difficult especially because it requires constructing measures of the beliefs of individuals and regulated businesses. Our study tackles this matter using stated choice scenarios posed to environmental management professionals working at businesses operating within the Clean Water Act regulatory framework. In addition, our study examines the influence of specific deterrence, which reflects individuals' responses to their own experiences with penalties. As important, our analysis explores the attitudes towards environmental protection held by facility management and facility environmental employees, which collectively reflect the corporate culture surrounding environmental protection efforts. We find that regulated facilities respond to increases in fine size and fine likelihood with equal sensitivity and that both specific deterrence and corporate culture are important determinants of compliance behavior.

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1. Introduction

According to the standard model of enforcement, deterrence stemming from the enforcement of laws, including both criminal laws and regulations imposed on businesses, is based on two components of expected penalty imposition: likelihood and size. The likelihood of a penalty reflects the certainty of punishment; the size of a penalty reflects the severity of punishment. Discerning the effects of these two components on behavior, however, is difficult because it requires constructing measures of the beliefs of individuals and businesses regarding the expected penalty likelihood and size. Since the two components are frequently correlated with each other, it is even more difficult to isolate the two components' effects in order to assess their relative influences. While several empirical studies attempt to assess the relative influences of these two factors (e.g., Eide, 2000), no consensus yet exists and studies of regulatory enforcement examining this topic are scarce due to the lack of data. A better understanding is important for policy considerations since enforcement agencies should place greater emphasis on the more effective tool – monitoring, which relates to the certainty of punishment, or sanctioning, which relates to the severity of punishment.

The current study contributes to our understanding of deterrence in five key ways. First, rather than exploring the contrast between penalty likelihood and size using observed behavior, this study analyzes stated behavior generated from hypothetical scenarios presented within a survey to facilities regulated under the US Clean Water Act. By appropriately varying the levels of penalty size and likelihood, we determine the absolute and relative degree of responsiveness to each deterrence component. Thus, we explicitly control the values of fine likelihood and fine size within these scenarios. Second, the current study examines the influence of penalties in an enforcement

context where very few facilities ever receive penalties.[1] Thus, use of the hypothetical scenarios improves the generalizability of our results as they do not rely on a very small sub-set of facilities. Third, in our survey of regulated facilities, we pose scenarios to environmental management professionals working at these regulated facilities. We structured the hypothetical scenarios to mimic actual situations in which these environmental professionals may respond to enforcement. This structure further adds to the generalizability of our results because they are based on the responses of professionals who make environmental management decisions on a daily basis.[2] As the fourth contribution, our analysis explores other potentially influential factors, especially the attitudes towards environmental protection held by facility management and facility environmental employees, which collectively reflect the corporate culture surrounding environmental protection efforts, as well as the recent history of inspections conducted at and enforcement actions taken against the particular facilities.

As the study's final contribution, we explore specific deterrence when punishment for noncompliance does not involve any upward ratcheting in the likelihood or size of any subsequent fine. In order to make this contribution, our study uses a theoretical understanding of deterrence to construct and test a particular notion of specific deterrence. Deterrence focuses on the *anticipation* of a penalty being imposed (Becker, 1968). Seen through this lens, a regulated entity should respond to the imposition of a penalty because it indicates an increase in one or both components of deterrence: (1) increased *subsequent* penalty likelihood due to greater monitoring scrutiny, and/or

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[1] As evidence of this dearth of experience with penalties, in the studied sample, no single facility had received a penalty within the 24-month period preceding the point of survey contact. Nevertheless, some of the sampled facilities experienced the imposition of informal enforcement actions and formal enforcement actions that did not involve penalties and most of the sampled facilities experienced the conduct of inspections within the 24-month period preceding the survey.

[2] In contrast, almost all experimental analysis of enforcement relies upon students as test subjects. An exception is Block and Gerety (1995), who use prisoners as well as students.

(2) increased *subsequent* penalty size (i.e., recidivist facilities receive higher *subsequent* penalties). From this perspective, the imposition of a penalty should not affect facility behavior absent any increase in future monitoring scrutiny or penalty size.

This calculus assumes full information and rationality. A regulated entity may incorrectly estimate the likelihood and/or size of potential penalties, in which case the imposition of a penalty may cause the entity to modify its estimate. Of course, the imposition of a specific penalty may raise or lower deterrence depending on whether the received penalty is bigger or smaller than initially expected. In contrast, the imposition of a penalty is likely to prompt an upward revision in the expected likelihood of a fine. In equilibrium, the costs of incorrect estimation would prompt a rational entity to estimate correctly penalty size and likelihood. However, lack of experience and imperfect information may lead to a different outcome. As important, the regulated entity may not rationally process its information on the expected penalty size and likelihood. The entity may exaggerate the importance of recent penalties, leading to upwardly biased expectations of fine likelihood and fine size to a lesser extent. We explore this point more fully in Sections 2 and 3.

It is difficult to test this theoretical hypothesis using actual choices made by regulated entities because of the need to disentangle the independent effect of the imposed penalty from subsequent penalty components. In addition, any analysis of actual choices needs to construct a measure of the beliefs of penalized facilities regarding penalty likelihood and size. In order to avoid these concerns, this study constructed a survey-based scenario that involves an initial (i.e., imposed) penalty, described by its likelihood of imposition and size, and a subsequent penalty, described in the same way. To test the neutrality of the initial penalty, the survey presented a scenario with no increase in the subsequent penalty likelihood or size relative to the initial penalty after the imposition of the initial penalty. According to standard deterrence theory, survey respondents should indicate no

willingness to increase their effort in response to the imposition of the initial penalty.

In order to make these five contributions, our study analyzes data collected from US chemical manufacturing facilities whose wastewater discharges are regulated under the Clean Water Act (CWA). This sector generates a significant proportion of CWA discharges and has received special scrutiny from the Environmental Protection Agency (EPA) in recent years. Our results demonstrate that facilities are equally responsive to increases in the likelihood or severity of a fine and that the experience of being fined significantly increases compliance even absent any upward ratcheting of enforcement parameters (i.e., specific deterrence). Results also reveal that a strong corporate culture, as measured by facility employees' and management's levels of environmental concern, increases the likelihood of compliance.

The rest of the paper proceeds as follows. In the next section, we review the relevant literature, focusing on the notion of specific deterrence. In Section 3, we theoretically derive four hypotheses to be tested with our data. We describe the data in Section 4 and interpret the experimental results in Section 5. In Section 6, we conclude by discussing policy implications and the limitations of our study.

2. Background and Literature Review

2.1. Standard Deterrence Model

In the standard economics of crime model (Becker, 1968; Polinsky and Shavell, 2000), crimes are committed when the expected gain from offending exceeds the expected penalty from offending. Potential offenders are rational economic agents with full knowledge of the enforcement regime; in particular, they know the likelihood of punishment when they commit a crime and the severity of the punishment when it is imposed.

One prediction from this model, known as the general theory of deterrence, is that increases

in either the probability of punishment or the size of the penalty (either fines or jail terms) reduce offenses. This prediction has been borne out in numerous studies of both general crime (Eide, 2000) and regulatory compliance (e.g. Gray and Shimshack, 2011).

A second prediction concerns the relative efficacy of punishment versus probabilities in deterring crime; here the evidence is more mixed. Becker (1968) identifies the key role of risk preferences in answering this question. In particular, risk neutral individuals consider only the expected penalty and not its composition, and are therefore indifferent to offsetting changes in the probability and severity of punishment that keep the expected penalty constant. Risk averse individuals, on the other hand, are deterred more by increases in the severity of punishment than an equivalent increase in the probability of punishment, while risk lovers are deterred more by increases in the probability of detection. Despite the fact that many extensions have been made to Becker's (1968) theoretical model, as summarized by Eide (2000) and Polinksy and Shavell (2000), the relative efficacy of violation detection versus severity remains an unresolved question.

Evidence from general crime data suggests that increases in the probability of punishment have a larger and more significant impact than increases in the severity of punishment (Eide, 2000).[3] Studies of regulatory compliance (e.g. Gray and Deily, 1996) and income tax compliance (e.g. Kirchler et al., 2010) typically contain measures of audit probabilities or fines but rarely both; thus, they are unable to address this question directly. In addition, a major challenge in empirical studies is to construct credible measures of the perceived probability and severity of punishment. Other issues included reverse causality, especially in aggregate-level data, and sample selection bias in individual-level data.

[3] Criminologists Doob and Webster (2003, p.143) go further claiming that, "sentence severity has no effect on the level of crime in society". They also discuss many of the data difficulties inherent in this type of empirical work.

Empirical analysis of experimental data offers an advantage in terms of control over perceptions and the ability to generate "ceteris paribus" changes. Results from experiments with student subjects situated in regulatory contexts contrast with the results in the empirical literature: individuals respond more to changes in punishment severity than changes in likelihood (Block and Gerety, 1995; Anderson and Stafford, 2003; Friesen, 2012), consistent with risk averse expected utility maximization.[4]

The contrast in results, between regulatory experiments with students and the empirical crime literature, suggests that both the context and the type of the participants are crucial. Indeed, the behavior of neither criminals nor students may generalize to regulatory decision-making, specifically environmental compliance decisions. This paper contributes to this literature by investigating the responses of key decision-makers, namely environmental managers, to a number of stated choice scenarios. We designed the scenarios to study both the general theory of deterrence and the efficacy of certainty versus severity of punishment in a controlled context of environmental compliance.

2.2. Specific Deterrence

In the standard economics of crime model, potential offenders possess full information about the enforcement parameters they face. In particular, they understand both the likelihood and severity of punishment. In reality, individuals possess only imperfect knowledge about these factors (Polinsky and Shavell, 2000). Enforcement agencies rarely, if ever, announce the probability of detection. Severity too is unclear, because while laws may prescribe maximum penalty rates, the imposition and size of these penalties is at the discretion of enforcement agencies and the courts. Individual behavior is driven by these perceptions, rather than the objective values, yet few studies

[4] Block and Gerety (1995) use a unique second subject pool, prisoners, who behave differently from the pool of students, responding more to increases in the probability of detection than increases in punishment severity.

investigate the factors influencing these perceptions.[5]

Individuals form their perceptions by learning from their own experience and from observing the experiences of others. The idea that punishment conveys information is reflected in the notions of specific and general deterrence. In particular, one purpose of punishment is to deter the same individuals from committing the crime again – specific deterrence. At the same time, punishments send a message to the wider community, and therefore enhance general deterrence. The implication is that the actual imposition of the penalty, as opposed to just the anticipation, makes a difference to future behavior. For such effects to occur, the very act of punishment must convey additional information or least prompt some (upward) revision in perceptions of either the likelihood or severity of punishment.

However, learning from one's own and others' experiences is complicated especially in regulatory contexts where fines are rarely imposed, thus, limiting the opportunities for learning. In particular, it is well known that individuals face difficulties in understanding and assessing probabilities and may apply heuristics resulting in judgment biases (Tversky and Kahneman, 1974).[6] The prevalence of the optimism bias (Weinstein, 1980; Garoupa, 2003) implies that people believe they are less likely to experience bad events than others are; therefore, they tend to underestimate the likelihood of being caught. The actual experience of being caught and punished may cause them to revise upwards this overly optimistic assessment. Alternatively, even if the initial perception is correct, the very act of being punished may cause an (incorrect) upward revision in perceptions. The underlying mechanism may be similar to that which drives increased purchases of insurance following natural disasters even when the underlying risk has not changed (Weinstein et al., 2000;

[5] See Lochner (2007) and the references therein for studies on perceptions of the criminal justice system. We are not aware of studies considering perceptions of regulatory enforcement regimes.

[6] Garoupa (2003) notes that probabilistic losses are particularly troublesome for people.

Kunreuther and Pauly, 2006). In both cases, the underlying risk has not changed, but the perception is revised upward. Similar arguments could also apply to the severity of punishment.

The "availability heuristic", whereby people judge the frequency of an event by how easy it is to recall such an instance, provides one explanation for this reassessment (Tversky and Kahneman, 1974). More recent and salient events are the most available (easiest) to recall. Punishment fits this category. Jolls et al. (1998, p. 1537) point out "that vivid and personal information will often be more effective than statistical evidence" in changing behavior. Experimental tax compliance work suggests that such mechanisms can be at work even when objective probabilities are known (Alm et al., 2009).[7]

Despite the appeal and widespread legal usage of the terminology, few theoretical models separately consider specific and general deterrence, or even model perceptions. As notable exceptions, Sah (1991) and Lochner (2007) model perceptions of the criminal justice system.[8] Other models are normative in nature, focusing on the optimal design of sanctions when potential offenders have imperfect information (e.g., Bebchuk and Kaplow, 1992; Kaplow, 1990) rather than on how perceptions are formed. Several papers explore the notion of increased scrutiny or higher penalties for repeat offenders (e.g., Harrington, 1988; Polinksy and Shavell, 1998). The notion of specific deterrence is conceptually different, influencing choices absent any upward ratcheting of enforcement.

Previous empirical studies focus on the effects of actual penalties on particular regulated entities, which reflect specific deterrence [see Gray and Shimshack (2011) for a recent survey]. Few

[7] In Alm et al. (2009)'s experiment, compliance is increased by announcing audit results even when the audit probability is preannounced.

[8] Malik (1990, p.99) uses "a firm's subjective probability of being audited" in his environmental compliance model but does not formally model the evolution of these beliefs.

studies explicitly scrutinize specific deterrence within a broader context of deterrence (Earnhart, 2004; Shimshack and Ward, 2005) or investigate (or even discuss) the mechanism through which specific deterrence operates. As the single exception, Scholz and Gray (1990) test a behavioral model of a firm, regulated by the Occupational Health and Safety Administration (OSHA), with limited attention capacity. They find a strong specific deterrence effect, even after controlling for general deterrence, which may relate to learning by the firm about the probability of being punished. The authors emphasize the role of surprise in generating specific deterrence.

All empirical work must grapple with the issue of constructing measures of perceived likelihoods and severities. However, measuring specific deterrence is particularly challenging because it requires disentangling the effect of specific deterrence from that of the upward ratcheting of enforcement against repeat offenders. Our study contributes to this literature by investigating specific deterrence in a controlled setting where the only change is the experience of being punished, which represents the treatment, therefore, we isolate the effect of specific deterrence.

2.3. Corporate Culture

Monetary incentives are the focus in the standard model of deterrence. In reality, regulatory compliance occurs within a particular organizational setting. Specifically, while individual managers are often responsible for making compliance decisions, their decisions are made in the context of their firms. Firm- specific factors, such as the corporate culture towards environmental issues, affect these decisions (Nakamura et al., 2001; Wu, 2009). For example, Nakamura et al. (2001) demonstrate that corporate culture, as reflected in managerial attitudes and perceptions, appears to influence the following decisions on the part of Japanese firms: (1) degree to which firms have developed and formally institutionalized environmental policies, (2) degree to which firms have integrated their environmental policies into general corporate policies and practices and the degree

these policies receive top management support, and (3) ISO 14001 certification. Corporate culture may be transmitted via the firm's operating and management procedures and incentive structures (e.g., promotion prospects).

We investigate the influence of corporate culture, as measured by the environmental attitudes of managers and employees, on compliance decisions, while also controlling for standard measures of deterrence. We are not aware of other studies that include both types of factors. Yet it seems important to control for attitudes, as they convey to managers the relative importance of environmental versus profit considerations.

2.4. Summary of Contributions

In sum, the present study contributes to the literature by explicitly identifying these deterrence components within stated choice scenarios posed to businesses operating within the Clean Water Act regulatory framework, rather than a convenient sample of undergraduate students. Both features represent the strength of our study. The scenarios control perceptions of enforcement, especially those associated with increased enforcement against repeat offenders, and draw upon the insight of practitioners. We are able to study both the general theory of deterrence and specific deterrence using the same dataset, while using measures of employee and managerial attitudes to assess the influence of organizational factors.[9]

3. Theoretical Framework and Hypotheses

In this section, we develop a simple theoretical framework derived from Becker's (1968) well-known economic model of crime and use this framework to derive four specific hypotheses to be tested with our data. The firm manager has a utility function $U(\Pi, Z)$, where Π reflects the firm's

[9] We also assess the influence of facility characteristics, which may reflect additional organizational factors.

net profits and Z reflects non-monetary factors (e.g., firm's corporate culture) that influence decisions (discussed further in Section 3.3). Utility is increasing in both components.[10] The firm generates gross profits per period of π and faces an environmental regulation that costs c each period to comply with. The probability of detection, if the firm violates this regulation, is p. Once detected, a violation leads to a fine of F.[11]

3.1. Standard Deterrence Model

In the standard deterrence model, the manager has full knowledge of the enforcement parameters. For ease of notation, in this section we suppress variable Z (which is held constant) in the utility function. The firm receives a certain net profit of π-c if it complies, yielding this level of managerial utility:

$$EU(\text{comply}) = U(\pi\text{-}c). \quad (1)$$

Expected utility in the case of violation is the following:

$$EU(\text{violate}) = pU(\pi\text{-}F) + (1\text{-}p)U(\pi). \quad (2)$$

In this simple discrete situation, the manager chooses to comply when (1) > (2), and violates otherwise. An increase in either p or F reduces (2), thereby, making it more likely that any given firm complies, as reflected in the first hypothesis:

Hypothesis 1 (Standard Deterrence): An increase in either the likelihood of a fine or the size of a fine increases compliance.

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[10] Underlying our model is the assumption that incentives of the environmental manager align with the incentives of the firm. For example, corporate culture towards environmental compliance may affect a manager's chances for promotion, i.e., a record of violations is detrimental to a manager's promotion prospects when the firm values compliance and vice versa.

[11] In reality, compliance depends on both the firm's efforts (costs) and random factors, such as weather and human error. Hence, the firm cannot guarantee its compliance status and always faces some probability of a fine. Agency inspections may also be inaccurate. These theoretical results still hold as long as the probability of being fined when the firm complies is sufficiently smaller than the probability of being fined when the firm violates.

The standard model also generates predictions about whether increasing the likelihood of a fine, *p*, has a larger impact on expected utility, and hence compliance behavior, than an equivalent increase in the fine size, *F*. As demonstrated by Becker (1968), the answer depends on the risk preference of the decision-maker.[12] To see this point, derive the elasticity of the change in EU(violate) with respect to *p*, denoted as η_p, and *F*, denoted as η_F, where both elasticities are defined as positive values:

$$\eta_p = -(p/EU)\,[U(\pi-F)-U(\pi)]\ , \text{ and} \tag{3}$$

$$\eta_F = (F/EU)\,pU'(\pi-F)\ . \tag{4}$$

Then, $\eta_p > \eta_F$, when the following condition holds:

$$[\{U(\pi)-U(\pi-F)\}/F] > U'(\pi-F)\ . \tag{5}$$

This inequality holds when the average rate of change in utility exceeds the marginal rate of change, which is true if $U''(\pi)>0$, i.e., the manager is risk loving. Thus, increasing the probability of detection, *p*, has a larger impact on deterrence than an equivalent increase in the fine, *F*, for risk loving managers, while risk averse managers are more deterred by rising punishments than probabilities. Risk neutral managers are indifferent.

This result is summarized in the second hypothesis.

Hypothesis 2 (Differential Deterrence): Consider an equivalent increase in either the likelihood or size of the fine, where equivalent means the same percentage change such that the expected fine remains the same, then:

(a) risk neutral managers are equally deterred by the changes,

(b) risk averse managers are more deterred by the increase in the size than the likelihood, and

(c) risk loving managers are more deterred by the increase in the likelihood than the size.

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[12] While Becker (1968) was among the first to derive the implications for crime, the result follows directly from the fact that a mean-preserving spread makes all risk averters worse off.

3.2. Specific Deterrence

As described in Section 2, managers possess only imperfect knowledge about the enforcement parameters that they are facing. In particular, let p° denote the manager's perception of the likelihood of being caught and F° be his/her assessment of the fine severity.[13] The expected utility from violation then becomes:

$$EU(violate)=p^{\circ}U(\pi-F^{\circ})+(1-p^{\circ})U(\pi) . \quad (6)$$

In such a world, one way that managers learn about the parameters is from the experience of actually being punished. This experience could lead to an upwards revision in the value of $p^{\circ}$and/or F°, thereby, increasing deterrence, which leads to the third hypothesis .

Hypothesis 3 (Specific Deterrence): The experience of receiving a fine increases a firm's compliance in future periods even when the objective enforcement parameters remain unchanged.

3.3. Corporate Culture

The manager's utility function also contains non-monetary factors that influence the manager's compliance decision, such as the firm's corporate culture towards environmental concerns. For simplicity, suppose that $Z=Z_c>0$ when the firm complies, while $Z=Z_v=0$ when the firm violates. The act of compliance may increase Z due to either warm glow feelings or, more pragmatically, manager promotion or bonus prospects. More generally, the size of Z_c depends on the firm's corporate culture through paths such as internal firm procedures and processes. An organization with a larger Z_c is therefore more likely to comply, ceteris paribus, which leads to the fourth hypothesis:

Hypothesis 4 (Corporate Culture): Organizations with a strong corporate environmental culture are more likely to comply.

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[13] Clearly more complicated versions are possible where managers hold probability distributions over these parameters.

Clearly, alternative formulations of Z_v and Z_c are possible. For example, violations may generate a cold prickle effect so that $Z_v<0$. Since the manager's utility is rising in Z, *Hypothesis 4* continues to hold as long as $Z_c>Z_v$.

4. Data

In order to test these theoretically derived hypotheses, we assess data drawn from a survey of regulated facilities and publicly available sources.

4.1. Survey of Regulated Entities

Our study critically draws upon survey data. This sub-section describes the set of facilities sampled by the survey, the hypothetical scenarios, and other information extracted by the survey.

4.1.1. Survey Sample

Our survey was distributed to a sample of U.S. chemical manufacturing facilities whose wastewater discharges were regulated by effluent limits imposed within permits issued as part of the National Pollutant Discharge Elimination System (NPDES) in 2001. By focusing on regulated facilities, our analysis is able to focus its assessment on compliance with the noted NPDES effluent limits. We focus on wastewater discharges because these noted effluent limits are numerically defined so the distinction between compliance and noncompliance is obvious and these numeric limits are systematically recorded and publicly available.

Unlike most previous studies of regulated facilities within the realm of environmental protection, our study considers facilities of all sizes. In particular, we examine both "minor facilities" and "major facilities" as classified by the EPA for the NPDES system. For the classification of each regulated facility, the EPA calculates a major rating with points assigned on the basis of toxic pollution potential, flow type, conventional pollutant load, public health impact, and water quality impact; the EPA classifies any discharger with a point total of 80 or more as a

"major facility".

We chose the industrial sector of chemical and allied products as the focus of our study because it serves as an excellent vehicle for examining the efficacy of enforcement on regulated facilities' environmental management. First, the EPA has demonstrated a strong interest in this sector as evidenced by its study, jointly authored with the Chemical Manufacturing Association, on the root causes of noncompliance in this sector (EPA, 1999) and its study on the compliance history for this sector (EPA, 1997). Consistent with this interest, two sub-sectors in the industry, industrial organics and chemical preparations (SIC-codes 2869, 2899), were regarded by the EPA as priority sectors during a portion of the study period. Second, this sector displays considerable variation in environmental management and compliance behavior (Earnhart and Glicksman, 2011). Third, this sector permits the analysis to exploit similarities and differences across sub-sectors. Fourth, this sector is responsible for a significant portion of the nation's industrial output and a meaningful portion of all wastewater discharges by facilities subject to Clean Water Act regulation.[14]

The population of CWA-regulated facilities in the chemical manufacturing industry was extracted from the EPA's Permit Compliance System (PCS) database as of September, 2001. This extract includes 2,596 chemical facilities. To remain in the survey population, facilities needed to meet the following criteria: (1) possessed a NPDES permit; (2) faced restrictions on their wastewater discharges, (3) discharged regulated pollutants into surface water bodies, (4) were operating as of 2002, and (5) contact information was available from either the EPA or alternative sources, e.g., phone books. Application of these criteria identified 1,003 facilities to contact. Of those facilities contacted between April of 2002 and March of 2003, 736 refused to participate in the

[14] The chemical industry is not necessarily representative of all industrial sectors. Indeed, its unique attributes contribute to our interest in studying it. For example, some firms in the chemical industry have demonstrated an interest in promoting pollution reduction and prevention through efforts prompted by the Responsible Care program, which is a voluntary initiative supported by the American Chemistry Council.

survey, while 267 facilities completed at least 90 percent of the survey, implying a 27 % response rate. This rate is comparable to previous large-scale surveys of industrial sectors (e.g., Arimura et al., 2008).[15]

When administering the survey, we first contacted those individuals responsible for signing their respective facilities' wastewater discharge monitoring reports, which facilities are required to submit to the EPA on a regular basis, generally monthly. This selection of survey participants allows our survey to exploit the insight of those individuals most knowledgeable about their facilities' wastewater operations.

4.1.2. Construction of Hypothetical Scenarios

Each survey respondent was asked to consider three scenarios. Scenario # 1 was the same across all respondents, while the likelihood and size of the penalty was varied across respondents in Scenarios # 2 and # 3, respectively. This sub-section describes the hypothetical scenarios in greater detail.

Respondents were told that their facility would be discharging wastewater over a two-year period in each scenario and that they would have to choose one course of action from a set of two available options after each year of any given scenario. Respondents were informed that the available options would not vary between years or across scenarios. Finally, the survey-givers clearly stated that the "choices should reflect how you [the respondent] believe that <u>your facility</u> (underlining added for emphasis) would respond to the circumstances described in each scenario"

[15] To assess the issue of possible sample selection bias, we compare the sample of survey respondents to the sample of survey recipients and estimate the decision to complete the survey. This analysis uncovers a bias in a single dimension: major facilities were more likely to respond to the survey than were minor facilities. We must, therefore, cautiously interpret the effect of major versus minor status on scenario responses. Otherwise, our study does not correct for any potential sample selection bias consistent with recent prominently published studies of environmental management practices (Anton et al., 2004; Arimura et al., 2008). Full details of our analysis are available from the authors.

and that "there are no right or wrong choices".

Then the survey provided the following information that applied to all of the scenarios: *"Suppose that your facility has the option to improve the maintenance of its wastewater treatment process. On an annual basis, this improved maintenance costs $ 10,000 net of any side benefits, such as extending the life of the treatment technology (underlining added for emphasis). In each scenario, the choice of whether or not to improve maintenance affects the likelihood of your facility exceeding its permitted discharge limit, which prompts the imposition of a single monetary fine. Assume that this imposition generates no additional costs, such as exposure to third-party liability, adverse publicity, or disqualification as a government contractor."*

Note that the instructions take into account any side benefits associated with the improved maintenance so that the respondents appreciate that the maintenance truly involves costs. More important, note that the instructions constrain the costs associated with the imposition of a fine. Consequently, respondents were not free to speculate on peripheral costs. However, the instructions did not explicitly constrain the benefits associated with compliance even though the same identified peripheral elements may remain relevant, e.g., compliance leads to positive publicity or qualification as a government contractor. We have no reason to believe that this lack of symmetry meaningfully influenced scenario responses.

Then the survey posed the first scenario: *"Consider the first year of a two-year period. Without improved maintenance, the chance of exceeding the permitted discharge limit and receiving a monetary fine equals 10 %. With improved maintenance, there is a 1 % chance of exceeding the permitted discharge limit and receiving a monetary fine. Since no system is fool-proof, better maintenance reduces but does not eliminate the risk of non-compliance. The monetary fine is a one-time fine of $10,000. Improved maintenance costs $ 10,000 per year."*

Respondents were then asked, "*Would your facility choose to improve maintenance in Year 1?"*. After stating their choice, respondents were informed that they had been fined $10,000 at the end of Year 1. This was regardless of their choice; however the wording was adjusted accordingly, with those who chose to improve maintenance in Year 1 told that "due to uncontrollable factors" they had violated their permit limit, while for those who chose not to improve the factors leading to violation were described as both "controllable and uncontrollable". Thus, regardless of the respondent's choice for Year 1, the survey imposed a fine of $ 10,000 at the end of Year 1. Put differently, the survey "treated" each respondent to a dose of specific deterrence at the end of Year 1. To test for the effect of specific deterrence (*Hypothesis 3*), respondents then moved into Year 2 of Scenario # 1 where they faced exactly the same choice as in Year 1. That is, neither the likelihood of the fine, size of the fine, nor cost of maintenance was altered from the initial scenario. Indeed the text read to subjects emphasized this lack of change.

In Scenario # 2 respondents repeated the Year 2 decision described above but faced an increased monetary fine size randomly assigned from the set of values $ 20,000; $ 50,000; $ 100,000; $ 200,000. The likelihood of a fine (if maintenance is not improved) remained at 10 % as in Scenario # 1. In Scenario # 3, respondents again repeated the Year 2 decision but this time faced an increased likelihood of a subsequent monetary fine (if maintenance is not improved) randomly assigned from the set of values: 20 %, 40 %, 60 %, 99 %. The fine size was returned to the Scenario # 1 level of $ 10,000. Table 1 shows the distribution of fine and likelihood values across respondents. The text read to respondents highlighted the changing parameter values.

In sum, each respondent faces three scenarios. Each of these three scenarios poses a comparable situation with differences only in key components. In the first year of Scenario # 1, each respondent faces the 10 % likelihood of a $ 10,000 fine if maintenance is not improved and faces

the 1% likelihood of a $10,000 fine if maintenance is improved. These identical parameter values apply to the second year of Scenario # 1. By contrast, respondents in the second year of Scenario # 2 face a randomly-assigned fine size that exceeds the fine size imposed after the first year, while respondents in the second year of Scenario # 3 face a randomly-assigned fine likelihood (if maintenance is not improved) that exceeds the fine likelihood faced in the first year. Otherwise, the parameter values in Scenarios # 2 and # 3 are identical to those in Scenario # 1.

By varying the randomly assigned level for penalty likelihood and for penalty size separately in two different scenarios, we are able to estimate separately facilities' responsiveness to each penalty component. By combining these two scenarios with the first scenario, we can determine which component(s) of deterrence — likelihood and size — are relevant for prompting environmental behavioral responses (*Hypothesis 1*) and which component is more important if the components differ in their importance (*Hypothesis 2*).

Finally, it is important to note that the individuals responding to the hypothetical scenarios are instructed to make choices consistent with their facilities' preferences. If this instruction was taken seriously, characteristics of the individual respondents should not be expected to influence scenario responses. Of course, survey respondents may still allow their personal perspectives creep into their responses; if true, individual respondents' characteristics may appear to influence scenario responses.

4.1.3. Other Survey Data

In addition to these scenario responses, the survey gathered data on facility characteristics, perceptions, and attitudes, along with characteristics of the individual respondents. First, the survey gathered data on these facility characteristics: number of employees, year of facility construction, and year of first NPDES permit. Second, the survey gathered data on perceptions and attitudes.

Specifically, the survey asked respondents whether they "think that the imposition of monetary fines is an effective way for inducing individual chemical facilities to comply with permitted water discharge limits". Respondents chose from these categories: definitely not, probably not, probably yes, and definitely yes. The survey also asked respondents to "rate the degree to which the environmental employees in your facility are concerned with environmental protection" on a scale of 1 (very low) to 10 (very high) and similarly to "rate the degree to which the management of your facility is concerned with environmental protection" on the same scale. Third, the survey gathered data on the individual respondents' characteristics: gender, age, and educational attainment based on these.[16] Table 2.a statistically summarizes these survey-based data elements.

Given the importance of the factors relating to concerns about environmental protection on the part of facility environmental employees and management for testing *Hypothesis 4*, we describe these data in more depth in Table 2.b by tabulating the frequency of respondents by degree of concern. As shown, 48 % of facilities possess environmental employees with very high (=10) concerns and 44 % of facilities possess management with very high (=10) concerns about environmental protection. In contrast, no facilities possess environmental employees or management with concerns below a degree of 4. Nevertheless, Table 2.b. displays meaningful variation in environmental protection concerns.

All of these factors may influence maintenance decisions. First, the number of facility employees serves as a proxy for facility size, which may capture the influence of economies or diseconomies of scale. Second, the age of the facility may serve as a proxy for the vintage of the facility's equipment. Third, years of experience in the NPDES system may capture "regulatory

[16] Respondents identified their educational attainment from these categories: less than 9th grade, some high school, high school degree or GED, some college, 2-year degree, 4-year degree, some graduate school, and graduate degree.

maturity"; while many interpretations are possible, a more mature facility may better appreciate the benefits of compliance. Fourth, perceived effectiveness of monetary fines might be expected to sharpen the respondent's sensitivity to the imposition of fines, thus, increasing the likelihood of improved maintenance in the presence of threatened fines. Fifth, facility environmental employees' concerns about environmental protection and facility management's concerns about environmental protection should reflect corporate culture about environmental management. Sixth, the gender and age of individual respondent may be correlated with risk preferences but presumably only those of the individual, not the risk preferences of the facility as a whole. Seventh, educational attainment of the individual respondent may influence the individual's assessment of the benefits of compliance stemming from improved maintenance.

4.2. Publicly Available Data on Regulated Entities

To complement the data gathered by our survey, we also collected information from the EPA Permit Compliance System (PCS) database, which records information on facilities permitted within the NPDES system. The PCS database provides information on each facility's (1) location, (2) NPDES major or minor classification, and (3) four-digit standard industrial classification [SIC] code.[17] The PCS database also provides data on these government interventions: inspections performed by federal and state regulators, fines and administrative orders imposed by federal administrative and civil courts, and informal enforcement actions issued by federal enforcement agencies.

Based on these underlying data elements, we construct the following factors that may

[17] The analysis aggregates the four-digit SIC codes into three broader sectoral categories: organic chemicals, inorganic chemicals, and "other" chemicals. The broad category of organic chemicals includes the following four-digit SIC codes: 2821, 2823, 2824, 2843, 2865, 2869, 2891, and 2899. The broad category of inorganic chemicals includes the following four-digit SIC codes: 2812, 2813, 2816, 2819, 2873, and 2874.

influence a facility's decision to improve maintenance in the face of penalties:

(1) EPA-designated status: major versus minor;

(2) industrial sector: organic chemicals versus inorganic chemicals versus "other chemicals";

(3) state and federal inspections conducted at a particular facility in the 24-month period preceding the survey's completion for each respondent (count);

(4) informal enforcement actions taken against a particular facility in the 24-month period preceding the survey's completion for each respondent (count);

(5) formal enforcement actions taken against a particular facility in the 24-month period preceding the survey's completion for each respondent (count).

Table 2.a statistically summarizes these factors derived from publicly available data.

The analysis is forced to exclude factors relating to fines because no fines were imposed on the surveyed facilities in the 24-month period preceding the survey's completion. As one of this study's contributions identified in the introduction, we use hypothetical scenarios to assess the influence of enforcement-based deterrence in a regulatory context where fines are infrequently imposed.

All of the identified factors may influence maintenance decisions. First, major facilities may benefit differently from compliance than do minor facilities. Second, industrial classification reflects differences in products and production processes. Third, recent experience with inspections and enforcement actions may color facilities' sensitivity to the threat of fines within the scenarios.

5. Empirical Results

In this section we describe our empirical results, beginning with a summary of the responses to the scenarios, followed by a description of the methods we employ to analyze the responses – nonparametric tests and multivariate estimation. We then present our main results regarding the four

hypotheses developed in Section 3.

5.1. Overview of Scenario Responses

We first report and assess the responses to individual scenarios and then the sequence of responses as a whole. Responses to the scenarios are summarized in Table 3.a.

Of the 268 respondents, 245 answered the first-year of Scenario # 1 question, with 87 % choosing to improve maintenance, while 13 % chose not to improve maintenance. This high proportion of "improve maintenance" responses may seem unexpected from a cleanly rational perspective. The expected fine for non-compliance equals $ 1,000 if maintenance is not improved and equals $ 100 if maintenance is improved, a difference of $ 900. In contrast, improved maintenance costs $ 10,000. As a better lens, if a facility fails to improve maintenance, it pays $ 10,000 at the most (when a fine is imposed); yet if the facility chooses to improve maintenance, it pays $ 10,000 at a minimum (when the fine is not imposed). Thus, it may appear "irrational" to improve maintenance. We explore this point more closely below. Our analysis reveals that the apparent influence of non-fine-related factors seems to indicate that the high proportion of improved maintenance choices is at least potentially "rational".

This conclusion is supported by the actual environmental management choices made by US chemical manufacturing facilities regulated under the Clean Water Act. Previous studies document the strong prevalence of compliance and indeed substantial overcompliance at these regulated facilities (Earnhart, 2009; Earnhart and Glicksman, 2011; Earnhart and Segerson, 2011). More than 90 % of the studied chemical manufacturing facilities comply with their effluent limits in a given month, and the average degree of overcompliance is approximately 60 %. Studies of other sectors also reveal a strong prevalence of compliance and substantial overcompliance with wastewater discharge limits (Earnhart, 2004; Bandyopadhyay and Horowitz, 2006). While consideration of only

enforcement costs may be sufficient to explain substantial overcompliance as long as discharges are sufficiently stochastic, the presence of dramatic overcompliance may also indicate a consideration of factors beyond enforcement costs in reality.

Scenario # 1 also poses a question about the second year of operation. Of the 247 respondents answering this question, 92 % chose to improve maintenance, while 8 % chose not to improve, as shown in Table 3.a. The proportion choosing to improve maintenance increased to 97 % in Year 2 of both Scenarios # 2 and # 3, as also shown in Table 3.a.

Table 3.b tabulates the sequence of responses across the scenarios. As shown, 82 % of the respondents always choose to improve regardless of the scenario (Group 6). In contrast, only 0.8 % of the respondents never improve maintenance (Group 1). In between, 8.4 % of the respondents choose not to improve maintenance only in Scenario # 1:Year 1 (Group 2). Similarly, 4.2 % of the respondents choose to improve maintenance only in Scenario # 2:Year 2 and/or Scenario # 3:Year 2 when either the fine likelihood or fine size is greater than initially (Groups 3, 4, and 5).[18]

5.2. Statistical Methods

This section describes the statistical methods deployed to examine the individual scenario responses. First, we begin with nonparametric univariate tests, followed by multivariate estimation techniques that involve parametric assumptions. By employing both types of methods, we expand the robustness of our statistically based conclusions.

5.2.1. Univariate Nonparametric Tests

We begin our statistical analysis with the nonparametric univariate tests. We first examine the responses to the baseline scenario – Scenario # 1:Year 1 – using nonparametric split sample tests.

[18] The remaining groups of respondents (4.2 %) make sequences of choices that appear internally inconsistent. For example, the one person in Group 7 chooses to improve maintenance in both years of Scenario # 1 but not in Scenario # 2:Year 2 and Scenario # 3:Year 2 when the fine size and fine likelihood, respectively, is greater than initially.

Our goal is to demonstrate that factors other than the likelihood and size of any fine influence facilities' decisions to improve maintenance in the constructed baseline scenario. We examine this possible influence on baseline scenario responses using appropriate split sample tests: Mann-Whitney Tests for the continuous variables and Pearson Chi-Square Tests for the qualitative variables.

Since the same respondents reply to multiple scenarios, we can use the Matched Pairs Sign test to assess *Hypothesis 1* (Standard Deterrence) and *Hypothesis 3* (Specific Deterrence). Specifically, to test *Hypothesis 3*, we compare Scenario # 1:Year 2 to Scenario # 1:Year 1 in order to assess the effect of punishment without any upward ratcheting in fine likelihood or fine size. To test *Hypothesis 1*, we compare Scenario # 2:Year 2 to Scenario # 1:Year 2 in order to assess the effect of upward ratcheting in fine size conditional upon punishment, i.e., both scenarios involve punishment yet only Scenario # 2 involves an increase in fine size. We also compare Scenario # 3–Year 2 to Scenario # 1–Year 2 in order to assess the effect of upward ratcheting in fine likelihood conditional upon punishment. We use a one-sided test in the direction of increased compliance stemming from improved maintenance.

5.2.2. Multivariate Analysis: Probit Estimation

We next employ multivariate (parametric) analysis, which controls for other factors beyond the likelihood and size of any fine and permits a direct comparison of the influences of fine likelihood versus fine size on the maintenance decision. The decision to improve maintenance in each scenario represents a binary choice variable, indicating whether the facility chooses to improve maintenance in a particular scenario. Specifically, facility *i* in scenario *t* decides either to improve maintenance, as denoted by $y_{it}=1$, or the facility decides not to improve maintenance, as denoted by $y_{it}=0$.

To estimate this decision as a function of various explanatory factors, denoted as *X*, we employ a probit model. We motivate this model as a latent variable model, where the latent index, denoted as *y*,* reflects the difference between the two levels of expected utility:

y^* = EU(improve) - EU(do not improve).

We model this latent index as a linear functional relationship between the dependent variable, y*, and a set of explanatory factors:

$$y^*_{it} = \alpha + X_{it}\beta + \mu_{it},$$

where α represents the intercept term, β represents the array of slope coefficients related to the explanatory factors, and μ_{it} represents the error term. The facility decides to improve maintenance (y_{it}=1) if y^*_{it}>0; otherwise, the facility decides not to improve maintenance (y_{it}=0).

Based on the responses to the baseline scenario (i.e., Scenario # 1:Year 1), we estimate the relationship between the explanatory factors and the initial maintenance decision using a standard probit model (Maddala, 1983). Each facility responds only once to the baseline scenario; therefore, we rely upon cross-sectional variation in the explanatory variables to explain the facilities' maintenance decisions.

The explanatory variables fall into these categories: facility characteristics, individual respondent characteristics, government intervention histories, and attitudes / perceptions. We consider a variety of regressor sets, i.e., models. We tabulate only two of the models considered. Model A1 includes facility characteristics, individual respondent characteristics, and attitudes about environmental protection. Model A2 additionally includes the perception of fine effectiveness for inducing compliance. In the text we also report on other models considered, in particular, models that include government intervention histories.

When examining all of the scenario responses, we must address the panel structure of the

data. We restrict our estimation to the 237 respondents who answered all four scenario questions. In order to accommodate and exploit the panel structure, we estimate the constructed linear relationship using a random effects probit model, which implies a division of the error term, μ_{it}, into two components: θ_i, which reflects unobserved individual heterogeneity, and ϵ_{it}, which represents the usual idiosyncratic error term. In essence, θ_i represents a random element not known to the researcher yet specific to an individual respondent facility that does not vary across the four scenarios (which explains the omission of the subscript *t*). Use of the random effects probit estimator seems appropriate since the treatments imposed by the hypothetical scenarios are randomly assigned.

As part of this panel data estimation, we incorporate scenario indicators, which control for the sequence within the series of hypothetical scenarios. For example, the Scenario # 1:Year 2 indicator equals one when the observation applies to Scenario # 1:Year 2 and equals zero otherwise. In general, these scenario indicators should control for learning and/or fatigue on the part of respondents. In the case of Scenario # 1:Year 2, the scenario indicator identifies the influence of specific deterrence that stems from punishment without any increase in either the likelihood or size of any subsequent fine (*Hypothesis 3*).

The explanatory variables fall into these categories: fine likelihood and fine size if maintenance is not improved, facility characteristics, individual respondent characteristics, government intervention histories, attitudes / perceptions, and scenario indicators. Clearly, we cannot include the likelihood of a fine if maintenance is improved since it is constant across all scenarios and all respondents. We consider two classes of regressor sets, i.e., models. The first class of models excludes attitudes and perceptions, while the second class of models includes these factors. Within the first class, we tabulate two of the models considered. Model B1 includes only fine size and fine likelihood, representing the most parsimonious model possible and our primary

regressor set. Model B2 adds scenario indicators, facility characteristics, and individual respondent characteristics. Within the second class, we tabulate three models. Models B3 and B4 exclude the perception of fine effectiveness for inducing compliance, while Model B5 includes this perception. Model B4 includes the full array of facility characteristics, while Models B3 and B5 include only those facility characteristics based on publicly available data. Again, we report on other models considered, in particular, models that include government intervention histories.

Lastly, in order to compare the effects of fine likelihood and fine size, we log both factors before incorporating them into the random effects probit estimation so that we can interpret the estimated coefficients as semi-elasticities. In this regard, the two coefficients share the same unit of measurement: a percent change in each factor as it relates to the likelihood of improved maintenance.

5.3. Statistical Analysis of the Baseline Scenario Responses

As the first part of our statistical analysis, we examine the responses to the baseline scenario (Scenario # 1:Year 1) using both nonparametric split sample tests and probit estimation. Our goal is to demonstrate that factors other than the likelihood and size of any fine influence facilities' decisions to improve maintenance in the constructed baseline scenario. By achieving this goal, we provide evidence that the high proportion of improved maintenance responses may be consistent with a model where utility is affected by factors beyond expected fines and maintenance costs.

5.3.1. Nonparametric Split Sample Test Results

We first assess the split sample tests statistics, which are shown in Table 4.a. The Mann-Whitney test statistics, shown in Table 4.a.i, support the following conclusions. Larger facilities, as measured by the count of employees, are more likely to improve maintenance. More important, facilities whose environmental employees or managers possess a greater concern about

environmental protection are more likely to improve maintenance. Figure 1 graphs the distribution of these two environmental concern factors, conditional on the facility's baseline scenario response. As shown, the distribution is clearly shifted to the right (greater concern) for those facilities that chose to improve maintenance in the baseline scenario relative to those facilities that chose not to improve. This conclusion holds for both the concerns of environmental employees and management.

The Pearson Chi-Square Test statistics, shown in Table 4.a.ii, support the following conclusions. Major facilities are more likely to improve maintenance. Surprisingly, facilities who perceive fines as an effective tool for inducing compliance are less likely to improve maintenance, as are better educated respondents. We interpret these two latter results jointly. Well-educated individuals who believe that fines are effective at inducing compliance have sufficient understanding to not be deterred when the expected fine is relatively small.

5.3.2. Probit Estimation Results

We next examine the baseline scenario responses using probit estimation. Table 5 displays the estimation results. These results clearly indicate that factors beyond the fine likelihood and size influence maintenance decisions. In particular, managerial and environmental employees' concerns about environmental protection positively affect decisions; specifically, as concerns rise, the likelihood of improved maintenance increases. In addition, the likelihood of improved maintenance depends positively on facility size (count of employees) and negatively on the perceived effectiveness of fines and the individual respondent's educational attainment. These connections are consistent with the results from the univariate nonparametric test results, although the significance of some factors is weaker in the multivariate analysis.

We also consider models that include the recent history of inspections conducted at the specific facilities and enforcement actions taken against the specific facilities within the 24-month

period preceding the survey's completion. Regardless of the included regressors, these government intervention history factors never prove statistically significant at levels of 10 % or less. This lack of influence may indicate that individual facilities' experiences with inspections and enforcement did not seep into their hypothetical scenario responses. As important, the overall conclusions drawn from the probit estimation results are robust to the inclusion of these government intervention history factors.[19]

Thus, both sets of statistical evidence suggest that decisions to improve maintenance in the baseline scenario, where the explicitly defined costs are minimized by not improving maintenance, regardless of risk preferences, are not necessarily irrational. In particular, the degree of concern about environmental protection held by both facility environmental employees and management significantly influence environmental management decisions, revealing a decision process that expands beyond a simple calculus of costs. This evidence is consistent with *Hypothesis 4*.

5.4. Statistical Analysis of Pooled Scenario Responses

This sub-section examines the statistical results generated by assessing the responses to all of the scenarios. Our goal is to test the four main hypotheses developed in Section 3.

5.4.1. Nonparametric Matched Pairs Sign Test Results

We first examine pairs of responses to selected scenarios using cross-tabulations (shown in Table 4.b.i) and the Matched Pairs Sign test (shown in Table 4.b.ii). First, we compare Scenario # 1:Year 2 to Scenario # 1:Year 1 to assess the effect of punishment without any increase in fine likelihood or size (i.e., specific deterrence). The decisions of 27 respondents changed following the imposition of a fine, with 20 respondents shifting from no "improved maintenance" to "improved

[19] Years of experience in the NPDES system also never proves statistically significant at levels of 10 % or less in any considered model.

maintenance", while seven respondents did the opposite. These shifts collectively reflect a significant increase in "improved maintenance" (p-value=0.010; Matched Pairs Sign Test) and provide support for *Hypothesis 3*. Second, we compare Scenario # 2:Year 2 to Scenario # 1:Year 2 to assess the effect of an increased fine size. Table 4.b.i.II indicates that 16 respondents made decisions that differ between the two scenarios, with 14 of these respondents shifting towards improved maintenance, collectively representing a significant increase in improved maintenance (p-value=0.002; Matched Pairs Sign Test). This result supports *Hypothesis 1*. Third, we compare Scenario # 3:Year 2 to Scenario # 1:Year 2 to assess the effect of increased fine likelihood. Of the 17 respondents who changed their decisions, 14 shifted to improved maintenance, collectively representing a significant increase in improved maintenance (p-value=0.006; Matched Pairs Sign Test). This result also supports *Hypothesis 1*.

5.4.2. Random Effects Probit Estimation Results

Table 6 displays the random effects probit estimation results. These results demonstrate that both the likelihood of a fine and the size of any imposed fine significantly and positively influence maintenance decisions. This conclusion is fully robust to the choice of model. In particular, the fine likelihood- and size-related coefficient signs and degrees of statistical significance, as reflected in p-values, are independent of the chosen model, with p-values lying below 0.08 for all of the models. Moreover, once scenario indicators are incorporated as explanatory factors, the p-value lies between the narrow band of 0.05 and 0.08. Lastly, the coefficient magnitudes are highly similar across the models. Clearly, these results reveal that an increase in either the fine likelihood or fine size prompts improved maintenance, consistent with *Hypothesis 1*.

Next we explore *Hypothesis 2* by testing the null hypothesis of equal fine effects:

H_0: $\beta_p = \beta_F$.

As reported in Table 6, the test statistics cannot reject this null hypothesis regardless of the chosen model even though both individual coefficients are strongly identified; in other words, failure to discern β_p from β_F is not driven by weak individual signal-to-noise ratios. This failure to reject is consistent with risk-neutral preferences. Thus, our results support the sub-hypothesis of risk-neutral preferences (H2a) while failing to support the sub-hypotheses of risk-averse or risk-loving preferences (H2b and H2c).

Collectively, these results indicate that punishment with an upward ratcheting in the subsequent fine size or likelihood similarly generates deterrence leading to improved maintenance, which increases the probability of compliance. The "Scenario # 1:Year 2" indicator reveals that punishment without any such ratcheting also generates deterrence, with the estimated coefficient on this indicator significantly positive regardless of the chosen model. Independent of all other factors, especially fine likelihood and fine size, facilities are more likely to improve maintenance in "Scenario # 1:Year 2" after receiving a $ 10,000 fine for non-compliance with their effluent limits. This result suggests that a fine raises the salience of environmental management, prompting facilities to improve their maintenance, consistent with *Hypothesis 3*.[20]

Factors not associated with fine-related deterrence also influence maintenance decisions as with the estimation of the baseline scenario responses. Of most interest, managerial and environmental employees' concerns about environmental protection positively affect maintenance decisions, supporting *Hypothesis 4*, which posits that corporate culture influences facilities' environmental management decisions. Moreover, the influence of management concern is equal to the influence of environmental employee concern, as shown in Table 6.b. The influences of other

[20] The indicators for Scenario # 2 and Scenario # 3 are never significant; thus, a simple trend in decisions during the implementation of the scenarios seems an unlikely explanation for the statistical significance associated with the Scenario # 1:Year 2 indicator.

factors are more mixed, with only respondent education generating a significant (negative) effect in all models, consistent with our statistical results presented above. Results from all but one model suggest that major facilities are significantly more likely than minor facilities to improve maintenance.

We also consider models that include the recent history of inspections conducted at the specific facilities and enforcement actions taken against the specific facilities within the 24-month period preceding the survey's completion. Regardless of the composition of the other regressors, these government intervention history factors never prove statistically significant at levels of 10 % or less. As important, all of the conclusions drawn from the random effects probit estimation results are robust to the inclusion of these government intervention history factors.[21]

The results in this section, therefore, provide strong evidence in support of our four hypotheses. This evidence is robustly present in the results generated by both analytical methods and from the estimation of various models containing different regressor sets.

To gain some insight into the magnitude of the estimated effects, we compute the average marginal effects using the estimation results from Model B4, which represents the largest regressor set. (Use of other models generates similar marginal effects.) The calculated marginal effects reveal these conclusions. A one-percent increase in the likelihood of a fine prompts a 3.2 percentage point increase in the probability of improved maintenance. Similarly, a one-percent increase in the fine size prompts a 2.2 percentage point increase in the probability of improved maintenance. The imposition of a $ 10,000 fine following Year 1 of Scenario # 1 (i.e., baseline scenario) without any upward ratcheting in the likelihood or size of any subsequent fine (i.e., specific deterrence) prompts

[21] Years of experience in the NPDES system also never proves statistically significant when included as a regressor.

a 1.5 percentage point increase in the probability of improved maintenance. For comparison we assess the corporate culture factors. A one-unit increase in the degree of concern about environmental protection held by facility environmental employees prompts a 1.3 percentage point increase in the probability of improved maintenance, while a similar increase in the degree of concern about environmental protection held by facility management prompts a 0.8 percentage point increase.

6. Conclusions

This study investigates environmental management decisions made within a survey-based hypothetical scenario set. Our statistical analysis provides evidence supportive of our four theoretical hypotheses. First, facilities respond to increases in both fine size and fine likelihood (*Hypothesis 1*) with equal sensitivity (*Hypothesis 2a*). Second, facilities respond to punishment in the form of fines even without any increase in the likelihood or size of any subsequent fine (*Hypothesis 3*). Third, corporate culture in the form of concern about environmental protection on the part of facility management and environmental employees affects behavior (*Hypothesis 4*), with the influence of environmental employees appearing equal to the influence of management. These results are robust to the choice of analytical method – nonparametric univariate tests and multivariate estimation – and to the choice of regressor set used for estimation.

These results lead to the following policy implications. Since fine likelihood and fine size are equally effective deterrents, enforcement agencies should emphasize use of the less costly option. Typically, increases in fine size are less costly because the costs of imposing a fine are mostly independent of size. In addition, our results imply that enforcement agencies could induce greater compliance by imposing fines even without threat of greater monitoring and/or higher fines in the future, thereby, exploiting behavioral tendencies that depend on salience. Moreover, encouraging

facilities to cultivate a stronger corporate culture towards environmental protection could be an effective alternative policy approach.[22]

Finally, we assess the methods for exploring behavior. While other studies have surveyed managers on environmental attitudes, as far as we know, our study is the first to pose hypothetical scenarios to environmental managers. We claim that, by surveying those managers on the front line of making compliance decisions, we enhance the external validity of our results. With this claim in mind, our results suggesting equal sensitivity to fine likelihood and fine size, while consistent with the standard assumption of risk-neutral firms, do not conform with the results generated by experiments using student subjects and by empirical studies of general crime (both discussed in Section 2). Thus, our results suggest a cautious approach when extrapolating results from one type of participant to another type and from one context to another context.

[22] The NPDES system requires regulated facilities to report regularly their wastewater discharges. However, other regulatory systems do not require regular reporting on compliance with requirements, such as compliance with toxic and hazardous waste regulations. If the results of this study extend to regulated environmental activities where reporting is limited, then enforcement agencies may wish to target their interventions, e.g., inspections, on facilities with weaker corporate cultures as these facilities are more likely to be out of compliance.

Table 1

Hypothetical Scenarios: Construction of Scenarios # 2 and 3

Scenario # 2: Year 2		Scenario # 3: Year 2	
Subsequent Penalty Size ($)	Sample %	Subsequent Penalty Likelihood (%)	Sample %
20,000	21.4	20	21.4
50,000	25.1	40	25.1
100,000	28.8	60	28.8
200,000	24.7	99	24.7

Table 2

Summary Statistics of Additional Regressors

2.a. Means and Standard Deviations

Regressor	N	Mean	Standard Deviation
Organic Chemical Sector [a]	268	0.437	0.496
Inorganic Chemical Sector [a]	268	0.310	0.463
Major Facility [b]	268	0.384	0.487
Facility Age	260	44.50	24.56
Number of Facility Employees	263	251.5	488.5
Years of Experience in NPDES System	266	20.30	9.149
Education of Respondent: Some graduate education or graduate degree [c]	261	0.433	0.496
Age of Respondent	256	45.71	8.580
Gender of Respondent: Female [d]	267	0.176	0.381
Environmental Employee Concern about Environmental Protection [e]	260	8.896	1.331
Managerial Concern about Environmental Protection [e]	261	8.843	1.402
Perceived Effectiveness of Monetary Fines [f]	262	0.786	0.411
Inspection History [preceding 24 months] (count)	268	1.687	3.009
Informal Enforcement History [preceding 24 months] (count)	268	0.149	1.132
Formal Enforcement History [preceding 24 months] (count)	268	0.063	0.744

[a] Omitted category: “Other Chemicals” sectors.
[b] Omitted category: minor facility.
[c] Omitted category: less than “some graduate education”.
[d] Omitted category: male gender.
[e] Measured on a 1 to 10 scale, where higher values reflect greater concern.
[f] Omitted category: perception of fines not being effective at inducing compliance.

2.b. Distribution of Concerns about Environmental Protection:
Facility Environmental Employees and Management (Scale of 1 to 10)

Scale	Environmental Employees			Management		
	N	%	Cum %	N	%	Cum %
4	1	0.38	0.38	3	1.15	1.15
5	8	3.08	3.46	7	2.68	3.83
6	4	1.54	5.00	11	4.21	8.05
7	24	9.23	14.23	20	7.66	15.71
8	54	20.77	35.00	39	14.94	30.65
9	45	17.31	52.31	67	25.67	56.32
10	124	47.69	100.00	114	43.68	100.00

Table 3

Responses to Hypothetical Scenarios

3.a. Individual Scenarios

Scenario	Choice to Improve Maintenance			
	Yes		No	
	Frequency	%	Frequency	%
Scenario # 1: Year 1	213	86.94	32	13.06
Scenario # 1: Year 2	227	91.90	20	8.10
Scenario # 2: Year 2	238	96.75	8	3.25
Scenario # 3: Year 2	237	96.73	8	3.27

3.b. Sequence of Responses to Hypothetical Scenarios

Group	Choice to Improve Maintenance				N	%
	Scenario 1		Scenario 2	Scenario 3		
	Year 1	Year 2	Year 2	Year 2		
1	No	No	No	No	2	0.84
2	No	Yes	Yes	Yes	20	8.40
3	No	No	No	Yes	2	0.84
4	No	No	Yes	No	2	0.84
5	No	No	Yes	Yes	6	2.52
6	Yes	Yes	Yes	Yes	196	82.35
7	Yes	Yes	No	No	1	0.42
8	Yes	Yes	No	Yes	1	0.42
9	Yes	Yes	Yes	No	2	0.84
10	Yes	No	No	Yes	1	0.42
11	Yes	No	Yes	No	1	0.42
12	Yes	No	Yes	Yes	4	1.68

Table 4

Nonparametric Tests

4.a. Split Sample Tests: Choice to Improve or Not Improve Maintenance in Scenario 1 – Year 1

4.a.i. Continuous Independent Variables: Mann-Whitney Tests (two-sided)

Variable	Not Improve: Median	Improve: Median	Mann-Whitney Test	
			Z statistic	p-value
Facility Age	38.5	40	- 0.164	0.870
Facility Employees (count)	69	120	- 2.101	0.036
Age of Respondent	45.5	46.0	- 0.595	0.552
Environ Protection Concern: Environ Employees [a]	8	10	- 3.897	0.001
Environ Protection Concern: Management [a]	9	9	- 3.208	0.001

[a] The degree of environmental protection concern is measured on a scale of 1 to 10; if each level is treated as a discrete category and the distribution is assessed using a Pearson chi-square test, the resulting test statistics reveal strong statistical significance with p-values of 0.001 and 0.002, respectively, for environmental employees and management.

4.a.ii. Qualitative Independent Variables: Pearson Chi-square Tests

Variable	Category	Maintenance Decision		Pearson χ^2 Test	
		Not Improve	Improve	Statistic	p-value
		N (cond %)	N (cond %)		
Industrial Sub-sector [a]	Inorganic	10 (12.7)	69 (87.3)	2.79	0.248
	Organic	10 (9.8)	92 (90.2)		
	Other	12 (18.8)	52 (81.3)		
Facility Type	Minor	25 (16.6)	126 (83.4)	4.23	0.040
	Major	7 (7.5)	87 (92.6)		
Education of Respondent [b]	< Graduate	12 (8.8)	125 (91.2)	5.07	0.024
	≥ Graduate	20 (18.5)	88 (81.5)		
Gender of Respondent	Male	26 (12.8)	178 (87.3)	0.15	0.699
	Female	6 (15.0)	34 (85.0)		
Perceived Effectiveness of Fines	Not Effective	3 (5.5)	50 (94.5)	3.34	0.068
	Effective	29 (15.3)	161 (84.7)		

[a] Statistics for Chi-square tests of pairwise comparisons involving (1) Organic Chemical sub-sector versus "Other Chemical" and (2) Inorganic Chemical sub-sector versus "Other Chemical" sub-sector equal 1.63 and 0.01, respectively, p-values of 0.201 and 0.897, respectively.

[b] Statistic for Chi-square test of full set of the categories for respondent's education equals 18.05, with p-value of 0.003.

4.b. Matched Pairs of Certain Scenarios

4.b.i. Pairwise Comparisons of Scenario Responses: Choice to Improve Maintenance or Not

4.b.i.I. Scenario # 1:Year 1 vs Scenario # 1:Year 2

Scenario # 1:Year 1	Scenario # 1:Year 2	
	Not Improve	Improve
Not Improve	12	20
Improve	7	202

4.b.i.II. Scenario # 1:Year 2 vs Scenario # 2:Year 2

Scenario # 1:Year 2	Scenario # 2:Year 2	
	Not Improve	Improve
Not Improve	5	14
Improve	2	223

4.b.i.III. Scenario # 1:Year 2 vs Scenario # 3: Year 2

Scenario # 1:Year 2	Scenario # 3:Year 2	
	Not Improve	Improve
Not Improve	5	14
Improve	3	222

4.b.ii. Matched Pairs Sign Tests [a]

Deterrence and Updating	Scenario Pairings	One-sided p-values [b]
Specific without any updating	#1:Year 1 vs #1:Year 2	0.010
Specific with fine size updating	#1:Year 2 vs #2:Year 2	0.002
Specific with fine likelihood updating	#1:Year 2 vs #3:Year 2	0.006

[a] Each Matched Pairs Sign Test statistic equals the number of positive changes from "not improve" to "improve"; these numbers are shown in Table 4.b.i above.

[b] One-sided test in the direction of greater likelihood of improved maintenance.

Table 5

Probit Estimation of Decision to Improve Maintenance in Year 1 of Scenario # 1

Regressor	Model A1		Model A2	
	Coeff	p-value	Coeff	p-value
Organic Chemical Sector [a]	0.3451	0.236	0.3712	0.210
Inorganic Chemical Sector [a]	0.4719	0.125	0.5131	0.103
Major Facility [b]	0.1472	0.604	0.1212	0.673
Facility Age	0.0009	0.852	0.0006	0.903
Number of Facility Employees	0.0011	0.097	0.0011	0.097
Education of Respondent: Some graduate education or graduate degree [c]	- 0.3989	0.104	- 0.3987	0.110
Age of Respondent	0.0093	0.508	0.0068	0.638
Gender of Respondent: Female [d]	- 0.0709	0.829	- 0.1011	0.759
Environmental Employee Concern about Environmental Protection	0.2031	0.027	0.2250	0.017
Managerial Concern about Environmental Protection	0.1606	0.071	0.1547	0.085
Perceived Effectiveness of Fines [e]			- 0.5915	0.101
Sample Size	229		228	
Log-likelihood Ratio Test (p-value)	28.40 (0.002)		31.43 (0.0009)	
Pseudo R^2	0.163		0.181	

All estimations also include an intercept term.
[a] Omitted category: "Other Chemicals" sectors.
[b] Omitted category: minor facility.
[c] Omitted category: less than "some graduate education".
[d] Omitted category: male gender.
[e] Omitted category: perception of fines not being effective at inducing compliance.

Table 6

Random Effects Probit Estimation of Decisions to Improve Maintenance in all Scenarios

6.a. Exclusion of Attitudes and Perceptions

Regressor	Model B1		Model B2	
	Coeff	p-value	Coeff	p-value
Fine Size (log)	0.7189	0.000	0.6899	0.055
Fine Likelihood (log)	0.8826	0.000	0.9809	0.056
Scenario # 1: Year 2 [a]			0.5449	0.021
Scenario # 2: Year 2 [a]			0.3292	0.590
Scenario # 3: Year 2 [a]			0.1235	0.861
Organic Chemical Sector [b]			0.2401	0.578
Inorganic Chemical Sector [b]			0.1286	0.775
Major Facility [c]			0.9903	0.020
Education of Respondent: Some graduate education or graduate degree [d]			- 1.0586	0.007
Age of Respondent			0.0433	0.046
Gender of Respondent: Female [e]			- 0.0214	0.963
LR Test of H_0: Equal Fine Effects (p-value)	0.45 (0.501)		0.28 (0.598)	
Sample Size	982		962	
Wald Test of Slope Coefficients (p-value)	23.13 (0.000)		31.40 (0.001)	
LR Test of Random Effects (p-value)	79.93 (0.000)		72.39 (0.000)	

All estimations also include an intercept term.
[a] Omitted category: Year 1 of Scenario # 1 (i.e., baseline scenario).
[b] Omitted category: "Other Chemicals" sectors.
[c] Omitted category: minor facility.
[d] Omitted category: less than "some graduate education".
[e] Omitted category: male gender.

6.b. Inclusion of Attitudes and Perceptions

Regressor	Model B3		Model B4		Model B5	
	Coeff	p	Coeff	p	Coeff	p
Fine Size (log)	0.7146	0.059	0.7203	0.075	0.7305	0.055
Fine Likelihood (log)	1.0117	0.060	1.0311	0.075	1.0341	0.056
Scenario # 1: Year 2 [a]	0.5201	0.030	0.5242	0.037	0.5249	0.029
Scenario # 2: Year 2 [a]	0.3196	0.607	0.4458	0.496	0.3036	0.625
Scenario # 3: Year 2 [a]	0.1117	0.877	0.2255	0.767	0.0912	0.900
Organic Chemical Sector [b]	0.0398	0.927	0.1411	0.760	0.0301	0.945
Inorganic Chemical Sector [b]	0.1603	0.717	0.3940	0.426	0.1788	0.689
Major Facility [c]	0.7630	0.063	0.5143	0.260	0.7434	0.072
Facility Age			- 0.0053	0.476		
Number of Facility Employees			0.0016	0.143		
Education of Respondent: Some grad education or graduate degree [d]	- 0.8211	0.028	- 0.6527	0.101	- 0.8411	0.026
Age of Respondent	0.0268	0.199	0.0183	0.404	0.0258	0.219
Gender of Respondent: Female [e]	- 0.0268	0.703	- 0.4088	0.409	- 0.1679	0.716
Environmental Employee Concern about Environmental Protection	0.3782	0.009	0.4244	0.007	0.3865	0.008
Managerial Concern about Environmental Protection	0.2212	0.084	0.2484	0.077	0.2166	0.092
Perceived Effectiveness of Fines [f]					- 0.3654	0.437
LR Test H_0: Equal Fine β (p-value)	0.26 (0.608)		0.26 (0.601)		0.27 (0.602)	
LR Test H_0: Equal Concern β (p-value)	0.49 (0.486)		0.53 (0.465)		0.56 (0.455)	
Sample Size	954		920		950	
Wald Test: Slope β's = 0 (p-value)	34.19 (0.001)		30.76 (0.009)		34.17 (0.002)	
LR Test of Random Effects (p-value)	54.37 (0.000)		47.84 (0.000)		54.85 (0.000)	

All estimations also include an intercept term.

[a] Omitted category: Year 1 of Scenario # 1 (i.e., baseline scenario).

[b] Omitted category: "Other Chemicals" sectors.

[c] Omitted category: minor facility.

[d] Omitted category: less than "some graduate education".

[e] Omitted category: male gender.

[f] Omitted category: perception of fines not being effective at inducing compliance.

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Figure 1: Distribution of Concern about Environmental Protection by Scenario #1: Year 1 Response