How Does the Deterrence Effect of Regulatory Enforcement Differ between Privately and Government-Owned Facilities?

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Abstract: Environmental protection laws apply to both privately owned and government-owned facilities. Regulatory agencies take actions against facilities to induce compliance. Privately owned and government-owned facilities' responses to enforcement may differ because of differences in objective functions, constraints, and incentives. We ask: do privately owned facilities and government-owned facilities respond differently to inspections and enforcement actions? We answer this question in the context of the U.S. Clean Water Act. Our analysis exploits monthly data that cover major facilities in all sectors within six U.S. states, comprising over one-third of all the major facilities operating in the U.S., from 1997 to 2016. We distinguish between government-owned municipal wastewater facilities, i.e., publicly owned treatment works (POTWs), and other government-owned facilities, e.g., hospitals, power plants. We find that, conditioning on past violations, POTW facilities receive more regulatory enforcement than privately owned facilities, while non-POTW government-owned facilities receive less. More importantly, while we find no significant evidence of a deterrence effect of enforcement actions for privately owned facilities, both kinds of government-owned facilities show evidence of deterrence. Thus, in this context, enforcement against government-owned facilities is in some cases at least as strong as enforcement against privately owned facilities, and elicits a stronger deterrence response.

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1. Introduction

Governments regulate privately owned entities, like manufacturing facilities, and government-owned entities, such as municipal wastewater treatment facilities owned by local governments. How well regulation achieves its desired ends in these two settings depends in part on how strong a deterrent effect regulatory enforcement generates in each setting. Do government-owned entities react more or less strongly to regulatory enforcement as compared to those that are privately owned? We examine this question in the context of the enforcement of water pollution regulations in the United States, i.e., the U.S. Clean Water Act.

Various laws seek to protect and improve the natural environment. Many major U.S. environmental laws, such the Clean Air Act, work to achieve these goals by constraining the amount of pollution emitted by point sources, such as industrial factories. Towards this end, the U.S. Environmental Protection Agency (EPA) has created a permitting system that imposes limits on the amount of pollution ("effluent limits") emitted by individual point sources ("regulated facilities"). Effluent limits only help to protect the environment to the extent that regulated facilities comply with these limits. The EPA's tools to induce compliance include regulatory monitoring (i.e., inspections) and enforcement actions (e.g., fines), along with other tools (e.g., technical assistance). Both inspections and enforcement actions represent regulatory pressure.

Theoretically, government-owned facilities might respond more or less strongly to regulatory pressure as compared to privately owned facilities. A bigger response reflects greater deterrence, while a smaller response reflects weaker deterrence. On the negative side, weaker deterrence may result for government-owned facilities if they are not as adept at minimizing costs; weaker deterrence would lead them to insufficiently react to expected financial costs of noncompliance. In addition, government-owned facilities may face binding budget constraints in the short run because raising public funds requires a time-intensive process, e.g., securing voter approval for bond issuance. On the positive side, a stronger deterrent effect may result if government-owned facilities are more sensitive to social welfare impacts; greater sensitivity may cause these facilities to be more driven to improve compliance after an inspection or enforcement action. Similarly, if government-owned facilities share closer relationships with their regulators, these facilities might act more collaboratively with their regulators to address quickly non-compliance problems in response to inspections or enforcement. On the other hand, these closer relationships might prompt government-owned facilities to discount the threat of further inspections or enforcement, implying a weaker deterrent effect. (Indeed, these relationships may

actually lead to fewer inspections and/or weaker enforcement, as Konisky and Teodoro, 2016 demonstrate; this situation would lead to worse environmental performance for goverment-owned facilities.)

Given these differences, a strongly policy-relevant research question presents itself: do privately owned facilities and government-owned facilities respond differently to regulatory pressure? We attempt to answer this question in the context of compliance with the U.S. Clean Water Act.

Since the early 1970s, regulatory agencies have primarily used inspections of polluting facilities and enforcement actions against violating facilities to induce compliance with environmental laws. The economics literature is rich with empirical analysis that examines the efficacy of such government interventions across a wide range of environmental media and economic sectors (e.g., Gray and Deily, 1996; Laplante and Rilstone, 1996; Helland, 1998b, a; Earnhart, 2004b, c). However, these studies do not assess heterogeneity with respect to ownership type, specifically, differences between privately owned facilities and government-owned facilities. As the only similar study, Earnhart (2009) explores heterogeneity within the category of privately owned facilities by comparing facilities owned by publicly held firms and facilities owned by other types of organizations (e.g., partnerships), finding that publicly held firms show similar deterrence effects for most sanctions, with some variation across sanction types.

A separate literature explores agency decisions over regulatory interventions. Konisky and Teodoro (2016) examine the difference between government-owned and privately owned facilities regulated under the U.S. Clean Air Act. The authors focus on agencies' enforcement decisions and demonstrate weaker enforcement against government-owned facilities, inferring that these are not arms-length regulatory relationships. This result differs from what we find in the context of U.S. water pollution enforcement.

Our study contributes to these literatures by exploring the influence of ownership type on the effects of government interventions, which include both enforcement actions and regulatory inspections, on environmental compliance by facilities regulated under the U.S. Clean Water Act, as well as the direct impact of ownership structure on compliance. Our study examines compliance with the U.S. Clean Water Act on the part of both privately owned and government-owned facilities operating between September 1997 and January 2016. (Technically, in the case of private ownership, private investors own a *firm*, which operates a *facility*; however, for brevity, we ignore this distinction and refer to only "facilities", consistent with the regulatory structure of the Clean

Water Act, which constrains discharges from facilities.)

Our sample includes government-owned facilities that are municipal wastewater treatment facilities, i.e., publicly owned treatment works (POTWs), and government-owned facilities that are not POTWs, e.g., public hospitals, power plants, as well as privately owned facilities. For our empirical analysis, we construct a facility-by-month panel using monthly data that cover major facilities operating in all sectors within six of the U.S. states with the most regulated facilities, which represent over one-third of all U.S. major facilities. For these six large states, we possess complete data on state enforcement actions, drawn from state agency databases, combined with data on federal enforcement actions, drawn from an EPA database. Our sample includes 728 privately owned facilities and 1,787 government-owned facilities, which comprise 1,346 municipal wastewater treatment facilities and 441 other government-owned facilities. We perform fixed effects and random effects panel regressions to determine the influence of government ownership on the deterrence-related impact of enforcement on compliance outcomes. We examine both effluent violations and reporting violations, arguing that the latter should be immune to concerns about omitted variables correlated with both ownership and compliance, as such correlations would be driven by systematic differences in discharge-relevant operations between privately and government-owned facilities. The regressions control for lagged compliance to ensure that persistence (i.e., serial correlation) in non-compliance does not bias our results. Our analysis assumes that any differential in how privately and government-owned facilities respond to enforcement, as measured by their later compliance with discharge limits and reporting requirements, is attributable to the difference in ownership (conditional on control factors).

The results of our statistical analysis support the following conclusions. While government-owned POTWs generate more effluent violations than privately owned facilities, they generate fewer reporting violations. In contrast, government-owned non-POTWs generate fewer of both kinds of violations. While the latter facilities receive less regulatory enforcement than privately owned facilities, government-owned POTWs receive more, even conditioning on past violations. Lastly, we find some evidence of deterrence for both kinds of government-owned facilities, yet find no significant evidence of deterrence for privately owned facilities. Government-owned POTW facilities respond more strongly to both formal enforcement and informal enforcement in the case of effluent violations and more strongly to formal enforcement in the case of reporting violations, while government-owned non-POTW facilities respond more strongly to inspections in the case of reporting violations.

These results possess important policy implications. First, we do not find evidence in the U.S. water pollution context that regulators "go easy" on government-owned entities. Second, regulatory interventions against government-owned entities effectively improve environmental performance; thus, depending on the associated costs, increases in these actions may be warranted. Third, private entities do not measurably respond to government interventions; this result requires further investigation and attention. Further, the results offer broader implications about the behavior of government entities. We find evidence that federal and state governments do not necessarily "go easy" when regulating local governments, but may actually regulate them more strictly, and that non-pecuniary motivations to improve social welfare broadly or at least the environment narrowly may prove important factors shaping how government entities operate.

The rest of our study elaborates on these points. Section 2 reviews the relevant literature. Section 3 describes the regulatory context. Section 4 constructs a conceptual framework. Section 5 depicts the econometric framework. Section 6 describes the data. Section 7 reports and interprets the results of the econometric analysis. Section 8 concludes.

2. Literature Review

This section reviews three strands of the literature. One strand offers theoretical analysis on the enforcement of environmental laws. The second strand offers empirical analysis on compliance with environmental protection laws. The third strand explores agencies' regulatory intervention decisions.

2.1. Enforcement of Environmental Laws: Theory

In economics, most theoretical analysis examining the enforcement of environmental laws focuses on the deterrence approach to enforcement, in which the enforcement agency monitors the compliance of regulated facilities and deters non-compliance by imposing sanctions in response to violations. See Becker (1968) for the theoretical foundation; see Polinsky and Shavell (2000) for a review of this literature.

On the other hand, the pecuniary maximization model implied by a deterrence approach need not explain the behavior of regulated entities. One reason that behavior might diverge is, as Gneezy et al. (2011) describe from a substantial literature grounded in models like Bénabou and Tirole (2006) and Frey and Jegen (2001), extrinsic motivations can backfire for various reasons, including a reduced ability to signal altruistic intention and a reframing of the nature of an interaction. This literature further demonstrates that intrinsic motivations can drive pro-social behavior even without extrinsic forces like sanctions. We are not aware of theoretical models

applying these ideas in the context of deterrence designed to improve environmental performance.

2.2. Compliance with Environmental Protection Laws

The second literature strand offers empirical analysis exploring the various factors influencing regulated facilities' environmental compliance decisions. Within this strand, most studies emphasize the role of regulatory pressure, generally in the form of interventions such as inspections and enforcement actions. Stafford (2002) analyzes the effect of a revision to the EPA penalty policy on facilities' compliance with hazardous waste regulations. Telle (2009) finds that the threat of inspections reduces firms' probability of violations of environmental regulations. Earnhart (2004c) examines the effects of both inspections and enforcement actions on municipal wastewater treatment facilities' extent of compliance with wastewater discharge limits; for both types of interventions, increased regulatory pressure leads to better compliance. Similarly, Shimshack and Ward (2005) analyze the importance of enforcement on pulp and paper manufacturing facilities' compliance with wastewater discharge limits; the authors conclude that increases in sanctions against the facility itself and against other similar facilities both lead to better compliance.

Other studies in this literature strand emphasize the roles of other types of external pressure, such as customer pressure and investor pressure. For example, several studies show pressure from local communities can also encourage compliance (Henriques and Sadorsky, 1996; Pargal and Wheeler, 1996; Dasgupta et al., 2000; Becker, 2003; Earnhart, 2004a; Gangadharan, 2006).

Nearly all of the previous empirical studies of regulatory pressure explore the deterrence model by examining the effect of regulatory interventions on facility-level or firm-level environmental performance or management (Gray and Deily, 1996; Laplante and Rilstone, 1996; Earnhart, 2004b, c; Gray and Shadbegian, 2004; Shimshack and Ward, 2005).[1] However, some recent studies explore behavioral factors. For example, Raff and Earnhart (2018) examine the role of behavioral factors within the context of wastewater-related enforcement. As another example, in a rare study investigating reporting violations (as we do), Benami et al. (2023) find that a reminder email message improves compliance with discharge reporting requirements.

Yet another stream of research explores the effects of firm or facility characteristics. We focus our review on studies of ownership type or structure. Earnhart and Lizal (2006) examine the effect of ownership structure – state ownership versus private ownership – on air pollutant emissions in the Czech Republic during the transition from communist rule, finding that state

[1] Gray and Shimshack (2011) thoroughly review this literature.

ownership reduces emissions. Earnhart and Leonard (2013) examine the effect of different private ownership structures on environmental management effort; they find stronger efforts from facilities owned by privately held firms as compared to publicly held firms. However, the authors do not examine government ownership. Konisky and Teodoro (2016) contrast government-owned and privately owned entities with regard to their compliance with the U.S. Clean Air Act and Safe Drinking Water Act. They find that government ownership is associated with weaker regulation and worse environmental performance. Wallsten and Kosec (2008) find no impact of government versus private ownership on community water systems' compliance with the Safe Drinking Water Act overall but find that benchmark competition between jurisdictions does improve performance for government-owned facilities.

However, no previous study explores the influence of firm or facility characteristics on deterrence effects of regulatory interventions, with two exceptions. As one exception, Earnhart (2009) explores the influence of firm and facility characteristics on the deterrence generated by inspections and enforcement against U.S. chemical manufacturing facilities regulated under the Clean Water Act. In particular, Earnhart (2009) compares facilities owned by publicly held (privately owned) firms and facilities owned by other types of organizations (e.g., privately held firms), with mixed and mostly null results. As the other exception, Earnhart and Segerson (2012) explore the influence of firm-level financial status – profitability, solvency, liquidity – on the effects of regulatory interventions on U.S. manufacturing facilities. They show that the influence of these factors is theoretically ambiguous and empirically demonstrate that firms with healthier finances respond more strongly to interventions. Still, we are aware of no study that examines the influence of government versus private ownership on deterrence.

2.3. Government Agency Intervention Decisions

The third literature strand explores government agency intervention decisions. We focus on interventions related to environmental protection laws. Several studies examine environment-related regulatory inspections (Deily and Gray, 1991; Dion et al., 1998; Helland, 1998a; Stafford, 2002, 2003; Earnhart, 2004b, c; Gray and Shadbegian, 2004; Rousseau, 2007; Eckert and Eckert, 2009). These studies of inspections examine factors influencing inspection decisions, such as a facility's compliance history, firm and facility characteristics (e.g., size), regulatory budgets, and local community characteristics (e.g., employment). We are only aware of one previous study that explores the effect of ownership type on agency intervention decisions. Konisky and Teodoro (2016) examine agency penalty decisions in the context of the U.S. Clean Air Act and Safe

Drinking Water Act and find that agencies enforce less rigorously against government-owned facilities.

2.4. Contributions

Our study contributes to all three literature strands. Our study contributes to the theoretical literature on public enforcement by constructing a model that captures the ways in which privately owned and government-owned facilities might behave differently in their reactions to enforcement. Our study also contributes to the empirical literature on environmental compliance by exploring the role of ownership type in shaping regulated entities' compliance in the face of inspections and enforcement actions. And our study contributes to the literature on government agency intervention decisions by examining empirically how ownership type affects regulatory attention.

3. Regulatory Context of the Clean Water Act

Our study examines the wastewater discharged by facilities permitted within the U.S. Clean Water Act's National Pollutant Discharge Elimination System (NPDES) between 1997 and 2016 and regulatory interventions taken by EPA and state agencies to ensure compliance with NPDES limits during this period.

3.1. National Pollutant Discharge Elimination System

The Clean Water Act (CWA) seeks to protect and restore surface water quality. To this end, the CWA primarily controls wastewater discharges from point sources.[2] The EPA created the National Pollutant Discharge Elimination System (NPDES) to control these point source discharges. The main form of control is the issuance of facility-specific permits, which identify pollutant-specific discharge limits imposed on regulated facilities. Permits are issued and re-issued generally on a 5-year cycle by the EPA or by state agencies where they are authorized to do so.

To establish discharge limits for individual facilities' permits, the issuing agency considers any relevant Effluent Limitation Guideline standard and water quality-based standard. The former is designed to require a minimum level of wastewater treatment for a given industry and the latter is designed to ensure that the water body receiving the discharges meets ambient surface water quality standards. A potential limit is calculated under each standard. The permitting agency writes the stricter of the two potential limits into the permit. Thus, due to considerations over local

[2] Point sources directly discharge into a water body, usually from a pipe or outfall. In contrast, non-point sources generate discharges more diffusely (e.g., through agricultural run-off), and industrial users discharge into municipal wastewater collection systems. The CWA requires municipal systems to manage these indirect discharges.

ambient water quality, discharge limits differ across facilities, even within the same industry at the same moment in time, and vary over time. The permitted discharge limit represents a performance-based standard. Compliance with this standard is based on a facility's discharges. Thus, each facility can use any abatement method to comply with its permitted limit. (Our study does not examine the abatement efforts expended by regulated facilities.)

The CWA requires facilities regulated under the NPDES program to monitor their discharges for specified pollutants. Facilities report discharge data and compliance with limits through periodic Discharge Monitoring Reports (DMRs) sent to the permitting authorities. Our study explores all pollutants regulated by facilities' permits.[3,4]

The NPDES program distinguishes between major facilities and minor facilities. Generally, major facilities are larger and discharge more wastewater.[5] Federal guidelines prompt the EPA and state agencies to scrutinize major facilities much more closely than minor facilities (Earnhart, 2009; Earnhart and Segerson, 2012; Earnhart and Harrington, 2014).

The NPDES program regulates discharges from point sources, which fall into one of two main categories: municipal sources and industrial sources. Our study explores both municipal and industrial sources. Municipal wastewater treatment facilities treat wastewater generated by households and some businesses known as "industrial users." Other than these industrial users of municipal wastewater treatment services (which we exclude from our study), industrial sources discharge directly into a surface waterbody. All municipal sources are government-owned POTW operations. Industrial sources divide between privately owned facilities and government-owned non-POTW facilities.

Despite the differences in ownership and sector (municipal treatment versus industrial), the

[3] Permits define: (1) the frequency with which facilities must submit reports (typically monthly or quarterly); (2) limits on the average discharge level and/or maximum level for a given period (e.g., month), and the minimum discharge level in the case of pH. Permits include limits that place a cap on discharges measured as a concentration (e.g., milligrams of pollutant per liter of effluent) and/or as a quantity (e.g., pounds per day). For simplicity and comparability across facilities, our outcomes of interest relate to noncompliance, rather than comparing discharges to limits.

[4] As noted above, regulated facilities monitor and self-report their discharges. Therefore, inspections are not necessary to assess discharge compliance. In fact, they are usually *unable* to assess compliance: most inspections do not sample discharges and even sampling inspections typically only sample for a short period, such as one day, rendering them unable to assess compliance with an effluent limit, which cover longer periods, like a full month. (The Clean Water Act impose no daily or weekly limits even though monitoring requirements may apply to a daily or weekly period.)

[5] 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; any discharger with 80 points or more is a "major facility."

three groups of facilities discharge a highly common set of pollutants. While privately owned facilities produce a larger variety of pollutants than either type of government-owned facility, the most prevalent pollutants are very similar across the three categories. For example, the EPA-designated "conventional pollutants" of Biological Oxygen Demand (BOD) and total suspended solids (TSS) are highly prevalent in all three categories. Consequently, the end-of-pipe treatment technologies also prove reasonably similar.

To induce compliance, EPA and authorized state agencies inspect facilities and take enforcement actions against non-compliant facilities. Inspections represent the main monitoring activity and prove central to environmental agencies' efforts to monitor compliance and collect evidence for enforcement (Wasserman, 1984). This regulatory monitoring supplements facilities' self-monitoring, as noted above. Inspections also help to maintain a regulatory presence (Environmental Protection Agency, 1990). In addition, agencies often use inspections to offer compliance assistance (Earnhart, 2004b). Agencies also use a mixture of informal enforcement actions (e.g., warning letters) and formal enforcement actions, which include penalties (i.e., fines).[6]

3.2. Regulatory Structure

Both the EPA and nearly all state agencies possess the authority to issue permits, inspect NPDES facilities, and take enforcement actions against non-compliant facilities. For state agencies, this authority is called "primacy."[7] To obtain approval for NPDES primacy, a state agency must demonstrate the regulatory capacity (including the legal authority and resources) to administer the NPDES program. While the EPA retains authority to monitor and impose sanctions on regulated facilities in all states, regardless of primacy, authorized state regulatory agencies are primarily responsible for monitoring and enforcement. For regulated facilities in states without primacy, EPA regional offices are fully responsible for monitoring and enforcement. For regulated facilities in states with primacy, EPA regional offices generally conduct inspections and take enforcement actions when state agencies fail to intervene or when federal pressure may be needed for inducing compliance (Earnhart, 2004a).

As noted above, both federal and state agencies enforce the Clean Water Act by issuing

[6] Formal enforcement requires involvement of a court; informal enforcement does not. The CWA authorizes the EPA to impose administrative penalties using administrative proceedings that involve dedicated enforcement officials or to bring suit in federal court to impose judicial penalties.

[7] Most states obtained NPDES primacy in the 1970's or 1980's. Most of the states in our sample held primacy for the entire sample period, except that Texas obtained primacy in September 1998 and Louisiana in August 1996.

warning letters or initiating and prosecuting cases before judges who are able to impose fines. Lower-level personnel at the EPA and state agencies possess broad discretion over inspections, deciding whom to inspect and when. Similarly, lower-level agency personnel possess broad discretion over informal enforcement actions: whom to take enforcement actions against and when.

Lawyers at environmental agencies are responsible for prosecuting enforcement cases before administrative judges or forwarding cases to the Department of Justice (DOJ) with a request for prosecution before civil judges. For example, lawyers at EPA regional offices may initiate an administrative proceeding to impose an administrative sanction; alternatively, these offices may request that the DOJ initiate a civil court proceeding to impose a civil sanction on facilities that are seriously non-compliant. These lawyers operate with much discretion. Once agency or DOJ lawyers initiate enforcement proceedings, administrative or civil judges decide on the imposition of formal sanctions.

4. Conceptual Framework

This section sketches a conceptual framework from which we derive testable hypotheses. The framework focuses on channels through which differences between government ownership and private ownership differentially affect compliance, enforcement, and deterrence. We focus on differences between government and private ownership in operational factors, social preferences, and budget constraints.[8]

4.1. Fundamental Elements

In our framework, a single investor owns a single firm. The investor is a private individual or a government. To simplify, we assume that the single firm owns a single facility and a single manager operates the individual facility i in period t. This facility manager represents the decision-maker in our conceptual framework.[9] Each facility faces environmental regulations, imposed within its NPDES permit, with which it must comply. For simplicity, the facility generates a single pollutant. The facility must report its discharges $D_{it,}$ of that pollutant and keep discharges at or below the NPDES permit limit, L_{it}. In each period t, the manager chooses the extent of effort the

[8] We leave aside the notion that government-owned facilities may focus less on cost minimization in the realm of corporate environmental management, as studied by Earnhart and Lizal (2006). We also ignore the notion that government-owned facilities may face a more complex decision-making context, with more agents participating in the decision-making process and different agents facing different accountabilities.

[9] In practice, a single facility manager is not the only person involved in decision-making. For example, facilities commonly hire consultants. As another example, government-owned municipal facility managers frequently engage public works directors on matters of environmental management. We hold constant any influence of agents we do not model; all that we require is for the motivations we describe to apply to some agent with decision-making power even if this agent is not the sole decision-maker.

facility expends on reporting, Z_{it}, and the extent of abatement effort, A_{it}. We define R_{it} as indicating whether the facility has a reporting violation: if the facility correctly reports its discharges, it is compliant with the reporting requirement and $R_{it} = 0$; otherwise, the facility is non-compliant and $R_{it} = 1$. We define C_{it} as indicating an effluent violation: if discharges are at or below the permit limit, $D_{it} \leq L_{it}$, the facility is compliant with its limit and $C_{it} = 0$, otherwise, $D_{it} > L_{it}$, and $C_{it} = 1$.

The facility's reporting and discharges are subject to random fluctuations due to personnel issues and weather conditions, among other factors. Thus, we do not model a deterministic choice of whether to be in compliance on either dimension, as in Earnhart and Segerson (2012). Instead, the facility manager can increase the *likelihood* of reporting compliance by expending greater reporting effort, Z_{it}, and increase the *likelihood* of effluent compliance by expending greater abatement effort, A_{it}. Thus, R_{it} is a decreasing function of Z_{it} denoted as R_{it} (Z_{it}), and C_{it} is a decreasing function of A_{it} denoted as C_{it} (A_{it}).

We assume greater stochasticity in translating abatement effort A_{it} into effluent compliance C_{it} than in translating reporting effort Z_{it} to reporting compliance R_{it}, as physical factors subject to random fluctuations can influence effluent levels significantly. Further, we assume that municipal wastewater treatment plants have less control over their influent and quantity of "production" than other facilities. Thus, they are subject to greater stochasticity in the translation of abatement effort A_{it} into effluent compliance C_{it} as compared to other facilities.

The facility manager derives utility from the facility's net profits, which we assume motivates them extrinsically (e.g., through salary), and with intrinsic rewards, such as adherence with norms in professional organizations, i.e., professional norms, and local communities, i.e., social norms. We assume the manager maximizes expected utility given risk-neutral preferences.

We first construct a standard model of compliance focusing on the certainty and severity of enforcement exerted by regulatory authorities. We then describe additional factors affecting compliance, namely, pro-social motivations, external benefits, and budget constraints.

4.2. Standard Model of Compliance

We adapt the Becker (1968) economic model of crime. The facility manager's utility U_{it} depends on the facility's production-based profits, Π_{it}. The facility faces reporting effort costs of w per unit of Z_{it} and abatement costs of k per unit of A_{it} in each period t. The regulatory agency can punish the facility for reporting violations or effluent violations by taking enforcement actions. These actions, which may be in the form of fines, impose a costly burden on the facility, denoted, in monetary equivalent terms, as B. The magnitude B is a function of both effort levels, $B(Z_{it}, A_{it})$.

The likelihood of a burdensome enforcement action, denoted P, is also a function of both effort levels, $P(Z_{it}, A_{it})$. The risk neutral facility manager's expected utility function is thus:

$$E(U_{it}) = \Pi_{it} - wZ_{it} - kA_{it} - \int [P(Z_{it}, A_{it}) \times B(Z_{it}, A_{it})] . \quad (1)$$

The likelihood of a violation may vary by violation type and across ownership types. Reporting violations are less stochastic than effluent violations. Reporting effort, however, is surely cheaper than abatement effort. Additionally, municipal wastewater treatment facilities face greater variance in their influent (wastewater entering the treatment operations), and this variance undermines these facilities' ability to avoid effluent violations as compared to other types of facilities, as previously noted. Thus, the likelihood of an effluent violation is greater for government-owned POTWs than other facility types.

While we do not develop a full model of the decision-making of the regulatory agency, we assume that the agency seeks to minimize total social costs, comprising pollution damage costs and compliance costs. The agency knows that the facility manager's optimand excludes some of these costs and seeks to induce optimal effort through its choice of P and B (Becker, 1968). However, the agency may be constrained in how much enforcement it can pursue due to political limitations, a binding budget constraint, or other factors. Therefore, we predict that the agency allocates enforcement to prioritize: (1) violations that cause greater social damages (e.g., excess pollution rather than misfiled paperwork), and (2) entities that respond more strongly to enforcement actions (i.e., those with a stronger deterrence reaction). An alternative model in which the regulator seeks to maximize compliance subject to a budget constraint (rather than minimize total social costs) yields the same predictions.

Since P and B are not explicitly announced by the agency, a facility manager must choose an effort level based only on the manager's *perceptions* of P and B, which we denote as $\beth$ and $\beth$, respectively. Consistent with previous empirical studies (e.g., Earnhart, 2009), we allow these perceptions to depend on recent enforcement burdens imposed in past periods on the manager's own facility, B_{it-1},[10] and on other similar facilities, B_{jt-1}, where $j \neq i$ (Sah, 1991). The former reflects specific deterrence, while the latter reflects general deterrence (Cohen, 2000; Earnhart, 2009;

[10] For simplicity, our notation implies that the manager only responds to enforcement in the single preceding period; in our empirical specification, we allow compliance in any month to depend on enforcement over the preceding 12 months.

Earnhart and Friesen, 2017). Both B_{it-1} and B_{jt-1} measure the total sum of recent costly enforcement burdens, which reflects both the likelihood and severity of enforcement since the sum includes zero values, i.e., the absence of enforcement burdens.[11] The perceived enforcement burden magnitude, Ɓ, and the perceived enforcement likelihood, ƥ, are both rising in both B_{it-1} and B_{jt-1}. Thus, our simplest model indicates that the agency can induce future compliance by imposing more or bigger enforcement burdens on the individual facility or other similar facilities, which increases the perceived likelihood or severity of an enforcement burden. (See Miceli et al., 2022, for a thorough analysis of this process.)

We summarize the standard model's predictions in a set of hypotheses labeled with "*S*" (where "*S"* stands for the "standard" model).

Hypothesis S.1: The likelihood of non-compliance does not differ between privately owned facilities and government-owned facilities, except that municipal wastewater treatment facilities are more likely to violate their effluent limits.

Hypothesis S.2: As the perceived likelihood of enforcement (ƥ) rises or as the perceived severity of an enforcement burden (Ɓ) rises, a facility manager increases reporting and abatement efforts, implying a lower likelihood of non-compliance with reporting requirements and effluent limits.

Hypothesis S.3: Ownership type does not influence the effects of enforcement likelihood or burden severity on the likelihood of non-compliance.

4.3. Non-Pecuniary Factors and Budget Constraints

Other factors may influence the facility manager's compliance decision. We examine the case in which the manager's utility function includes pro-social preferences. A large body of research suggests that some humans are pro-social, e.g., altruists, reciprocators, conformists (e.g., List, 2009). While standard theory assumes that firms simply maximize profits, some studies of corporate environmental management reveal a role for social preferences. First, some studies demonstrate that managers' attitudes and perspectives affect firms' environmental management actions (Nakamura et al., 2001). Second, studies show that the regulator's enforcement style affects

[11] To separately capture the likelihood and severity factors, the analysis must, respectively, divide the number of enforcement actions by the number of opportunities to take an action, i.e., facility-months, and divide the total sum by the number of actions; see Earnhart and Friesen (2022).

the compliance behavior of regulated entities, which the standard model does not predict. For example, explicit threats (Short and Toffel, 2010) and coercive enforcement styles (Winter and May, 2001; Earnhart and Glicksman, 2015) reduce compliance.[12] Third, evidence shows that professional norms influence environmental managers (Earnhart and Ferraro, 2021).

We let M_{it} denote the value of such non-pecuniary motivations and α denote their importance in the facility manager's utility function. These motives are multifaceted and may comprise factors including altruism, efficiency-seeking, preferences for environmental stewardship, and norm conformance. Still, we only note the motives' aggregate effects. Overall, if these motives have any impact on the baseline level of compliance, they would generally induce more compliance effort of both types. Their impact on deterrence is more complicated. Studies offer substantial evidence that extrinsic motivators like enforcement actions may "crowd out" intrinsic motivations to behave pro-socially (e.g., Gneezy and Rustichini, 2000; Frey and Jegen, 2001; Bénabou and Tirole, 2006). Yet other results show that extrinsic motivations can reinforce pro-social motivations. For example, Aquino et al. (2022) show in a lab experiment that the presence of crowding-out or deterrence in an agent's reaction depends partially on the size of sanctions that the principal chooses to levy. Thus, stronger non-pecuniary preferences on the part of a decision-maker could increase or decrease deterrence impacts of enforcement. As these motives relate to both compliance and past enforcement burdens, we write M_{it} as a function of these factors: $M_{it}(R_{it}, C_{it}, F_{it-1})$.

Ownership structure may be associated with differences in intrinsic motivation of the manager. More pro-social individuals select into public service (e.g., Carpenter and Myers, 2010; Banuri and Keefer, 2016). Further, even a more self-interested person who becomes a manager of a government-owned facility may feel pressure to exert higher compliance effort if there are many motivated managers in this sector who set a strong compliance norm in the industry. Thus, the importance of intrinsic motivations, α, is greater for government facility managers.

Additionally, a facility's financial budget may constrain the manager's compliance decisions. We denote whether the budget constraint is binding with λ, which equals 1 if the facility is not budget constrained and lies below 1 otherwise. We assume that λ is smaller for government-owned facilities, which may be unable to increase "prices" or borrow money as easily (e.g., changes in utility rates require permission from a public utility commission, borrowing requires

[12] One explanation is that different styles change the nature of the regulated-regulator relationship (Earnhart and Glicksman, 2015).

voter approval). Since compliance effort is costly, this difference implies that a government-owned facility is less likely to comply with its discharge limit and responds less to enforcement actions. A related, but potentially opposing, force arises if managers of government-owned facilities are subject to an agency problem in that they fail to maximize profits or minimize costs or if they face soft budget constraints (Bartel and Harrison, 2005); these factors may cause managers to disregard either sanction costs or compliance costs, with an ambiguous impact.

We incorporate these additional elements into the facility manager's objective function:

$$E(U_{it}) = \Pi_{it} - wZ_{it} - kA_{it} - \int [P(Z_{it}, A_{it}) \times F(Z_{it}, A_{it})] + \alpha M_{it}(R_{it}, C_{it}, F_{it-1}). \quad (2)$$

We represent a facility's difficulty marshalling the money to pay compliance effort costs by indicating in the budget constraint that not all possible financial resources can be deployed:

$$\max \; E(U_{it}) \;\; \text{s.t. } wZ_{it} + kA_{it} = \lambda[\text{financial resources}] , \quad (3)$$

where "financial resources" are arbitrarily large for private ownership with no budget constraints. This model nests the standard model of sub-section 4.2: the standard model is recovered if intrinsic motivations play no role ($\alpha = 0$) and the budget constraint does not bind ($\lambda = 1$).

This richer model yields the following hypotheses, in which "*N*" indicates hypotheses derived from the model with non-pecuniary factors. Where these factors generate ambiguous impacts, we state opposing hypotheses denoted by *a* and *b*, where the "*a*" versions imply stronger compliance and deterrence for government-owned facilities due to factors like preferences for environmental stewardship and norm conformance, whereas the "*b*" versions imply the opposite, driven by inattention to sanction costs, a binding budget constraint, and motivational crowding.

Hypothesis N.1.a: Government-owned facilities are less likely to violate requirements as compared to privately owned facilities.

Hypothesis N.1.b: Government-owned facilities are more likely to violate requirements as compared to privately owned facilities.

Hypothesis N.2: As the perceived likelihood of enforcement (p) rises or as the perceived severity of an enforcement burden (B) rises, a facility manager *decreases* reporting and abatement efforts, increasing the likelihood of non-compliance with reporting requirements and effluent limits.

Hypothesis N.3.a: Enforcement generates a stronger deterrence impact on government-owned facilities as compared to privately owned facilities.

Hypothesis N.3.b: Enforcement generates a weaker deterrence impact on government-owned facilities as compared to privately owned facilities.

Even though we do not model the regulator decision in detail, we informally conjecture that, controlling for recent compliance status, the regulator may enforce more (or less) vigorously against government-owned facilities than privately owned facilities due to facilities' stronger (or, respectively, weaker) expected deterrence reaction.

4.6. Forms of Regulatory Interventions: Inspections and Enforcement Actions

Our analysis considers regulatory interventions comprising inspections and both informal and formal enforcement. We offer conjectures about the heterogeneity of deterrence across these intervention types. Regulators typically follow an "enforcement ladder," whereby a single violation prompts an informal enforcement action (e.g., warning letter), but repeated violations prompt a formal action. The influence of ownership on the effectiveness of enforcement actions may differ between the two forms of enforcement. Since informal actions serve as a soft nudge towards compliance, they should match reasonably well with government ownership. Moreover, enforcement actions may signal deviations from norms and government-owned facilities care more about norms. On the other hand, formal enforcement involves a court and judge, so may not match well with government ownership. However, formal enforcement actions signal strong deviations from norms and government-owned facilities care more about norms. Thus, we conjecture that both informal and formal enforcement actions generate stronger deterrence responses from government-owned than from privately owned facilities. Similar to informal enforcement, inspections offer a soft nudge towards compliance, especially when inspections offer technical assistance. Thus, like informal enforcement, we conjecture that inspections generate stronger deterrence responses from government-owned facilities than from privately owned facilities.

5. Econometric Framework

This section constructs the econometric framework we use to examine a panel dataset consisting of monthly observations for regulated facilities in our sample.

5.1. Dependent Variable and Primary Regressors

Our empirical analysis mostly explores the facility manager's compliance decision. Even though the theoretical framework depicts a facility manager's choice over compliance effort, in our econometric framework, the *count* of violations in a period is our dependent variable, as a facility manager typically faces multiple limits, yielding the potential for multiple violations. We also conduct robustness analysis using a binary variable representing the presence of a violation.

In each month m of year t, facility i operating in state k has a violation count, denoted as C_{it}. We consider two types of violations. As the primary type, we explore effluent violations. As

the secondary type, we explore reporting violations. We estimate these two outcomes separately.

The primary regressors are ownership type and regulatory interventions.

For ownership type, we generate two indicators: N_i^w, which equals 1 if the facility is a government-owned POTW and 0 otherwise, and N_i^o, which equals 1 if the facility is a government-owned non-POTW and 0 otherwise. Private ownership is the omitted category. We denote the indicators collectively as N_i. In our sample, ownership type does not vary over time for any facility.

Regulatory interventions include inspections and enforcement actions. For our analysis, inspections include both federal inspections and state inspections and enforcement actions include both federal and state informal and formal actions. Our core analysis focuses on specific deterrence: regulatory interventions targeting one's own facility. As robustness check, we control for general deterrence: regulatory interventions against other facilities in the same geographic area.

We construct regulatory intervention regressors as follows. Consider first inspections. For the measure of specific deterrence, the analysis uses the number of federal and state inspections conducted in the preceding 12 months at the individual facility, denoted as $I_{it\text{-}1}^s$. For the measure of general deterrence, the analysis uses the number of federal and state inspections conducted in the preceding 12 months at other facilities in the same state, divided by the number of facilities in the same state, denoted as $I_{it\text{-}1}^g$. The analysis constructs specific and general deterrence measures for informal and formal enforcement actions in a manner identical to inspections. The resulting specific deterrence measures for informal and formal actions are denoted as $G_{it\text{-}1}^s$ and $H_{it\text{-}1}^s$, respectively, while the general deterrence measures are denoted as $G_{it\text{-}1}^g$ and $H_{it\text{-}1}^g$, respectively. As noted in our conceptual framework, facilities' compliance effort should be influenced by the perceived probability and severity of enforcement, and these perceptions are reasonably influenced by recent observations of enforcement actions taken by the regulatory agency.

However, the agency does not randomly engage in enforcement actions or inspections. Consequently, these regulatory interventions may be endogenously determined. However, past research argues that separation in time mitigates endogeneity concerns because preceding regulatory interventions are pre-determined with respect to facilities' current compliance decisions, i.e., agencies conduct their interventions before facilities make their decisions (Earnhart, 2004c; Earnhart and Friesen, 2023). Moreover, as discussed below, we include additional control variables to mitigate further any remaining endogeneity concerns.

5.2. Control Factors

The empirical analysis controls for variation in other explanatory variables. Our analysis

controls for variation in regulatory pressure not already reflected in government intervention measures by including state indicators, S_i, when possible (in the random effects models), year indicators, D_t, and month indicators, M_t, as regressors. We do not interact the year and month indicators or interact the state indicators with either the year or month indicators, as either interaction would absorb a great deal of the variation in our data.

As a key control factor, we include a lagged dependent variable (specifically, the cumulative number of violations over the preceding year) to address concerns about the endogeneity of specific deterrence factors. As noted above, separation in time mitigates endogeneity concerns because regulatory interventions are conducted by the time facilities make compliance decisions (Earnhart, 2004c); however, any serial correlation in violation status makes specific deterrence factors endogenous. Put differently, if violations are persistent, as seems likely because (1) facilities need time to fix equipment or adjust processes and (2) some violations stem from persistent factors, then the targeting of enforcement actions against non-compliant facilities generates a positive correlation with contemporaneous violations because both are correlated with past violations. Including the lagged dependent variable as a regressor mitigates this concern.[13,14]

Lastly, we construct specifications with facility fixed effects as well as specifications with random effects. Facility fixed effects preclude the inclusion of time-invariant regressors, including ownership type, but control for all facility-specific factors that do not vary over time. Our core results present both sets of estimates. Clearly, to capture the direct effect of ownership, we must rely exclusively on the random effects estimates.

5.3. Regression Equations

Our base model ignores the interactions between ownership type and regulatory interventions. For the main specification, we include only the specific deterrence-related regulatory intervention factors. In this section, we present regression equations for effluent violations; regression equations for reporting violations simply change the outcome variable. The following equation captures the functional relationship between effluent violations and explanatory variables for the main specification in our base model:

$$f(C_{it}) = \alpha + \delta N_i + \beta_1 I_{it-1}^{s} + \beta_2 G_{it-1}^{s} + \beta_3 H_{it-1}^{s} + \gamma C_{it-1} + \psi S_i + \mu D_t + \varphi M_t + \epsilon_i + \eta_{it} , \qquad (4)$$

[13] We alternatively include one year of lagged violations and two years of lagged violations. The main tables display results from the first specification. Appendix Tables A-11 and A-12 display results from the second specification. The two sets of results are broadly similar; the second set proves more precise in some cases.

[14] Even without this inclusion, Earnhart and Friesen (2023) demonstrate that preceding regulatory interventions appear exogenously determined with respect to current compliance decisions.

where δ is the slope coefficient for our first primary regressor (ownership type dummies), β_1 through β_3 are the slope coefficients for our second set of primary regressors (enforcement and inspections), ϵ_i is a facility-specific error or intercept term (depending on the estimator), and η_{it} is a random error term. The function $f(\cdot)$ shows that the estimated relationship need not be linear; as noted below, we employ a Poisson estimator. The β coefficients reflect the specific deterrence effects of inspections and enforcement on compliance. As a robustness check, we control for general deterrence within our set of regulatory intervention measures.

In the extended model, we interact ownership structure with the regulatory intervention measures. Again, the main specification includes only specific deterrence-related regulatory intervention factors. The following equation captures the relationship between effluent violations and the explanatory variables for the main specification in our extended model:

$$f(C_{it}) = \alpha + \delta N_i + \beta_1 I_{it-1}^{s} + \beta_2 G_{it-1}^{s} + \beta_3 H_{it-1}^{s} + \theta_1 (N_i \times I_{it-1}^{s}) + \theta_2 (N_i \times G_{it-1}^{s}) + \theta_3 (N_i \times H_{it-1}^{s}) + \gamma C_{it-1} + \psi S_i + \mu D_t + \varphi M_t + \epsilon_i + \eta_{it}\,, \quad (5)$$

where θ_1 through θ_3 reflect the coefficients on the interactions between ownership and specific deterrence. As a robustness check, we control for general deterrence.

Given the interaction terms in the extended model, we must take extra steps to identify the marginal effects of regulatory interventions. The baseline intervention-related specific deterrence coefficient, β, reveals the marginal effect of intervention-related specific deterrence on compliance for privately owned facilities. For each specific deterrence type, the sum of the baseline regulatory intervention coefficient and the interaction term ($\beta + \theta$) reveals the marginal effect for government-owned facilities. Thus, the interaction coefficient, θ, reveals the *difference* in the marginal effect of a particular intervention-related specific deterrence type between government-owned and privately owned facilities, i.e., the differential deterrence effect.

5.4. Econometric Methods

Consider our econometric methods. First, we conduct our analysis at the facility-month level. Second, our dependent variables are count variables; accordingly, we employ a Poisson estimator. Third, inclusion of the lagged dependent variable as a regressor within panel data estimation with fixed effects estimation can introduce bias; however, this bias is inversely proportional to the length of the sample, i.e., the number of observations per facility (Nickell, 1981). Fortunately, our monthly sample includes up to 209 observations per facility. Thus, the bias is trivial. Fourth, we use robust standard errors clustered at the facility level.

We consider two specifications of our regulatory intervention variables. The main

specification includes only specific deterrence measures of regulatory interventions. The alternative specification adds general deterrence measures as controls. Estimation of the alternative specification generates results that are highly similar to the main results. Thus, we relegate these alternative estimates to Appendix Tables A-13 and A-14.

These analyses assume that our control factors sufficiently capture differences across facilities so that any remaining difference among facilities reflects the role of ownership type. Government-owned and privately owned facilities tend to run different types of operations, which can imply differences in the mechanics of achieving compliance. However, any such operational differences should not yield differences in the ability to comply with reporting requirements. Thus, if we find deterrence in both effluent and reporting violations, the pair of results must indicate that the observed differences in management decisions between facility types are driven by ownership.

The analyses also assume that the marginal deterrence effect of a regulatory intervention does not depend significantly on the level of that intervention.

6. Data

This section describes the data used to estimate the constructed econometric models.

6.1. Sample and Data Sources

Our study's scope is the population of all NPDES-permitted facilities operating in six large U.S. states – CA, FL, LA, NY, PA, and TX – which were chosen because they have a large number of facilities and their enforcement data were obtainable, as we describe below. From this population, our study sample includes all major, non-federally owned facilities.

Our study considers all sectors regulated under the Clean Water Act. Previous empirical studies of wastewater pollution often focus on a single manufacturing sector, e.g., chemical manufacturing or pulp and paper manufacturing (Laplante and Rilstone, 1996; Barla, 2007; Earnhart, 2009; Earnhart and Harrington, 2014), or focus on municipal wastewater treatment facilities (Earnhart, 2004b, a, c). The inclusion of multiple sectors facilitates a meaningful contrast between private and government ownership.

The EPA stores data on violations, inspections, and facility characteristics, along with partial data on enforcement, for all major and some minor facilities in the EPA Integrated Compliance Information System (ICIS) database. Since data on minor facilities are incomplete, we focus exclusively on major facilities, consistent with previous studies of U.S. wastewater discharges (Earnhart, 2004c; Shimshack and Ward, 2005; Earnhart, 2009; Earnhart and Segerson,

2012).[15] The EPA makes the ICIS data publicly available through the Enforcement and Compliance History Online (ECHO) portal. We use the underlying ICIS data. Data on state-issued enforcement actions are incomplete in the ICIS database because state agencies incompletely report these data to the EPA; therefore, we supplement the information on state-initiated enforcement actions with data retrieved directly from state enforcement agencies for as much of the sample period as possible.[16] Our efforts therefore use richer enforcement data than previous studies that use ICIS data, which either ignore state enforcement actions (e.g., Earnhart and Segerson, 2012) or use only the incomplete ICIS data (e.g., Shimshack and Ward, 2008).

We estimate our regression on 2,515 facilities for the period of September 1997 to January 2016 inclusively.[17] Since we construct deterrence factors using a preceding 12-month window, our regression period starts 12 months after September 1997, so that our analysis spans 209 months. The unit of analysis is a single facility in a given month.

We identify ownership type based on the facility type code. This code offers certain values corresponding to government ownership of different types (e.g., county, municipal). The other values identify private ownership. A separate ICIS variable, facility type indicator, identifies a publicly owned treatment works (POTW). Of our 2,515 facilities, 728 are privately owned, 1,346 are government-owned POTWs, and 441 are government-owned non-POTWs. This latter category largely comprises stormwater permits, sludge permits associated with POTWs, power plants, hospitals, and small plants that collect wastewater before sending it to a POTW. The category of government-owned non-POTWs spans a variety of facility types. These types collectively differ in their operations from POTWs; for example, these facility types often have more control over their influent than POTWs do. Thus, it proves valuable to analyze POTWs and government-owned non-POTWs separately.

Table 1 shows that these categories are not distributed evenly across states.

[TABLE 1 ABOUT HERE]

The ICIS data do not contain a historical record of when a facility operated. To identify

[15] Nevertheless, we acknowledge that major and minor facilities may respond differently to regulatory interventions in ways that may differ by ownership type.

[16] Specifically, our state-supplemented data cover the following date ranges (inclusive): CA: January 1996 to January 2016; FL: January 1996 to June 2012; LA: January 1997 to June 2013; NY: January 1996 to May 2013; PA: January 1996 to March 2017; TX: July 1999 to December 2013.

[17] The Significant Non-Compliance (SNC) National Compliance Initiative (NCI) targets Municipal facilities for enforcement attention. However, this program began in October 2017, which lies beyond the end of our sample period.

this status, we use data from the EPA's Compliance Tracking System, which records dates associated with each tracking status for a given facility. Based on these dates, we discern when a facility enters the NPDES system, when it leaves the system (if it does), and when it temporarily goes offline (e.g., during an expansion). Accordingly, for our main regressions, we trim each facility's representation in our panel to only the months in which the facility is actively regulated under the Clean Water Act. Of the 2,515 facilities in our sample, we find a match in the Compliance Status Tracking system for all but 216 facilities. In addition, the Compliance Status Tracking system reveals that one facility is never active during our sample period. Thus, our final sample includes 2,298 facilities.

Since the Compliance Status Tracking system may not accurately capture active status, we also present estimates using the full sample of observations.

We assess the robustness of our conclusions further by exploring two alternative samples. First, we restrict the sample to the period for which we enhance our enforcement data using state agencies' data on state-issued enforcement actions, since our state-collected enforcement data should be more complete. Second, we remove observations for the state of Florida during the period prior to the EPA's migration of the state's NPDES data to the ICIS database on March, 2011. We do so because Florida facilities that were closed at the time of the transition were not imported into the new database, implying the ICIS data for the pre-transition years contain only facilities that survived until March 2011.

As reported in sub-section 7.4, in all cases, results of our robustness specifications are substantially similar to the results we report in the main tables.

6.2. Statistical Summary of Regression Variables

Table 2 summarizes the variables in our analysis. It shows that POTWs generate more violations than privately owned facilities, particularly effluent violations, while government-owned facilities that are not POTWs generate relatively few violations. Some categories of government-owned non-POTWs face few enforceable discharge limits and thus cannot generate effluent violations; thus, it is unsurprising that government-owned non-POTWs generate so few effluent violations. This said, similar categories of privately owned facilities also generally do not face enforceable discharge limits. Table 2 also shows that POTWs face more enforcement attention on each dimension as compared to privately owned facilities. In some cases, this difference appears disproportionate, even given the greater likelihood of a violation. In contrast, government-owned non-POTWs face less regulatory attention than privately owned facilities.

[TABLE 2 ABOUT HERE]

7. Empirical Results

In turn, we test conjectures regarding agency behavior, test hypotheses derived from our conceptual framework on facility behavior, and discuss the economic importance of our estimates.

7.1. Testing Conjectures about Agency Behavior

We first test our conjectures about regulator behavior. We estimate the effect of ownership type on the individual forms of regulatory intervention, while controlling for basic factors (year indicators, month indicators, state indicators) and lagged measures of effluent violations and reporting violations. To retain the time-invariant factor of ownership type, we use a random effects estimator. Given the count nature of our regulatory intervention outcomes, we use a random effects Poisson estimator. Table 3 displays the estimation results. Rather than coefficient magnitudes, we report incidence rate ratios, which reveal a positive impact when the ratio exceeds 1 and a negative impact when the ratio lies below 1. Reassuringly, an increase in violations prompts more enforcement, though this effect is never statistically significant for effluent violations and is not significant for reporting violations in all cases. In addition, POTWs receive more regulatory attention than privately owned facilities based on all forms of regulatory intervention even though our analysis conditions on past violations. In contrast, government-owned non-POTW facilities receive less regulatory attention than privately owned facilities. The increased regulatory attention that POTWs receive contrasts with results from Konisky and Teodoro (2016): in the context of air pollution, regulatory agencies take fewer enforcement actions against government-owned facilities than against privately owned facilities. However, the reduced regulatory attention given to government-owned non-POTWs comports with the results of Konisky and Teodoro (2016).

[TABLE 3 ABOUT HERE]

7.2. Testing Hypotheses about Facility Behavior

We next test the theoretically derived hypotheses. We present results from our base model (equation (4)) in Table 4, which shows incidence rate ratios from Poisson regressions, with compliance as the outcome variable and ownership type and regulatory interventions as the primary regressors. The coefficients for intervention types are similar between the fixed effects and random effects regressions. Thus, conclusions are robust to the estimation method. Moreover, lagged violations are strongly predictive of violations in the present, indicating that facilities may indeed need time to correct violations; thus, controlling for lagged violations appears necessary for mitigating endogeneity.

[TABLE 4 ABOUT HERE]

We first test the competing *Hypotheses S.1*, *N.1.a*, *and N.1.b* regarding the direct effect of ownership on compliance decisions. We interpret only the random effects Poisson estimates since they retain the ownership factors. POTW facilities generate more effluent violations than privately owned facilities, which supports part of *Hypothesis S.1*. In contrast, government-owned non-POTW facilities generate fewer effluent violations and both POTWs and government-owned non-POTWs generate fewer reporting violations. These results reject the rest of *Hypothesis S.1* – that violations are the same between government-owned and privately owned facilities – in favor of *Hypothesis N.1.a* – that government-owned facilities comply better because non-pecuniary factors drive facility managers to exert higher compliance effort. By comparing the ownership coefficients, we see that POTWs are more likely to generate effluent violations than government-owned non-POTWs ($p<0.01$), yet the two types of government-owned facilities appear equally likely to generate reporting violations ($p=0.245$). These results support our assumption that effluent violations are harder for POTWs to avoid than other facilities because they have less control over their influent.

We next use Table 4 to test competing *Hypotheses S.2* and *N.2*, which capture the deterrence generated by regulatory interventions, for which we interpret both the Poisson random effects and fixed effects estimates, with a greater focus on the latter estimates. The base model results reveal that formal actions apparently deter facilities from effluent violations and inspections appear to deter reporting violations. These results support *Hypothesis S.2*, while rejecting *Hypothesis N.2*, and reveal that the effect of motivational crowding out, if it exists, does not overwhelm the deterrence impacts of enforcement on average.

Finally, we answer our core research question by testing competing *Hypotheses S.3, N.3.a*, and *N.3.b*, which concern the influence of ownership type on deterrence. For this test, we must evaluate the extended model (equation (5)). Table 5 displays the results. The random effects estimates do not differ much from the fixed effects estimates. Still, we prefer the fixed effects estimates because they control for all facility-specific factors that do not vary over time. Thus, we focus our discussion on these preferred estimates.

As an aside, we use the random effects estimates to re-assess the direct impacts of ownership types. Given the inclusion of interactions between ownership type and regulatory interventions, the main incidence rate ratios reflect the marginal effect of ownership when all intervention types are absent. The reported results are similar to those in Table 4, supporting the

same conclusions as before: POTWs generate more effluent violations (consistent with *Hypothesis S.1*) but government-owned non-POTW facilities generate fewer violations (rejecting the rest of *Hypothesis S.1* in favor of *Hypothesis N.1.a*).

[TABLE 5 ABOUT HERE]

Results in Table 5 reveal that ownership type influences the effects of both formal enforcement actions and informal enforcement actions on effluent violations. The main (uninteracted) enforcement action coefficients show the impact of enforcement on violations by privately owned facilities. These coefficients reveal no statistically significant deterrence impact for privately owned facilities from any form of regulatory action. More important, both formal and informal enforcement lower effluent violations more when taken against government-owned POTW facilities as compared to enforcement against privately owned facilities. The point estimates for both kinds of enforcement on government-owned non-POTWs also show negative differentials; however, these estimates are noisier and not statistically significant. Inspections have no statistically significant impact on effluent violations generated by privately owned facilities. (This said, the impact is almost marginally significant, with a p-value of 0.11.) The inspection impact does not differ significantly across ownership types.

The results in Table 5 also demonstrate that ownership type influences the effects of both formal enforcement and inspections on reporting violations. As with effluent violations, privately owned facilities show no deterrence impact of enforcement, whereas government-owned POTW facilities show a much stronger deterrent impact of formal enforcement actions as compared to privately owned facilities. In addition, inspections more effectively lower reporting violations at non-POTW government-owned facilities than at privately owned facilities; however, the impact does not differ when comparing POTWs to privately owned facilities. These results are particularly notable because no inherent operational differences arise from ownership type that affect reporting compliance, ensuring that the differences we observe in deterrence between privately and government-owned facilities stem solely from environmental management differences.

Since these results show no statistically significant deterrence impact at all for privately owned facilities and significantly stronger deterrence on several dimensions for government-owned facilities, these results reject *Hypotheses S.3* and *N.3.b* in favor of *Hypothesis N.3.a*. Thus, we conclude that non-pecuniary factors, such as norm conformance and external benefits internalization, are significant drivers of government facility manager decision-making and dominate the effect of a binding budget constraint.

To assess the full marginal effect of deterrence under each type of ownership, we sum the main coefficient associated with each regulatory intervention type, which captures the marginal effect of deterrence under private ownership (the omitted ownership category), and the interactive coefficient for each regulatory intervention type. Table 6 displays the p-values for these summed coefficients from the regression results (obtained using Stata's "lincom" command), shown in Table 5.

[TABLE 6 ABOUT HERE]

We reiterate that the main coefficients reveal no support for *Hypothesis S.2*, that enforcement has a deterrent impact under private ownership. Table 6 results reveal a significant marginal effect of formal enforcement for government-owned POTWs regarding both effluent and reporting violations and a significant marginal effect of inspections for government-owned non-POTWs regarding reporting violations. Both results support *Hypothesis S.2* for these facilities. However, in other cases, the marginal effect does not prove significant.

7.3. Economic Importance

We now examine the economic importance of our estimates by scrutinizing the coefficient magnitudes shown in Tables 4 and 5. The difference between the reported incidence rate ratios and one reflects the percentage change in the violation count prompted by a one unit increase in the associated regressor. We base our examination of economic importance only on the statistically significant marginal effects.

We first examine the direct effect of a switch from private ownership to government ownership based on the random effects Poisson incident rate ratios. Using the base model results shown in Table 4, a government-owned POTW has 43 % more effluent violations but 42 % fewer reporting violations as compared to a privately owned facility. In contrast, a government-owned non-POTW facility has fewer of *both* kinds of violations: 76 % for effluent violations and 50 % for reporting violations. Thus, the impacts of ownership on non-compliance are quite large. The extended model results reveal reasonably similar levels of economic importance for the direct effect of ownership type on compliance (evaluated at a level of zero for all regulatory interventions).

We next examine the deterrence effect of regulatory interventions along with the influence of government ownership on this effect. As shown in Table 5, the preferred fixed effects estimates reveal that none of the regulatory interventions significantly shape compliance by privately owned facilities as reflected in the main (uninteracted) intervention coefficients. Thus, we treat the

influence of government ownership on each regulatory intervention effect (i.e., the interaction coefficient) as reflecting the full magnitude of economic importance. Under POTW government ownership, one additional formal enforcement action reduces effluent violations by 8 % and reduces reporting violations by 24 %. Under this same ownership type, one additional informal enforcement action reduces effluent violations by 3 %. Under non-POTW government ownership, one additional inspection reduces reporting violations by 17 %. Effluent violations undoubtedly are more socially harmful than reporting violations; thus, even the small reduction in effluent violations that we observe may yield significant social benefits.

7.4. Sensitivity Analysis

As described in sub-section 6.1, we conduct sensitivity analysis by assessing the robustness of our conclusions to alternative specifications.

In several robustness checks, we change the sample we use for the analysis. First, we present estimates using the full sample of observations rather than observations with an identified "active" status in the Compliance Status Tracking system. See Appendix Tables A-1 to A-3. Second, we restrict the sample to the period for which we enhance our enforcement data using state agencies' data on state-issued enforcement actions, since our state-collected enforcement data should be more complete than the data from the federal system. See Appendix Tables A-4 to A-6. Third, we remove observations for the state of Florida during the period prior to the EPA's migration of the state's NPDES data to the ICIS database, since we are not able to identify which facilities are active during this period. See Appendix Tables A-7 to A-9.

We also use two alternative sets of additional controls. First, we control for enforcement actions that occurred in the preceding two years, rather than only the preceding year. See Appendix Tables A-10 to A-12. Second, we add controls for general deterrence: enforcement actions taken against other facilities in the same state. See Appendix Tables A-13 to A-14.

In all of the aforementioned cases, results of our robustness specifications are substantially similar to the results reported in the main tables.

As one last alternative specification, we use violation status as the dependent variable. This specification reduces the extent of variation in facilities' compliance decisions; as such, it constrains our ability to link the primary regressors to compliance outcomes. Not surprisingly, the resulting estimates, shown in Appendix Tables A-15 and A-16, generally reveal that this alternative dependent variable fails to capture strongly variation in compliance outcomes, as demonstrated by the weak statistical significance of the slope coefficients for the primary

regressors. For example, formal enforcement actions no longer significantly affect POTW compliance and inspections no longer significantly affect government-owned non-POTW compliance. In addition, the alternative results differ from the main results in a few other ways. This said, by focusing on the results that answer our key research questions, which concern the role of ownership type for explaining deterrence impacts on compliance outcomes, this alternative specification's results differ in only one case. Government-owned POTWs, relative to privately owned facilities, are more likely to violate reporting requirements. When this result is considered alongside the main result from Table 5, we can infer that government-owned POTWs are more likely to generate a reporting violation, but choose to constrain the number of violations more tightly, as compared to privately owned facilities. As lesser points, Appendix Table A-15, the counterpart to Table 4, displays non-interacted specification estimates that reveal different effects for certain government interventions. For example, lagged formal enforcement actions significantly increase the likelihood of a reporting violation. Again, Poisson estimation of the violation count, as presented in our main analysis in Tables 4 and 5, is the superior approach to estimating violations since it exploits greater true variation in the compliance outcome.

8. Conclusions

This study asks whether government-owned entities respond more or less strongly as compared with privately owned entities to regulatory interventions conducted by environmental regulatory agencies. Government-owned entities may respond more strongly because of greater pro-social motivations like a higher concern for environmental stewardship and stronger pro-environmental norms. However, these same entities may respond less strongly because of agency problems, binding budget constraints, and non-pecuniary factors like motivational crowding out. We examine these points in the context of the U.S. Clean Water Act using a panel of data at the facility-month level covering more than 2,000 major facilities over 17 years. We first show that, controlling for past violations, government-owned POTWs receive more regulatory attention than privately owned facilities, in contrast to the finding from Konisky and Teodoro (2016) that regulators treat government entities with a lighter touch. However, our results also show that government-owned *non*-POTWs receive *less* attention than privately owned facilities. Thus, distinguishing the type of government-owned entity proves critical. We further find that government-owned POTWs generate more effluent violations than privately owned facilities, perhaps because the former are less able to control their discharges than other entities. However, government-owned *non*-POTWs generate *fewer* effluent violations. Again, the distinction between

POTWs and non-POTWs is important. Regarding reporting violations, over which facility managers may have more control and which should not depend on the type of operation (thus, not subject to omitted factors that correlate with both ownership and compliance), both types of government-owned facilities generate fewer violations. Finally, to our central research question, most results reveal that government-owned facilities respond *more* strongly to regulatory interventions than privately owned facilities respond.

Collectively, our results imply that forces beyond the managers' control affect the effluent violations of government-owned POTW facilities, yet non-pecuniary forces motivate the facility managers to achieve better environmental performance and respond more strongly to regulatory interventions. These impacts of ownership are large and novel in the literature. Still, they fit with new research revealing socially driven managers of government facilities (e.g., Earnhart and Ferraro, 2021). Regulators may already be aware of this greater deterrence responsiveness on the part of government-owned entities; this awareness would help to explain the greater regulatory attention paid to government-owned facilities.

Our results also raise interesting unanswered questions. In particular, why do our results about regulator attention differ from those of Konisky and Teodoro (2016)? On this point, future research should explore the variation in regulation and deterrence across contexts. Our study examines the Clean Water Act, while Konisky and Teodoro (2016) examine the Clean Air Act and Safe Drinking Water Act. Further, our conceptual framework only explains some of the variation in the impacts of different regulatory interventions on different types of facilities. More research is clearly needed to explain the full extent of variation.

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Tables

Table 1
Number of Facilities by Type and State

	Private Ownership	Government Ownership – POTW	Government Ownership – Non-POTW
CA	51	183	39
FL	88	100	236
LA	142	97	102
NY	111	212	5
PA	119	294	11
TX	217	460	48
Total	728	1,346	441

Table 2
Summary of Regression Variables

Variable	Private Ownership	Government Ownership – POTW	Government Ownership – Non-POTW
Dependent Variables			
Number of effluent violations	0.232 (1.141)	0.333 (1.029)	0.042 (0.429)
Number of reporting violations	1.387 (15.519)	1.438 (13.327)	1.049 (11.942)
Primary Regressors			
Number of formal enforcement actions in preceding 12 months	0.069 (0.305)	0.146 (0.443)	0.033 (0.209)
Number of informal enforcement actions in preceding 12 months	0.225 (0.704)	0.334 (0.940)	0.097 (0.416)
Number of inspections in preceding 12 months	1.073 (1.550)	1.742 (2.224)	0.446 (1.919)
Observations			
N	118,149	235,509	40,383

Means of facility-month-level values reported.
Standard deviations shown in parentheses.

Table 3
Effect of Ownership Type on Regulatory Attention:
Poisson Random Effects Estimation

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Formal Enforcement Actions (count)	Informal Enforcement Actions (count)	Inspections (count)
Government-owned POTW	1.811 *** (0.142)	1.683 *** (0.139)	1.436 * (0.267)
Government-owned non-POTW	0.574 (0.225)	0.292 *** (0.060)	0.433 (0.384)
Effluent violations in preceding 12-months	1.030 (0.022)	1.016 (0.012)	1.005 (0.006)
Reporting violations in preceding 12-months	1.000 (0.000)	1.001 ** (0.000)	1.000 (0.000)
Control Factors			
Month indicators	X	X	X
Year indicators	X	X	X
State indicators	X	X	X
Regression Statistics			
N	388,441	388,441	388,441
# of Facilities	2,298	2,298	2,298
Zero Slopes χ^2 Test (p-value)	34,263 (0.00)	28,021 (0.00)	45,872 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Table 4
Effect of Ownership Type on Violation Count – Base Model:
Poisson Random Effects and Fixed Effects Estimation

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)	
	Random Effects	Fixed Effects	Random Effects	Fixed Effects
Effluent violations in preceding 12-months	1.035 *** (0.003)	1.035 *** (0.002)		
Reporting violations in preceding 12-months			1.001 *** (0.000)	1.001 *** (0.000)
Government-owned POTW	1.433 *** (0.077)		0.581 *** (0.081)	
Government-owned non-POTW	0.242 *** (0.053)		0.497 *** (0.084)	
Formal enforcement actions in preceding 12 months	0.963 (0.031)	0.959 ** (0.018)	0.978 (0.043)	0.977 (0.043)
Informal enforcement actions in preceding 12 months	0.996 (0.013)	0.995 (0.010)	1.034 (0.027)	1.034 (0.027)
Inspections in preceding 12 months	1.006 (0.006)	1.006 (0.005)	0.972* (0.016)	0.972* (0.016)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	388,441	343,482	388,441	353,653
# of Facilities	2,298	2,009	2,298	2,070
Zero Slopes χ^2 Test (p-value)	5,300 (0.00)	923.9 (0.00)	1,474 (0.00)	469.5 (0.00)

* p<0.1; ** p<0.05; *** p<0.01.
Robust standard errors clustered on facility shown in parentheses.
Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Table 5
Effect of Ownership on Deterrence – Extended Model:
Poisson Random Effects and Fixed Effects Estimation

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)	
	Random	Fixed	Random	Fixed
Effluent violations in preceding 12 months	1.035 *** (0.003)	1.035 *** (0.002)		
Reporting violations in preceding 12 months			1.001 *** (0.000)	1.001 *** (0.000)
Government-owned POTW	1.495 *** (0.081)		0.586 *** (0.086)	
Government-owned non-POTW	0.255 *** (0.110)		0.544 *** (0.100)	
Formal Enforcement				
Formal enforcement actions in preceding 12 months	1.034 (0.071)	1.024 (0.041)	1.220 (0.162)	1.219 (0.162)
POTW × formal enforcement	0.917 (0.055)	0.924 * (0.040)	0.760 ** (0.105)	0.760 ** (0.105)
Non-POTW × formal enforcement	0.940 (0.325)	0.897 (0.209)	0.890 (0.161)	0.889 (0.161)
Informal Enforcement				
Informal enforcement actions in preceding 12 months	1.029 (0.029)	1.025 (0.019)	1.093 (0.064)	1.093 (0.064)
POTW × informal enforcement	0.962 (0.025)	0.965 * (0.021)	0.935 (0.057)	0.935 (0.057)
Non-POTW × informal enforcement	1.018 (0.188)	0.985 (0.065)	1.019 (0.117)	1.018 (0.117)
Inspections				
Inspections in preceding 12 months	1.017 (0.011)	1.016 (0.010)	0.949 (0.039)	0.949 (0.039)
POTW × inspections	0.987 (0.011)	0.987 (0.012)	1.040 (0.047)	1.040 (0.047)
Non-POTW × inspections	0.956 (0.227)	0.913 (0.104)	0.827 * (0.083)	0.826 * (0.083)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	388,441	343,482	388,441	353,653
# of Facilities	2,298	2,009	2,298	2,070
Zero Slopes χ^2 (p-value)	5,397 (0.00)	999.8 (0.00)	1,572 (0.00)	542 (0.00)

* p<0.1; ** p<0.05; *** p<0.01.
Robust standard errors clustered on facility shown in parentheses.
Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Table 6
Tests of Marginal Effects of Deterrence from Table 5 Regressions

(signs of marginal effects and p-values for tests of a zero effect)

Variable	Effluent Violations (count)		Reporting Violations (count)	
	Random	Fixed	Random	Fixed
Formal Enforcement				
Formal enforcement for privately owned	Positive 0.622	Positive 0.546	Positive 0.136	Positive 0.137
Formal enforcement for government-owned POTW	Negative 0.038 **	Negative 0.007 ***	Negative 0.036 **	Negative 0.036 **
Formal enforcement for government-owned non-POTW	Negative 0.943	Negative 0.713	Positive 0.507	Positive 0.511
Informal Enforcement				
Informal enforcement for privately owned	Positive 0.304	Positive 0.184	Positive 0.134	Positive 0.131
Informal enforcement for government-owned POTW	Negative 0.453	Negative 0.364	Positive 0.369	Positive 0.374
Informal enforcement for government-owned non-POTW	Positive 0.819	Positive 0.870	Positive 0.294	Positive 0.296
Inspections				
Inspections for privately owned	Positive 0.111	Positive 0.114	Negative 0.201	Negative 0.201
Inspections for government-owned POTW	Positive 0.506	Positive 0.523	Negative 0.421	Negative 0.421
Inspections for government-owned non-POTW	Negative 0.906	Negative 0.511	Negative 0.009 ***	Negative 0.008 ***

* p<0.1; ** p<0.05; *** p<0.01.

Each cell displays the sign of the marginal effect for the specified form of enforcement action on the specified type of facility based on the given specification, as well as the p-value associated with the test of a null hypothesis of a zero marginal effect.

APPENDIX TABLES

This appendix contains the following sets of tables:

- A-1 to A-3: Full Sample (i.e., Compliance Status Tracking facility activity data are not used to screen observations) (corresponding to Tables 3, 4, and 5, respectively)
- A-4 to A-6: Sample Restricted to Period with State Data on State-Issued Enforcement Actions (corresponding to Tables 3, 4, and 5, respectively)
- A-7 to A-9: Sample Excludes Florida Facilities for the Period before the Transition to ICIS (corresponding to Tables 3, 4, and 5, respectively)
- A-10 to A-12: Controlling for Two Years of Lagged Enforcement (corresponding to Tables 3, 4, and 5, respectively)
- A-13 to A-14: Controlling for General Deterrence (corresponding to Tables 4 and 5, respectively)
- A-15 to A-16: OLS Regressions with Binary Violation Outcomes (corresponding to Tables 4 and 5, respectively)

Appendix Table A-1
Effect of Ownership Type on Regulatory Attention:
Poisson Random Effects Estimation
Full Sample (i.e., Compliance Status Tracking Facility Activity Data Not Used)

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Formal Enforcement Actions (count)	Informal Enforcement Actions (count)	Inspections (count)
Government-owned POTW	1.860 *** (0.199)	1.610 *** (0.207)	1.449 (0.423)
Government-owned non-POTW	0.230 ** (0.169)	0.186 * (0.161)	0.205 * (0.193)
Effluent violations in preceding 12 months	1.029 (0.025)	1.017 (0.011)	1.006 (0.005)
Reporting violations in preceding 12 months	1.000 (0.000)	1.001 * (0.000)	1.000 (0.000)
Control Factors			
Month indicators	X	X	X
Year indicators	X	X	X
State indicators	X	X	X
Regression Statistics			
N	525,635	525,635	525,635
# of Facilities	2,515	2,515	2,515
Zero Slopes χ^2 Test (p-value)	38,029 (0.00)	28,642 (0.00)	39,546 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes all facility-month combinations, regardless of the EPA Compliance Status Tracking system data.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Appendix Table A-2
Effect of Ownership Type on Violations – Base Model:
Poisson Random Effects and Fixed Effects Estimation
Full Sample (i.e., Compliance Status Tracking Facility Activity Data Not Used)

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)	
	Random Effects	Fixed Effects	Random Effects	Fixed Effects
Effluent violations in preceding 12 months	1.039 *** (0.004)	1.039 *** (0.002)		
Reporting violations in preceding 12 months			1.001 *** (0.000)	1.001 *** (0.000)
Government-owned POTW	1.482 *** (0.076)		0.709 *** (0.070)	
Government-owned non-POTW	0.116 *** (0.060)		0.284 *** (0.048)	
Formal enforcement actions in preceding 12 months	0.967 (0.038)	0.963 * (0.020)	0.982 (0.044)	0.981 (0.044)
Informal enforcement actions in preceding 12 months	0.989 (0.014)	0.988 (0.010)	1.044 * (0.027)	1.043 * (0.027)
Inspections in preceding 12 months	1.017 ** (0.008)	1.017 *** (0.005)	0.992 (0.016)	0.992 (0.016)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	525,635	420,926	525,635	433,884
# of Facilities	2,515	2,014	2,515	2,076
Zero Slopes χ^2 Test (p-value)	6,778 (0.00)	1,113 (0.00)	1,570 (0.00)	668 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes all facility-month combinations, regardless of the EPA Compliance Status Tracking system data.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Appendix Table A-3
Effect of Ownership on Deterrence – Extended Model:
Poisson Random Effects and Fixed Effects Estimation
Full Sample (i.e., Compliance Status Tracking Facility Activity Data Not Used)

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)
	Random	Fixed	Fixed
Effluent violations in preceding 12 months	1.039 *** (0.004)	1.039 *** (0.002)	
Reporting violations in preceding 12 months			1.001 *** (0.000)
Government-owned POTW	1.540 *** (0.087)		
Government-owned non-POTW	0.111 *** (0.027)		
Formal Enforcement			
Formal enforcement actions in preceding 12 months	1.041 (0.083)	1.034 (0.051)	1.223 (0.160)
POTW × formal enforcement	0.911 (0.060)	0.916 * (0.048)	0.759 ** (0.103)
Non-POTW × formal enforcement	1.036 (0.504)	0.977 (0.268)	0.988 (0.162)
Informal Enforcement			
Informal enforcement actions in preceding 12 months	1.000 (0.036)	0.996 (0.022)	1.100 (0.068)
POTW × informal enforcement	0.987 (0.033)	0.990 (0.023)	0.936 (0.059)
Non-POTW × informal enforcement	1.145 (0.453)	1.078 (0.069)	1.080 (0.134)
Inspections			
Inspections in preceding 12 months	1.029 ** (0.014)	1.028 ** (0.013)	0.985 (0.034)
POTW × inspections	0.985 (0.014)	0.986 (0.013)	1.016 (0.040)
Non-POTW × inspections	1.026 (0.374)	0.949 (0.119)	0.827 * (0.084)
Control Factors			
Facility indicators		X	X
Month indicators	X	X	X
Year indicators	X	X	X
State Indicators	X		

Regression Statistics			
N	525,635	420,926	433,884
# of Facilities	2,515	2,014	2,076
Zero Slopes χ^2 Test (p-value)	6,922 (0.00)	1,159 (0.00)	770 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes all facility-month combinations, regardless of the EPA Compliance Status Tracking system data.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.
The reporting violation random effects specification does not successfully run.

Appendix Table A-4
Effect of Ownership Type on Regulatory Attention:
Poisson Random Effects Estimation
Sample Restricted to Period with State Data on State-Issued Enforcement Actions

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Formal Enforcement Actions (count)	Informal Enforcement Actions (count)	Inspections (count)
Government-owned POTW	1.766 *** (0.257)	1.640 *** (0.171)	1.451 ** (0.264)
Government-owned non-POTW	0.509 (0.307)	0.276 *** (0.064)	0.445 (0.461)
Effluent violations in preceding 12 months	1.030 (0.021)	1.016 (0.011)	1.006 (0.004)
Reporting violations in preceding 12 months	1.000 (0.000)	1.001 ** (0.000)	1.000 * (0.000)
Control Factors			
Month indicators	X	X	X
Year indicators	X	X	X
State indicators	X	X	X
Regression Statistics			
N	341,733	341,733	341,733
# of Facilities	2,288	2,288	2,288
Zero Slopes χ^2 Test (p-value)	30,325 (0.00)	24,709 (0.00)	38,016 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes only facility-month combinations for state-month combinations in which we obtained added enforcement data from the state and in which the Compliance Status Tracking system indicates that facility exists in that month.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Appendix Table A-5
Effect of Ownership on Violations – Base Model:
Poisson Random Effects and Fixed Effects Estimation
Sample Restricted to Period with State Data on State-Issued Enforcement Actions

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)
	Random	Fixed	Fixed
Effluent violations in preceding 12 months	1.034 *** (0.003)	1.033 *** (0.002)	
Reporting violations in preceding 12 months			1.001 *** (0.000)
Government-owned POTW	1.418 *** (0.077)		
Government-owned non-POTW	0.237 *** (0.056)		
Formal enforcement actions in preceding 12 months	0.952 (0.033)	0.947 *** (0.019)	0.965 (0.045)
Informal enforcement actions in preceding 12 months	0.997 (0.014)	0.996 (0.010)	1.026 (0.027)
Inspections in preceding 12 Months	1.008 (0.006)	1.008 (0.005)	0.968 ** (0.016)
Control Factors			
Facility indicators		X	X
Month indicators	X	X	X
Year indicators	X	X	X
State indicators	X		
Regression Statistics			
N	341,733	301,284	306,247
# of Facilities	2,288	1,990	2,038
Zero Slopes χ^2 Test (p-value)	4,940 (0.00)	806 (0.00)	381 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes only facility-month combinations for state-month combinations in which we obtained added enforcement data from the state and in which the Compliance Status Tracking system indicates that facility exists in that month.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.
The reporting violation random effects specification does not successfully run.

Appendix Table A-6
Effect of Ownership on Deterrence – Extended Model:
Poisson Random Effects and Fixed Effects Estimation
Sample Restricted to Period with State Data on State-Issued Enforcement Actions

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)
	Random	Fixed	Fixed
Effluent violations in preceding 12 months	1.034 *** (0.003)	1.033 *** (0.002)	
Reporting violations in preceding 12 months			1.001 *** (0.000)
Government-owned POTW	1.477 *** (0.082)		
Government-owned non-POTW	0.252 *** (0.116)		
Formal Enforcement			
Formal enforcement actions in preceding 12 months	1.024 (0.072)	1.012 (0.040)	1.193 (0.172)
POTW × formal enforcement	0.915 (0.056)	0.923 * (0.041)	0.769 * (0.114)
Non-POTW × formal enforcement	0.985 (0.324)	0.938 (0.214)	0.854 (0.174)
Informal Enforcement			
Informal enforcement actions in preceding 12 months	1.028 (0.030)	1.023 (0.020)	1.067 (0.068)
POTW × informal enforcement	0.965 (0.026)	0.969 (0.021)	0.955 (0.064)
Non-POTW × informal enforcement	1.011 (0.218)	0.969 (0.069)	1.010 (0.131)
Inspections			
Inspections in preceding 12 months	1.017 (0.011)	1.017 (0.011)	0.934 (0.040)
POTW × inspections	0.990 (0.012)	0.990 (0.012)	1.055 (0.049)
Non-POTW × inspections	0.936 (0.219)	0.893 (0.102)	0.841 (0.089)
Control Factors			
Facility indicators		X	X
Month indicators	X	X	X
Year indicators	X	X	X
State indicators	X		

Regression Statistics			
N	341,733	301,284	306,247
# of Facilities	2,288	1,990	2,038
Zero Slopes χ^2 Test (p-value)	5,038 (0.00)	865 (0.00)	418 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.

Robust standard errors clustered on facility shown in parentheses.

Sample includes only facility-month combinations for state-month combinations in which we obtain added enforcement data from the state and in which the Compliance Status Tracking system indicates that facility exists in that month.

Omitted ownership type is private ownership.

Unit of analysis is facility-month.

The reporting violation random effects specification does not successfully run.

Appendix Table A-7
Effect of Ownership Type on Regulatory Attention:
Poisson Random Effects Estimation
Sample Excludes Florida Facilities for the Period before the Transition to ICIS

(coefficient magnitudes displayed as incidence rate ratios)

	Formal Enforcement Actions (count)	Informal Enforcement Actions (count)	Inspections (count)
Government-owned POTW	1.730 ** (0.390)	1.774 *** (0.350)	1.436 (0.365)
Government-owned non-POTW	0.613 ** (0.136)	0.304 *** (0.113)	0.404 (0.487)
Effluent violations in preceding 12 months	1.029 (0.028)	1.015 (0.013)	1.006 (0.006)
Reporting violations in preceding 12 months	1.000 (0.000)	1.001 ** (0.000)	1.000 (0.000)
Control Factors			
Month indicators	X	X	X
Year indicators	X	X	X
State indicators	X	X	X
Regression Statistics			
N	367,265	367,265	367,265
# of Facilities	2,296	2,296	2,296
Zero Slopes χ^2 Test (p-value)	32,618.70 (0.00)	26,182.65 (0.00)	45,342.76 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes only facility-month combinations in which the Compliance Status Tracking system indicates that facility exists in that month. In addition, Florida observations dropped before March 2011, when the data system transition drops some facilities.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Appendix Table A-8
Effect of Ownership Type on Violations – Base Model:
Poisson Random Effects and Fixed Effects Estimation
Sample Excludes Florida Facilities for the Period before the Transition to ICIS

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)	
	Random	Fixed	Random	Fixed
Effluent violations in preceding 12 months	1.035 *** (0.003)	1.035 *** (0.002)		
Reporting violations in preceding 12 months			1.001 *** (0.000)	1.001 *** (0.000)
Government-owned POTW	1.425 *** (0.089)		0.586 *** (0.083)	
Government-owned non-POTW	0.250 *** (0.048)		0.508 *** (0.087)	
Formal enforcement actions in preceding 12 months	0.986 (0.035)	0.981 (0.019)	0.971 (0.045)	0.971 (0.045)
Informal enforcement actions in preceding 12 months	0.993 (0.014)	0.992 (0.010)	1.032 (0.027)	1.032 (0.027)
Inspections in preceding 12 months	1.008 (0.006)	1.008 (0.005)	0.974 (0.017)	0.974 (0.017)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	367,265	324,339	367,265	333,734
# of Facilities	2,296	1,986	2,296	2,039
Zero Slopes χ^2 Test (p-value)	5,308 (0.00)	1,048 (0.00)	1,503 (0.00)	466 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes only facility-month combinations in which the Compliance Status Tracking system indicates that facility exists in that month. In addition, Florida observations dropped before March 2011, when the data system transition drops some facilities.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Appendix Table A-9
Effect of Ownership Type on Deterrence – Extended Model:
Poisson Random Effects and Fixed Effects Estimation
Sample Excludes Florida Facilities for the Period before the Transition to ICIS

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)	
	Random	Fixed	Random	Fixed
Effluent violations in preceding 12 months	1.035 *** (0.003)	1.035 *** (0.002)		
Reporting violations in preceding 12 months			1.001 *** (0.000)	1.001 *** (0.000)
Government-owned POTW	1.479 *** (0.087)		0.601 *** (0.091)	
Government-owned non-POTW	0.262 *** (0.101)		0.566 *** (0.106)	
Formal Enforcement				
Formal enforcement actions in preceding 12 months	1.040 (0.079)	1.028 (0.044)	1.208 (0.176)	1.208 (0.176)
POTW × formal enforcement	0.938 (0.061)	0.946 (0.044)	0.765 * (0.115)	0.765 * (0.115)
Non-POTW × formal enforcement	0.922 (0.302)	0.882 (0.207)	0.872 (0.167)	0.872 (0.167)
Informal Enforcement				
Informal enforcement actions in preceding 12 months	1.020 (0.030)	1.016 (0.020)	1.086 (0.066)	1.086 (0.066)
POTW × informal enforcement	0.969 (0.026)	0.972 (0.021)	0.941 (0.059)	0.940 (0.059)
Non-POTW × informal enforcement	1.030 (0.174)	1.000 (0.066)	1.021 (0.119)	1.021 (0.119)
Inspections				
Inspections in preceding 12 months	1.020 * (0.012)	1.020 * (0.012)	0.960 (0.053)	0.961 (0.053)
POTW x inspections	0.986 (0.013)	0.986 (0.013)	1.025 (0.060)	1.025 (0.060)
Non-POTW x inspections	0.957 (0.235)	0.910 (0.107)	0.804* (0.090)	0.802** (0.089)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	367,265	324,339	367,265	333,734
# of Facilities	2,296	1,986	2,296	2,039
Zero Slopes χ^2 Test (p-value)	5,416	1,139 (0.00)	1,597 (0.00)	534 (0.00)

	(0.00)			

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes only facility-month combinations in which the Compliance Status Tracking system indicates that facility exists in that month. In addition, Florida observations dropped before March 2011, when the data system transition drops some facilities.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Appendix Table A-10
Effect of Ownership Type on Regulatory Attention:
Poisson Random Effects Estimation
Controlling for Two Years of Lagged Enforcement

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Formal Enforcement Actions (count)	Informal Enforcement Actions (count)	Inspections (count)
Government-owned POTW	1.810 *** (0.125)	1.691 *** (0.128)	1.439 ** (0.267)
Government-owned non-POTW	0.598 (0.238)	0.293 *** (0.049)	0.442 (0.412)
Effluent violations in preceding 12 months	1.028 *** (0.010)	1.017 * (0.009)	1.004 (0.004)
Effluent violations in 13-24 months prior	1.008 (0.008)	0.998 (0.009)	1.002 (0.003)
Reporting violations in preceding 12 months	1.000 (0.000)	1.001 *** (0.000)	1.000 (0.000)
Reporting violations in 13-24 months prior	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
Control Factors			
Month indicators	X	X	X
Year indicators	X	X	X
State indicators	X	X	X
Regression Statistics			
N	380,879	380,879	380,879
# of Facilities	2,298	2,298	2,298
Zero Slopes χ^2 Test (p-value)	33,978 (0.00)	28,146 (0.00)	46,287 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Appendix Table A-11
Effect of Ownership Type on Violation Count – Base Model:
Poisson Random Effects and Fixed Effects Estimation
Controlling for Two Years of Lagged Enforcement

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)	
	Random Effects	Fixed Effects	Random Effects	Fixed Effects
Effluent violations in preceding 12 months	1.036 *** (0.003)	1.036 *** (0.002)		
Effluent violations in 13-24 months prior	0.997 * (0.002)	0.996 *** (0.001)		
Reporting violations in preceding 12 months			1.001 *** (0.000)	1.001 *** (0.000)
Reporting violations in 13-24 months prior			1.000 *** (0.000)	1.000 *** (0.000)
Government-owned POTW	1.435 *** (0.078)		0.582 *** (0.080)	
Government-owned non-POTW	0.243 *** (0.051)		0.494 *** (0.085)	
Formal enforcement actions in preceding 12 months	0.968 (0.029)	0.964 * (0.018)	0.998 (0.044)	0.998 (0.044)
Informal enforcement actions in preceding 12 months	0.996 (0.013)	0.995 (0.011)	1.029 (0.026)	1.029 (0.026)
Inspections in preceding 12 months	1.006 (0.006)	1.005 (0.005)	0.971 * (0.016)	0.971 * (0.016)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	380,879	337,090	380,879	345,085
# of Facilities	2,298	2,008	2,298	2,060
Zero Slopes χ^2 Test (p-value)	5,138 (0.00)	885 (0.00)	1,518 (0.00)	492 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.
Robust standard errors clustered on facility shown in parentheses.
Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Appendix Table A-12
Effect of Ownership on Deterrence – Extended Model:
Poisson Random / Fixed Effects Estimation - Control for 2 Years of Lagged Enforcement

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)	
	Random	Fixed	Random	Fixed
Effluent violations in preceding 12 months	1.036 *** (0.003)	1.036 *** (0.002)		
Effluent violations in 13-24 months prior	0.997 ** (0.002)	0.996 *** (0.001)		
Reporting violations in preceding 12 months			1.001 *** (0.000)	1.001 *** (0.000)
Reporting violations in 13-24 months prior			1.000 *** (0.000)	1.000 *** (0.000)
Government-owned POTW	1.492 *** (0.080)		0.586 *** (0.085)	
Government-owned non-POTW	0.258 *** (0.107)		0.540 *** (0.101)	
Formal Enforcement				
Formal enforcement actions in preceding 12 months	1.032 (0.065)	1.022 (0.037)	1.216 (0.156)	1.216 (0.156)
POTW × formal enforcement	0.928 (0.053)	0.934 * (0.038)	0.782 * (0.103)	0.782 * (0.104)
Non-POTW × formal enforcement	0.893 (0.341)	0.848 (0.233)	0.906 (0.170)	0.906 (0.170)
Informal Enforcement				
Informal enforcement actions in preceding 12 months	1.031 (0.028)	1.027 (0.020)	1.086 (0.060)	1.086 (0.060)
POTW × informal enforcement	0.961 (0.025)	0.963 * (0.021)	0.936 (0.054)	0.936 (0.054)
Non-POTW × informal enforcement	1.013 (0.178)	0.982 (0.064)	1.027 (0.114)	1.027 (0.114)
Inspections				
Inspections in preceding 12 months	1.015 (0.011)	1.014 (0.010)	0.949 (0.041)	0.949 (0.040)
POTW × inspections	0.989 (0.011)	0.989 (0.012)	1.039 (0.048)	1.039 (0.048)
Non-POTW × inspections	0.951 (0.224)	0.908 (0.108)	0.825 * (0.084)	0.824 * (0.083)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	

Regression Statistics				
N	380,879	337,090	380,879	345,085
# of Facilities	2,298	2,008	2,298	2,060
Zero Slopes χ^2 Test (p-value)	5,232 (0.00)	986 (0.00)	1,587 (0.00)	551 (0.00)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$.

Robust standard errors clustered on facility shown in parentheses.

Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.

Omitted ownership type is private ownership.

Unit of analysis is facility-month.

Table A-13
Effect of Ownership Type on Violation Count – Base Model:
Poisson Random Effects and Fixed Effects Estimation
Controlling for General Deterrence
(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violation (count)		Reporting Violations (count)	
	Random	Fixed	Random	Fixed
Effluent violations in preceding 12 months	1.035 *** (0.003)	1.035 *** (0.002)		
Reporting violations in preceding 12 months			1,001 *** (0.000)	1,001 *** (0.000)
Government-owned POTW	1.432 *** (0.0077)		0.564 *** (0.082)	
Government-owned non-POTW	0.243 *** (0.053)		0.475 *** (0.083)	
Formal enforcement actions in preceding 12 months	0.964 (0.032)	0.960 ** (0.018)	0.968 (0.043)	0.967 (0.043)
Informal enforcement actions in preceding 12 months	0.998 (0.014)	0.997 (0.011)	1.030 (0.027)	1.029 (0.027)
Inspections in preceding 12 Months	1.007 (0.006)	1.007 (0.005)	0.980 (0.015)	0.980 (0.015)
Formal enforcement actions on other facilities in state in in preceding 12 months	0.919 (0.232)	0.932 (0.227)	8.457 *** (3.864)	8.464 *** (3.868)
Informal enforcement actions on other facilities in state in in preceding 12 months	0.948 (0.064)	0.952 (0.062)	1.251* (0.154)	1.252 * (0.154)
Inspections of other facilities in the state in preceding 12 months	0.951 (0.037)	0.951 (0.037)	0.753 ** (0.088)	0.752 ** (0.087)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	388.441	343,482	388,441	353,653
# of facilities	2,298	2,009	2,298	2,070
Zero Slopes χ^2 Test (p-value)	5,319 (0.00)	937 (0.00)	1,556 (0.00)	505 (0.00)

* p<0.1; ** p<0.05; *** p<0.01.
Robust standard errors clustered on facility shown in parentheses.
Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Table A-14
Effect of Ownership on Deterrence – Extended Model:
Poisson Random Effects and Fixed Effects Estimation
Controlling for General Deterrence

(coefficient magnitudes displayed as incidence rate ratios)

Variable	Effluent Violations (count)		Reporting Violations (count)	
	Random	Fixed	Random	Fixed
Effluent violations in preceding 12 months	1.035 *** (0.003)	1.035 *** (0.002)		
Reporting violations in preceding 12 months			1.001 *** (0.000)	1.001 *** (0.000)
Government-owned POTW	1.494 *** (0.081)		0.569 *** (0.086)	
Government-owned non-POTW	0.255 *** (0.109)		0.523 *** (0.099)	
Formal Enforcement				
Formal enforcement actions in preceding 12 months	1.034 (0.071)	1.024 (0.040)	1.204 (0.160)	1.203 (0.160)
POTW × formal enforcement	0.919 (0.054)	0.925 * (0.040)	0.763 ** (0.105)	0.763 ** (0.105)
Non-POTW × formal enforcement	0.948 (0.325)	0.903 (0.206)	0.887 (0.164)	0.887 (0.163)
Informal Enforcement				
Informal enforcement actions in preceding 12 months	1.032 (0.030)	1.028 (0.019)	1.087 (0.064)	1.087 (0.064)
POTW × informal enforcement	0.962 (0.026)	0.965 * (0.020)	0.936 (0.057)	0.936 (0.057)
Non-POTW × informal enforcement	1.016 (0.187)	0.984 (0.065)	0.998 (0.118)	0.997 (0.118)
Inspections				
Inspections in preceding 12 months	1.018 (0.011)	1.017 (0.011)	0.957 (0.038)	0.957 (0.038)
POTW × inspections	0.987 (0.012)	0.988 (0.012)	1.040 (0.046)	1.039 (0.046)
Non-POTW × inspections	0.958 (0.224)	0.915 (0.104)	0.826 * (0.085)	0.825 * (0.085)
General Deterrence Controls: actions on other facilities in same state over preceding 12 months				
Formal enforcement actions against other facilities	0.930 (0.233)	0.941 (0.230)	8.425 *** (3.856)	8.434 *** (3.859)
Informal enforcement against other facilities	0.946 (0.066)	0.951 (0.061)	1.255 * (0.154)	1.256 * (0.154)
Inspections of other facilities	0.953 (0.038)	0.954 (0.037)	0.762 ** (0.090)	0.761 ** (0.089)

Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	388,441	343,482	388,441	353,653
# of facilities	2,298	2,009	2,298	2,070
Zero Slopes χ^2 (p-value)	5,409 (0.00)	1,006 (0.00)	1,625 (0.00)	555.6 (0.00)

* p<0.1; ** p<0.05; *** p<0.01.
Robust standard errors clustered on facility shown in parentheses.
Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.
Omitted ownership type is private ownership.
Unit of analysis is facility-month.

Table A-15
Effect of Ownership Type on Violation Indicators – Base Model:
OLS Random Effects and Fixed Effects Estimation

Variable	Effluent Violations		Reporting Violations	
	Random Effects	Fixed Effects	Random Effects	Fixed Effects
Effluent violations (indicator) in preceding 12-months	0.014 *** (0.001)	0.013*** (0.001)		
Reporting violations (indicator) in preceding 12-months			0.000 *** (0.000)	0.000 *** (0.000)
Government-owned POTW	0.037 *** (0.004)		0.007 ** (0.003)	
Government-owned non-POTW	-0.060 *** (0.005)		-0.051 *** (0.005)	
Formal enforcement actions in preceding 12 months	-0.004 (0.003)	-0.007 *** (0.003)	0.006 ** (0.003)	0.005 * (0.003)
Informal enforcement actions in preceding 12 months	0.000 (0.001)	-0.001 (0.001)	0.004 ** (0.002)	0.003 (0.002)
Inspections in preceding 12 months	0.001 * (0.001)	0.001 (0.001)	-0.001 * (0.001)	-0.001* (0.001)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	388,441	388,441	388,441	388,441
# of Facilities	2,298	2,298	2,298	2,298
Constant	0.080 *** (0.010)	0.081 *** (0.007)	0.107 *** (0.008)	0.039 *** (0.005)
Overall R^2	0.162	0.153	0.0603	0.0420

* p<0.1; ** p<0.05; *** p<0.01.

Robust standard errors shown in parentheses.

Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.

Omitted ownership type is private ownership.

Unit of analysis is facility-month.

Table A-16
Effect of Ownership on Deterrence – Extended Model:
OLS Random Effects and Fixed Effects Estimation Using Violation Dummies

Variable	Effluent Violations		Reporting Violations	
	Random	Fixed	Random	Fixed
Effluent violations (indicator) in preceding 12 months	0.014 *** (0.001)	0.013 *** (0.001)		
Reporting violations (indicator) in preceding 12 months			0.000 *** (0.000)	0.000 *** (0.000)
Government-owned POTW	0.037 *** (0.005)		0.009 ** (0.003)	
Government-owned non-POTW	-0.060 *** (0.005)		-0.050 *** (0.005)	
Formal Enforcement				
Formal enforcement actions in preceding 12 months	-0.001 (0.006)	-0.007 (0.006)	0.004 (0.004)	0.003 (0.004)
POTW × formal enforcement	-0.004 (0.006)	-0.000 (0.006)	0.003 (0.005)	0.003 (0.005)
Non-POTW × formal enforcement	0.001 (0.008)	0.003 (0.009)	-0.002 (0.010)	-0.005 (0.010)
Informal Enforcement				
Informal enforcement actions in preceding 12 months	0.001 (0.002)	-0.001 (0.002)	0.003 (0.002)	0.002 (0.002)
POTW × informal enforcement	-0.001 (0.003)	-0.000 (0.003)	0.001 (0.003)	0.000 (0.003)
Non-POTW × informal enforcement	0.005 (0.004)	0.005 (0.004)	0.001 (0.003)	0.000 (0.003)
Inspections				
Inspections in preceding 12 months	0.001 (0.001)	0.000 (0.001)	0.001 (0.001)	0.000 (0.001)
POTW × inspections	0.000 (0.001)	0.001 (0.001)	-0.002 * (0.001)	-0.002 * (0.001)
Non-POTW × inspections	-0.001 (0.001)	-0.000 (0.001)	-0.001 (0.001)	-0.001 (0.001)
Control Factors				
Facility indicators		X		X
Month indicators	X	X	X	X
Year indicators	X	X	X	X
State indicators	X		X	
Regression Statistics				
N	388,441	388,441	388,441	388,441
# of Facilities	2,298	2,298	2,298	2,298
Constant	0.048 *** (0.007)	0.081 *** (0.007)	0.065 *** (0.006)	0.039 *** (0.005)
Overall R^2	0.162	0.154	0.060	0.042

* p<0.1; ** p<0.05; *** p<0.01.

Robust standard errors shown in parentheses.

Sample includes observations only if the EPA Compliance Status Tracking system indicates that the particular facility was active in the specific month.

Omitted ownership type is private ownership.

Unit of analysis is facility-month.