Original Manuscript - Full Length

Business & Society
1–35

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Learning or Leaking? Enforcement Spillover Effects Within and Beyond the Firm

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Abstract

We posit and find evidence consistent with a new mechanism of intra-firm enforcement spillovers: the leakage of scarce compliance resources across facilities within a firm. Using a facility-level panel data set of Clean Air Act (CAA) enforcement actions from 2005 to 2017, we find a facility is more likely to violate the CAA following penalties on its same-industry-same-state siblings. In contrast, there is no significant spillover across firms. We show that the intra-firm spillover is not due to changes in regulatory attention or production shifting. Instead, our results suggest it may result from the redeployment of scarce compliance resources across siblings. Consistent with this mechanism, we find compliance leakage only occurs at privately held firms and facilities that lack the resources to invest in pollution prevention. The findings contribute to understanding the efficacy of environmental enforcement and have important implications for intra-firm management of environmental performance and regulatory enforcement approaches.

Keywords

regulation, enforcement, environmental performance, deterrence

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Enforceable regulations are a leading motivator for businesses to improve their environmental performance (Aragòn-Correa et al., 2020; Blackman et al., 2018; Darnall et al., 2010; Delmas & Toffel, 2008) and have played an essential role in the tremendous improvement of environmental quality over the last several decades (Currie & Walker, 2019). Their powerful impacts hinge on rigorous enforcement of the standards set out in laws and statutes (Gray & Shimshack, 2011). Without strong enforcement programs, standards can easily become mere "toothless" guidelines (King & Lenox, 2000).

Given the central role of enforcement in environmental protection, it is critical to understand its impacts on the environmental performance of regulated entities and to seek out any possible efficiency improvements. A large body of empirical work finds that enforcement actions do lead to fewer subsequent violations and pollution emissions (Gray & Shimshack, 2011; Shimshack, 2014). Moreover, clever dynamic targeting of enforcement can significantly reduce the cost of enforcement (Blundell et al., 2020). Spatial effects are also important, as the impacts of enforcement actions are not limited to targeted facilities (Deily & Gray, 2006; Earnhart, 2004), but may also spill over to nearby nontargeted ones (Evans et al., 2018; Gray & Shadbegian, 2007; Shimshack & Ward, 2005). Such spillovers create a phenomenon known as general deterrence, according to which nontargeted facilities update their beliefs about the regulator's propensity to enforce and adjust their behavior accordingly.

An important yet understudied issue is the extent to which enforcement spillovers differ across facilities owned by different firms and facilities within the same firm, that is, corporate siblings. There are good reasons to expect that such differences may exist and may be substantial. First, intra-firm learning from enforcement actions may be stronger than interfirm learning since corporate parents have incentives to share information internally. This suggests intra-firm spillover of deterrence effects should be *greater* than interfirm spillovers. Second, corporate siblings make use of shared compliance resources, which may potentially be reallocated across facilities following an enforcement action. This suggests intra-firm spillover of deterrence effects should be *smaller* than or in the *opposite* direction from interfirm spillovers. The net effect is an empirical matter, which is the focus of our study, conducted in a facility-level panel data set for CAA enforcement from 2005 to 2017.

With the data set, we examine how a focal facility's environmental performance, which is measured by the chance of violation, changes following sanctions on other facilities within and beyond the firm that owns the focal facility. Our results provide no evidence for general deterrence across firms, as a facility's probability of violation is not affected by penalties on nonsibling facilities. However, we do find evidence of intra-firm spillover. A focal facility is more likely to violate the CAA in the following year if its same-industry-same-state (In1St1) siblings are targeted by penalties. The higher chances of violation are not due to stricter regulatory scrutiny, as we find that regulators do not change the likelihood of inspection, a key metric for regulatory attention, on a focal facility following penalties on its siblings. Nor is the spillover due to enforcement-induced production shifting, as a facility's production level does not change significantly following penalties on siblings. However, we do find suggestive evidence that the spillover effect does not exist for focal facilities with adequate environmental compliance resources, or within publicly traded firms. Both of these findings suggest that compliance leakage only occurs at firms with weaker environmental management programs, as can occur as a result of resource constraints. Taken together, our findings suggest that the diversion of compliance resources dominates any internal learning effect, that is, that leaking dominates learning.

This study contributes to our understanding of multi-unit firms' responses to external pressure as it relates to their environmental performance, enriching the literature on how common ownership affects sibling facilities' environmental performance. While previous studies have investigated how businesses react to extra-jurisdictional regulations, they focus on spillovers from the imposition of new regulations or across-the-board shift of regulatory stringency within a jurisdiction (Doshi et al., 2013; Fremeth & Shaver, 2014; Gibson, 2019) whereas this study examines the spillover of enforcement actions against specific facilities within the firm. Moreover, the study presents a new mechanism, intra-firm compliance resource redeployment, which we characterize as a form of regulatory leakage. Prior work on regulatory leakage has focused on the shifting of polluting *production* from regulated to unregulated facilities (Fowlie, 2009; Gibson, 2019), or from facilities within a firm that are high-priority violators to sibling facilities that are in compliance (Gibson, 2019; Rijal & Khanna, 2020). Our results are novel because they explore a different margin of behavior: the possibility of shifting of *compliance resources* between siblings rather than the shifting of actual production. These insights have important implications for business managers (on the intra-firm management of environmental capacities and resources) and policymakers (on enforcement strategies and the use of different regulatory approaches) to improve the environmental performance of multi-unit firms.

Literature Review

Multifacility firms play a critical role in the global economy, employing 78% of the manufacturing workforce and producing 88% of the manufacturing output in the United States (Bernard & Jensen, 2007). Their environmental performance, especially its heterogeneity across their various facilities, has received much attention from researchers. One of the most closely examined questions is the "pollution haven hypothesis," under which firms lower the environmental performance of their operations in jurisdictions with lower environmental standards (Christmann, 2004; Dowell et al., 2000). Most studies find that instead of adjusting environmental performance from jurisdiction to jurisdiction, firms tend to standardize their practice and performance across jurisdictions. For example, multinational firms' operations in developing countries are significantly more environmentally friendly than local firms (Christmann & Taylor, 2001; Eskeland & Harrison, 2003). A related question pertains to whether firms respond to environmental regulations in jurisdictions where they do not operate. For instance, researchers (Dutt & Joseph, 2019; Fremeth & Shaver, 2014) have found that firms take actions in response to renewable portfolio standards in other jurisdictions, which may portend regulatory changes in jurisdictions where they operate. Another question relates to how sibling facilities within a firm shape a facility's responses to external pressure. For example, scholars have found that proximity to a sibling facility amplifies stakeholder pressure from information disclosure on a focal facility (Doshi et al., 2013) and a focal facility is more likely to be shut down in the face of more stringent environmental regulation when it has sibling facilities in the same county (Cui & Moschini, 2020). This study addresses a closely related, but unexplored question: how multi-unit firms respond to enforcement actions (more specifically, how enforcement actions on sibling facilities affect the environmental performance of a focal facility).

The empirical literature on the impacts of regulatory pressure is extensive (Aragòn-Correa et al., 2020; Carberry et al., 2019; Helmig et al., 2016). When it specifically comes to enforcement actions, the type of regulatory pressure studied in this article, most of the studies examine how indicators of facilities' environmental performance—such as violations, pollution discharges, and adoption of environmental management practices—respond to enforcement actions. They show that enforcement actions have strong specific deterrence effects, that is, deterrence effects on the specific targeted facility. For example, enforcement actions under the CAA have led targeted facilities to reduce emissions (Keohane et al., 2009), increase compliance (Deily & Gray, 2006; Short & Toffel, 2010), and adopt pro-environmental practices (Short & Toffel, 2008).

Beyond specific deterrence, many studies have found that enforcement actions have general deterrence effects—that is, they affect nontargeted facilities' environmental performance, by changing their expectations about regulatory stringency. General deterrence is strongest among facilities in the same jurisdictions, which face the same regulators, since enforcement actions enable other facilities to learn about the preferences of specific regulatory agencies. For instance, in the context of the Clean Water Act, research shows that nontargeted facilities improve their compliance records (Shimshack & Ward, 2005) and reduce water pollution discharges (Evans et al., 2018) following penalties imposed on other facilities in the same states. Similar general deterrence is documented under the CAA (Gray & Shadbegian, 2007) and for oil and gas drilling regulations (Maniloff, 2019), and utility investment decisions are also influenced by regulatory reputation spillovers within a given state (Lyon & Mayo, 2005).

Studies on general deterrence focus on spillover effects between targeted and nontargeted facilities within a given political jurisdiction, but generally ignore the effects of shared corporate parents. In contrast, two recent studies explore intra-firm spillover effects among corporate siblings in separate jurisdictions. Unlike the mostly positive spillover from general deterrence, these articles show that intra-firm spillovers across jurisdictions may be negative. For example, Gibson (2019) found that more stringent county-wide enforcement of ambient air quality regulation led air emissions at an affected plant's sibling facilities in other areas to increase by 11%. Rijal and Khanna (2020) found that a facility's toxic air emissions increased by about 35% to 56% when it had a sibling facility designated as a high-priority violator. These studies attribute the intra-firm spillover of pollution to regulation-induced production shifting. They differ from the literature on general deterrence in that they study sharp shifts in the enforcement regime affecting one facility (i.e., because its county goes into "nonattainment status" or because it is designed a high-priority violator) that do not apply to a firm's sibling facilities. Thus, the learning effect that is central to general deterrence is not present, and these articles capture only the leakage of polluting production across facilities.

By incorporating both the possibility of learning and the possibility of leakage, our study builds on and expands the existing literature in several ways. First, it sheds new light on general deterrence effects within and beyond a given jurisdiction, and how these are affected by common ownership. Second, it proposes and provides some suggestive evidence for a novel mechanism, intra-firm redeployment of compliance resources, which can explain negative intra-firm spillovers from enforcement even without production shifting. Third, unlike previous intra-firm spillover studies, which mostly ignore the jurisdictional match of sibling facilities, this study categorizes sibling facilities into four groups based on jurisdiction and industry matches, which provides sharper insights to better understand and prevent negative intra-firm spillovers.

A Theoretical Framework for Intra-Firm Spillovers

Sibling facilities are connected through common corporate parents, and prior work has shown that corporate parents can influence the financial performance of their subsidiaries (Feldman, 2021). The influence derives from corporate parents' involvement in the strategic and managerial decisions of subsidiaries, ability to facilitate intra-firm learning, and flexibility to redeploy resources across subsidiaries (Goold et al., 1994). Through these mechanisms, a focal facility's environmental performance may also be affected by enforcement actions on its sibling facilities. Specifically, we propose two mechanisms by which intra-firm spillovers from enforcement may occur.

Intra-Firm Learning

Facilities constantly learn about the regulatory environment from the experience of other facilities that either belong to the same firm or not, and they adapt their behaviors based on this learning (Reid & Toffel, 2009; Yue & Wang, 2023). For instance, an electric utility increases its renewable power generation if other electric utilities in the same state have siblings operating in other states with renewable portfolio standards (Dutt & Joseph, 2019; Fremeth & Shaver, 2014). More specific to environmental enforcement, the general deterrence literature reviewed above also suggests that a focal facility improves its environmental performance following enforcement actions targeted at other facilities in the same state/jurisdiction, as these actions strengthen the reputation for toughness of the regulatory agency that conducts them (Evans et al., 2018; Gray & Shadbegian, 2007; Shimshack & Ward, 2005).

The above-described learning effect does not exclusively pertain to sibling facilities, but studies show that corporate parents can further facilitate learning among siblings, making intra-firm learning stronger than general learning (Argote & Miron-Spektor, 2011). For example, learning and transfer of knowledge occurred among pizza shops owned by the same franchisee but not across stores owned by different franchisees (Darr et al., 1995).

When it comes to environmental knowledge, there also exists strong evidence for intra-firm learning. Doshi et al. (2013) found that a facility's environmental performance improved more, following pressure from information disclosure, if it had nearby same-industry siblings, because of knowledge transfer. Berchicci et al. (2012) demonstrated that the opportunities to transfer environmental knowledge were important motivations for firms' acquisition decisions, and Berchicci et al. (2017) further showed that transfer of environmental knowledge did occur after acquisitions.

The above arguments suggest that a facility may learn more from enforcement actions against its sibling facilities than from actions against nonsibling facilities. Sibling facilities share the same higher-level management and have more opportunities to communicate detailed information on the enforcement actions with each other. The knowledge could also be more relevant as sibling facilities often are more similar in their equipment, production process, and pollution management practices. Thus, we recognize:

Mechanism 1 (Learning): Enforcement actions on sibling facilities enable a focal facility within the same jurisdiction to update its beliefs about regulator behavior and hence to improve its environmental compliance.

Intra-Firm Compliance Resource Redeployment

A facility's environmental performance is influenced by the relevant resources available to it (Hart, 1995; Xu & Kim, 2022). Although some resources—such as knowledge and information—are scale-free and can be shared across facilities simultaneously, many resources are non-scale-free (Levinthal & Wu, 2010). These resources—such as plant and equipment, financial assets, human resources in environmental management, or the time and energy of corporate managers—cannot be used simultaneously at multiple facilities. The use of them in one facility precludes other facilities from using them. Intra-firm resource redeployment means reallocating this type of resource from a focal facility to its sibling facilities that have been targeted by enforcement.

When faced with external opportunities and shocks, multi-unit firms often reallocate resources across their subunits (Dickler & Folta, 2020). Increases in foreign competition resulting from tariff changes led multibusiness firms to allocate more resources to the business affected by the tariff and fewer to the unaffected business (Morandi Stagni et al., 2020). Similarly, the introduction of new airline routes between headquarters and plants, which represented a positive shock to investment opportunities, caused corporate parents to withdraw capital and labor from sibling plants to provide the treated plants with additional resources (Giroud & Mueller, 2015). In addition, employment at local establishments fell as a result of negative shocks to consumer demand in other regions where sibling establishments were operating (Giroud & Mueller, 2019).

Environmental enforcement actions can be significant shocks to facilities (Congressional Research Service, 2014). Facilities' expenditures on environmental compliance are substantial. Pollution control accounted for more than 20% of the total capital expenditure of U.S. manufacturers in 2005 (Xu & Kim, 2022). When targeted, facilities must often mobilize significant amounts of resources to address enforcement actions. They may need to maintain and upgrade existing pollution control equipment, change production processes, or modify their supply chains. In addition, enforcement actions often come with monetary penalties. For instance, in our sample, the average penalty assessed is US$210,000. The shock is similar in financial magnitude to that studied by Giroud and Mueller (2015), who found investment at a plant increased by US$186,000 when a new, direct air route connected it with headquarters.

Because enforcement actions are legal orders that require the targeted facilities to achieve compliance and rectify relevant environmental damages, it is extremely likely that the need for environmental compliance resources will increase at targeted facilities. These resources not only include financial assets and new pollution control equipment, but also, perhaps more importantly, extensive management and employee involvement to ensure better housekeeping, equipment maintenance, and supply chain and production process improvement (Hart, 1995). The heightened attention to targeted facilities may lead to fewer environmental resources being allocated to a nontargeted sibling facility.

Sharing of compliance resources is common among siblings. In our sample, 53% of the facilities share environmental compliance managers with at least one other sibling facility in 2017.[1] Environmental compliance managers themselves (e.g., their expertise, attention, and supervision) are personnel resources that shape the environmental performance of facilities (Delmas & Toffel, 2008; Hart, 1995; Raff & Earnhart, 2019). In addition, physical resources, such as equipment, and financial resources may also be relatively easier to redeploy between facilities that are overseen by the same managers. To the extent that firms/managers prioritize and redeploy non-scale-free resources to siblings targeted by enforcement actions, environmental performance of a focal facility may deteriorate, and we recognize:

> *Mechanism 2 (Leaking): Enforcement actions on sibling facilities will tend to lead to the redeployment of compliance resources away from a focal facility and hence to worsen its environmental compliance.*

Although the two mechanisms work in opposite directions, for both of them we expect the spillover effects to be stronger for sibling facilities in the same state and same industry. For intra-firm learning, since knowledge about the reputation and preferences of specific regulators is likely to be most relevant for a facility that faces the same regulators (Shimshack & Ward, 2005), a facility is likely to learn more from siblings in the same state. Similarly, the experience of siblings in the same industry is likely more relevant because of the similarities in operations, production processes, environmental problems, and compliance requirements, as requirements under the CAA are usually industry specific. For intra-firm resource redeployment, sibling facilities in the same states are often geographically and organizationally closer to each other, which makes redeployment of resources easier. Resources could also be more fungible, thus more likely to be redeployed, among sibling facilities in the same industry because of similarities, again, in production processes and compliance requirements. The closer connections between In1St1 siblings are also empirically reflected in the sharing of compliance managers in our sample. Among facilities with In1St1 siblings, 71% of them share compliance managers with at least one other In1St1 sibling in 2017. However, only 22% of facilities share compliance managers with non-In1St1 siblings. The closer connections between In1St1 siblings may make resource redeployment between them easier.

The two mechanisms highlight two different aspects of corporate parents' influence on the environmental performance of facilities. Intra-firm learning emphasizes the sharing of knowledge, but it does not specify whether non-scale-free resources would increase in a focal facility. The corporate parent may well increase the resources at a focal facility if it mobilizes additional resources or there are slack resources for compliance. The non-scale-free resources may also be kept at the same level. In contrast, intra-firm resource redeployment depicts a scenario where non-scale-free resources increase for targeted siblings and decrease for a nontargeted focal facility, which will be reflected in the change in their environmental performance. Since the two mechanisms have opposite predictions and can be offsetting, we are able to observe the dominating mechanism but are unable to rule out the existence of the weaker one.

Research Context and Data

The empirical context in which we conduct our study is the CAA, which is the primary law that regulates air pollution in the United States. The CAA is jointly implemented by the federal Environmental Protection Agency (EPA) and states. The EPA establishes and revises various air quality, emissions, and technology standards, and states are required to develop enforceable state implementation plans (SIPs) to meet and maintain air quality that meets these standards. SIPs must be submitted to and approved by the EPA. Once approved, state regulators assume the primary responsibility of ensuring facilities' compliance with the requirement in SIPs.

Regulators detect violations through monitoring, inspecting, citizen reporting, or self-reporting by regulated entities (Congressional Research Service, 2014). When violations are found, regulators have the authority to take enforcement actions. Enforcement options include informal administrative sanctions such as warning letters, telephone calls, and notices of violation, formal administrative sanctions such as administrative orders of compliance (with or without penalties), and less common civil and criminal judiciary actions (Congressional Research Service, 2014). In this study, we examine how enforcement actions, more specifically penalties, on sibling facilities affect a focal facility's compliance with the CAA.

The primary data source is EPA's Enforcement and Compliance History Online (ECHO) database. This database compiles CAA inspection and enforcement activities and facilities' compliance status. Another important data source is EPA's Toxics Release Inventory (TRI) database. The TRI requires certain facilities to disclose detailed information about their management of toxic chemicals on an annual basis. We use the TRI database for facilities' production levels and, most importantly, to identify each facility's sibling facilities.

Sample

Our sample includes facilities that are regulated by both the CAA and the TRI during 2005–2017. With our focus on the spillover among sibling facilities under the CAA, a natural sample would be all CAA facilities. However, the CAA facility data set only provides a list of CAA facilities that ever existed and their current operating status, but it does not indicate when a facility was established or shut down (Congressional Research Service, 2014). Thus, it cannot be used to identify the universe of operating CAA facilities for the analysis period. In addition, the CAA data sets do not contain information on facilities' parent companies and production levels, which is critical for our analyses. Fortunately, the information is reported to the TRI, and as with many studies that focus on CAA enforcement (Gibson, 2019; R. N.Hanna & Oliva, 2010; Rijal & Khanna, 2020), we create the sample by triangulating CAA facilities with TRI facilities to take advantage of the richer information in the TRI.

Since the TRI disclosure requirements apply only to facilities above certain sizes (with 10 employees or more and which manage chemicals in quantities above threshold levels) and in certain industries (primarily manufacturing, metal and coal mining, electric power generators, etc.), the triangulation inevitably excludes some CAA facilities. Despite this limitation, since the TRI is one of the most comprehensive sources of pollution information in the United States, the sample captures the most important air polluters. We also exclude single-unit facilities from the main analysis as they have no siblings. The resulting data set for analysis consists of 4,138 facilities (56,134 facility-year observations for 2005–2017).

Identifying Sibling Facilities

We identify sibling facilities using the TRI data. In the TRI data set, facilities report the names and Dun and Bradstreet numbers (D&B number) of their parent companies. For a specific facility, other facilities that belong to the same parent company are considered its siblings. We further characterize sibling facilities along two dimensions: state match and industry match (based on six-digit North American Industry Classification System [NAICS] codes).[2] Following this approach, we identify four groups of siblings: same-industry-same-state (In1St1) siblings, same-industry-different-state (In1St2) siblings, different-industry-same-state (In2St1) siblings, and different-industry-different-state (In2St2) siblings.

Dependent Variable

The key dependent variable is a dummy that indicates facilities' violation of the CAA. We use it because CAA violations are systematically observable to researchers for most facilities, but other metrics of performance in the CAA, such as pollution emissions, are not continuously monitored or made available to the public (Gray & Shimshack, 2011). We derive the measure from ECHO's violation history data set, which records cases of violation in the CAA. If a facility incurs new violations in a certain year, the violation dummy takes the value 1; otherwise, it is 0. We follow previous work (Stafford, 2012) and use a dummy to measure violation because most facilities have only one count of violation in a year when violations are detected and information on the nature of violations is limited, making it difficult to develop a continuous measure of compliance.

Independent and Control Variables

Enforcement/Penalties. The key independent variable is CAA enforcement actions. In the main analysis, we focus on formal enforcement actions with penalties, which are relatively strong actions. We conduct additional analyses for formal enforcement actions (with and without penalties) and enforcement actions (formal and informal enforcement actions combined) in the Supplemental Appendix.

For a specific facility, we calculate penalties on itself and its four categories of sibling facilities (defined by matches of industry and state). We operationalize penalties in two formats: (a) dummy variables that indicate the existence of penalties and (b) dollar amount of penalties. The dummy variable approach compares a facility's chances of getting into violation when it has versus does not have penalized siblings, while the amount variable approach compares the impact of different degree of penalties. We include the results based on penalty dummies in the main analysis and the results based on penalty amount in the Supplemental Appendix. The penalty dummies take the value of 1 if penalties have been assessed on the facility and its four categories of siblings, respectively; they are 0 otherwise. For penalty amount, we take the logarithm of the dollar amount after adding 1, a common practice in empirical analysis to scale a variable that is heavily right-skewed (Chatterji & Toffel, 2010).

Inspections/Regulatory Attention. We use a dummy variable to indicate whether a facility has been inspected by regulators in a year and use it as a proxy for regulatory attention on the facility. Regulators conduct inspection activities—such as reviews of records, visual inspections of facilities and equipment, and stack tests—to monitor performance of facilities (U.S. EPA, 2016). Their monitoring practices principally follow a target model, by adjusting the intensity of monitoring/scrutiny of a facility based on the facility's historical environmental performance, to achieve a high level of deterrence with relatively low levels of monitoring activities (Friesen, 2003; Harford & Harrington, 1991; U.S. EPA, 2016). They implement a lax monitoring regime on "good" facilities and a stringent regime on "bad" facilities.

If a facility receives more attention from regulators, it may be more likely to be found in violation (the outcome variable) because of the closer scrutiny. We use inspection as a proxy for regulatory attention because inspection is a core component of regulatory monitoring and regulators have large discretion in which facilities to inspect and when (Shimshack, 2014). Inspections are also costly, and regulators face tradeoffs in their decisions to inspect. As a result, inspections signal regulatory attention and priority (Blundell et al., 2020; R. N. Hanna & Oliva, 2010).

Production Index. We develop our measure of the production index from the TRI data set. Facilities do not report absolute production levels to the TRI. However, they submit information on their production ratio, which measures their production level compared with that in the previous year. By multiplying the ratios over time from a base year, we generate a production index compared with the base year (Berchicci et al., 2017; Doshi et al., 2013). We pick 2005 as our base year, and the production index measures the ratio of production level in a certain year to that in 2005. We exclude facilities with production index greater than 10 (larger than the 99-percentile cutoff) or smaller than 0.1 (smaller than the 1-percentile cutoff) to avoid outliers and potential reporting mistakes.

We use the logarithmic form of the production index in the regression. The log of the production index can be decomposed in the following way:

$$Ln\left(production\,index_{it}\right) = \ln\left(\frac{production\,level_{it}}{production\,level_{i2005}}\right)$$
$$= \ln\left(production\,level_{it}\right) - \ln\left(production\,level_{i2005}\right)$$

Since $\ln\left(production\,level_{i2005}\right)$ is a facility-specific constant, which will be absorbed by facility-fixed effects in our model, including $Ln\left(production\,index_{it}\right)$ is equivalent to having $\ln\left(production\,level_{it}\right)$ in the regression model.

Tables 1 and 2 present descriptive statistics and correlations between the variables. They show that about 7% of facility-years incurred violations during the analysis period, while 60% of facility-years received inspections. The average change in production level—an increase in about 1%—was small, but the variation across facilities was large. As for penalties, about 6% of facility-years had penalties on self, and for those that had penalties, the average amount of penalties was about US$210,000.

Empirical Model

To evaluate the net impact of the two mechanisms we consider, we regress a facility's violation of the CAA in a given year on the CAA penalties levied on itself and its siblings in the year before. We lag the penalty measures by 1 year following the convention of the environmental enforcement literature (Earnhart, 2004) as facilities need time to adjust. Doing so also circumvents the concern of reverse causality (Gray & Shimshack, 2011). Specifically, we estimate the following model.

$$Violation_{it} = \beta_1 PltyIn1St1_{i(t-1)} + \beta_2 PltyIn1St2_{i(t-1)} + \beta_3 PltyIn2St1_{i(t-1)}$$
$$+ \beta_4 PltyIn2St2_{i(t-1)} + \beta_5 Pltyself_{i(t-1)} + \alpha_i + t\alpha_i$$
$$+ \varphi_t + \theta_{kt} + \gamma_{st} + \rho_{ct} + \varepsilon_{it.}$$

$Violation_{it}$ is a dummy variable that equals 1 if facility i incurs a CAA violation in year *t*. $PltyIn1St1_{i(t-1)}$, $PltyIn1St2_{i(t-1)}$, $PltyIn2St1_{i(t-1)}$, $PltyIn2St2_{i(t-1)}$, and $Pltyself_{i(t-1)}$ measure penalties on the four categories of siblings, and self, respectively. The coefficients on the penalty measures

Table 1. Descriptive Statistics.

Variable	Obs	*M*	*SD*	Minimum	Maximum
Number of In1St1 siblings	56,134	0.52	1.13	0	8
Number of In1St2 siblings	56,134	3.72	7.14	0	56
Number of In2St1 siblings	56,134	0.57	1.37	0	14
Number of In2St2 siblings	56,134	8.00	15.25	0	89
1 Violation dummy	56,134	0.07	0.26	0	1
2 Inspection dummy	56,134	0.60	0.49	0	1
3 Log production index	56,134	0.01	0.49	−2.28	2.28
4 1-year lagged penalties on self (dummy)	56,134	0.06	0.24	0	1
5 1-year lagged penalties on In1St1 sibling (dummy)	56,134	0.03	0.17	0	1
6 1-year lagged penalties on In1St2 sibling (dummy)	56,134	0.14	0.35	0	1
7 1-year lagged penalties on In2St1 sibling (dummy)	56,134	0.04	0.19	0	1
8 1-year lagged penalties on In2St2 sibling (dummy)	56,134	0.21	0.41	0	1

Note. In1St1 = same-industry-same-state; In1St2 = same-industry-different-state; In2St1 = different-industry-same-state; In2St2 = different-industry-different-state.

Table 2. Correlations of Variables.

Variable	1	2	3	4	5	6	7	8
1 Violation dummy	1.00							
2 Inspection dummy	0.16	1.00						
3 Log production index	0.00	−0.03	1.00					
4 L1 penalties on self (dummy)	0.23	0.12	0.00	1.00				
5 L1 penalties on In1St1 sibling (dummy)	0.14	0.06	0.01	0.19	1.00			
6 L1 penalties on In1St2 sibling (dummy)	0.08	0.10	0.00	0.10	0.10	1.00		
7 L1 penalties on In2St1 sibling (dummy)	0.09	0.01	0.01	0.11	0.13	0.00	1.00	
8 L1 penalties on In2St2 sibling (dummy)	0.02	0.02	0.01	0.02	0.01	0.04	0.19	1.00

Note. In1St1 = same-industry-same-state; In1St2 = same-industry-different-state; In2St1 = different-industry-same-state; In2St2 = different-industry-different-state.

represent the effects of penalties on the environmental performance of facility i.

Our identification strategy primarily relies on a battery of fixed effects. Facility-fixed effects α_i control for facility characteristics that remain the same over the study period but are potentially correlated with both violation and penalties. These characteristics include industry, location, and numbers of each category of siblings among others. Facility-fixed effects also absorb firm fixed effects, which control for stable firm-level confounders, such as firm culture regarding environmental issues. We also include facility-specific linear time trends $t\alpha_i$, which allow facilities to have different trends in technology, local demographic and economic conditions, and other factors that may affect penalties and environmental performance.

To further minimize endogeneity concerns, we also include the following fixed effects in different specifications. Year fixed effects φ_t control for the common trends of violations and penalties for all facilities. They capture time-varying factors at the national level that affect all facilities equally, such as broad technology improvement, national economic conditions, preferences of the White House, Congress, and changes at the federal EPA. Not all national factors affect all facilities equally. For example, the EPA often develops industry-based enforcement priorities. Shocks to demand, prices, and supply chains often only affect facilities in certain industries. We capture these industry-specific time-varying factors with industry-year fixed effects θ_{kt}.

State-year fixed effects γ_{st} account for common shocks at the state level. State regulators assume primary responsibility in the implementation of the CAA and have large discretion in their enforcement strategies, which are often shaped by governors, state legislatures, and state financial and economic conditions. State-year fixed effects also absorb the general deterrence effect of enforcement, which affect all facilities in the same state in a year as they all face the same regulatory agency. County-year fixed effects ρ_{ct} further rule out the confounding effects of local time-varying factors, such as changes in local environmental, socioeconomic, and political conditions, which influence the behaviors of both facilities and regulators (Doshi et al., 2013).

Importantly, the county-year fixed effects address concern about the National Ambient Air Quality Standards (NAAQS), a major provision of the CAA. Specifically, the CAA mandates the EPA to establish NAAQS for certain common and widespread pollutants. The EPA will also designate areas that fail to meet the standards as nonattainment areas, and following the designation, states need to submit to the EPA implementation plans for nonattainment areas, which usually involve additional and more stringent requirements on facilities in nonattainment areas (Gibson, 2019). Since the designation is made at the county level, inclusion of the county-year fixed effects will address the impacts of NAAQS nonattainment, which may affect both violation and penalties.

As a robustness check, we have also estimated a model with firms' financial fundamentals such as assets, income, property, plant, and equipment, and debts as control variables in addition to the granular fixed effects. Due to limits in data availability, for this analysis we are only able to include public companies, which own about 30% of the facilities in our sample. We find the results from models with versus models without the additional control variables are almost identical (Tables A5–A7 in the Supplemental Appendix), which suggest that these additional firm-specific time-varying factors are unlikely to drive the results in the main analysis. As we describe below, however, there turn out to be important differences in the extent of compliance leakage between the subsamples of publicly traded and privately held firms.

While our models have addressed many factors that may confound the estimates, a few concerns remain. First, since the dependent variable can be affected by either facility environmental performance or regulatory attention, if regulators change the regulatory attention on a focal facility after its siblings have been targeted by penalties, results from the above models will be biased. To address this concern, we directly test the scenario by running a similar model to equation (1) but with whether a focal facility has been inspected as the dependent variable. We find that penalties on sibling facilities have no impact on regulatory scrutiny of a focal facility.[3]

Another potential issue is serial correlation between penalties and violations. The model examines the relationship between violations and 1-year lagged penalties. However, lagged penalties are results of earlier violations. In other words, the treatment, penalties, is triggered by higher levels of violation, the dependent variable, in prior periods. If a facility has a natural tendency to improve its environmental record following episodes of bad environmental performance even without the threat of penalties, the model may attribute this natural tendency to the effect of penalties levied on self. In this sense, the relationship between penalties on self and violation is correlational. Of course, our facility-level fixed effects capture the general proclivity of a given facility to comply, or not, over the sample period. In any event, this is not the focus of our analysis.

The concern of serial correlation may be less likely to apply to the relationship between a violation at a focal facility and penalties levied on its siblings, the key focus of this study. However, if there are omitted, serially correlated common shocks that lead sibling facilities to violate the CAA in sequence over time, the model might mistakenly attribute a facility's getting into violation to penalties levied on its sibling facilities when in reality it has nothing to do with the penalties. With the inclusion of control variables and granular fixed effects, we have addressed many concerns about such shocks. We can also explicitly test whether such a serial pattern exists by examining whether penalties on siblings are preceded by abnormally high or low levels of violation of a focal facility. To do so, we add leading measures of treatment (penalties on siblings) to the right side of the model (Wing et al., 2018). This approach investigates whether future treatment (penalties on siblings) is anticipated by current outcome (violation of a focal facility). If coefficients on the leading measures of treatment are not statistically different from zero (which is what we find, as will be shown in Figure 2), it indicates that future treatment is not associated with current outcome. This is equivalent to saying that current treatment is not associated with historical outcomes, which contradicts the scenario of serial correlation.

Results

We estimate the model with a linear probability regression and report the results in Table 3.[4] Each column in the table represents results based on a model with a different set of fixed effects. Key results from the table are also presented in Figure 1.

The results show that a facility's probability of violating the CAA increases following penalties on its In1St1 siblings. Across the specifications, the probability of violation increases by 0.017 to 0.023 when In1St1 siblings had penalties the year before, which is about a 24% to 33% increase from the baseline violation probability of 0.07. The results do not suggest strong spillovers from penalties on other categories of siblings. While the coefficients for the penalties on In1St2 siblings are also consistently positive, they are much smaller and mostly statistically insignificant. The coefficients for the penalties on In2St1 and In2St2 siblings are even smaller, less significant, and are inconsistent across specifications. These results are consistent with the prediction of intra-firm resource redeployment. They also suggest that firms mostly redeploy compliance resources among facilities that are similar (same industry)[5] and geographically and organizationally close (same state). The results also show very large and strong impacts of penalties levied on self. When a facility has penalties on itself, the probability of violation in the next year declines by about 0.07, which largely wipes out the baseline probability of violation.

To investigate whether the spillover identified in the main analysis is driven by changes in regulatory attention, we estimate a similar model as above but with whether a facility is inspected in a given year as the dependent

Table 3. Intra-Firm Spillover of Environmental Performance From Penalties (Dummy).

	DV: Incur violation (1 = yes; 0 = no)			
	(1)	(2)	(3)	(4)
1-year lagged penalties on In1St1 sibling (dummy)	0.021** (0.008)	0.017** (0.008)	0.018**(0.008)	0.023** (0.011)
1-year lagged penalties on In1St2 sibling (dummy)	0.007 (0.004)	0.006 (0.004)	0.006 (0.004)	0.010 (0.006)
1-year lagged penalties on In2St1 sibling (dummy)	0.001 (0.008)	−0.001 (0.009)	−0.000 (0.009)	−0.005 (0.011)
1-year lagged penalties on In2St2 sibling (dummy)	−0.001 (0.004)	−0.003 (0.005)	−0.004 (0.005)	−0.001 (0.006)
1-year lagged penalties on self (dummy)	−0.069*** (0.005)	−0.070*** (0.005)	−0.070*** (0.005)	−0.080*** (0.007)
Year fixed effects	Yes	Yes	Yes	Yes
Facility-fixed effects	Yes	Yes	Yes	Yes
Facility-specific time trends	Yes	Yes	Yes	Yes
Industry-year fixed effects	No	Yes	Yes	Yes
State-year fixed effects	No	No	Yes	Yes
County-year fixed effects	No	No	No	Yes
N	51,816	51,299	51,287	43,477
R^2	.392	.434	.446	.585

Note. This table presents estimates for the intra-firm spillover of environmental performance from penalties (the main model; estimates also presented in Figure 1). The outcome variable is a dummy variable that indicates whether a facility incurs violation in a year. All penalty measures are measured as dummy variables (1 = penalized; 0 = not penalized). In1St1 = same-industry-same-state; In1St2 = same-industry-different-state; In2St1 = different-industry-same-state; In2St2 = different-industry-different-state. All standard errors are clustered at facility level and in parentheses.
*$p < .10$, ** $p < .05$, *** $p < .01$.

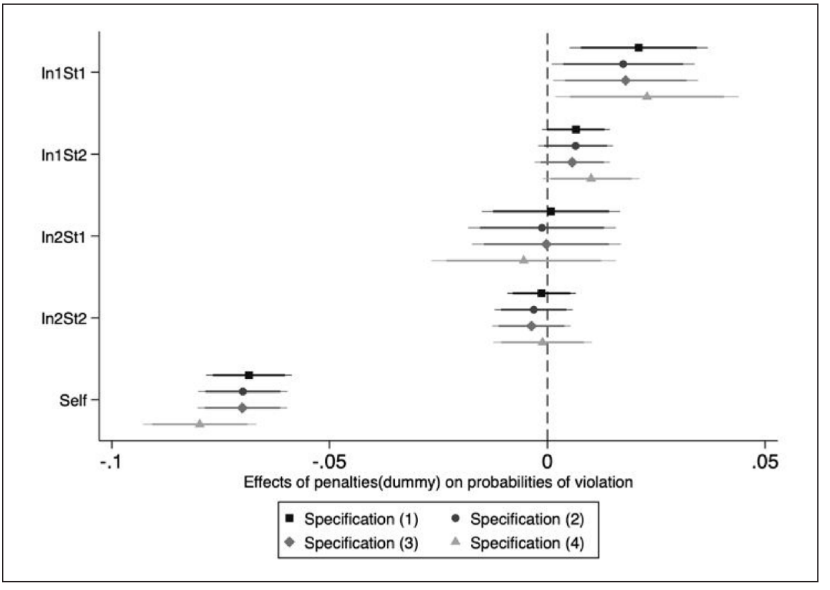

Figure 1. Intra-Firm Spillover of Environmental Performance From Penalties (Dummy).

Note. This figure is a graphic presentation of the estimates for the intra-firm spillover of environmental performance from penalties (the main model; estimates also presented in Table 3). The outcome variable is a dummy variable that indicates whether a facility incurs violation in a year. All penalty measures (on the *y*-axis) are measured as 1-year lagged dummy variables (1 = penalized; 0 = not penalized). In1St1 = same-industry-same-state; In1St2 = same-industry-different-state; In2St1 = different-industry-same-state; In2St2 = different-industry-different-state. Specification (1) = year fixed effects + facility-fixed effects + facility time trends; Specification (2) = specification (1) fixed effects + industry-year fixed effects; Specification (3) = specification (2) fixed effects + state-year fixed effects; and Specification (4) = specification (3) fixed effects + county-year fixed effects. All standard errors are clustered at facility level.

variable. Results are reported in Figure 2 (also in Table A8 in the Supplemental Appendix). They show that penalties on siblings do not lead to significant changes in regulatory attention on a focal facility. Most notably, the increase in the chances of inspection following penalties on In1St1 siblings, the major source of spillover identified in the main analysis, is small and insignificant. Moreover, in all four specifications, the coefficients on penalties on siblings are not significant at even the 10% level and their magnitudes are less than 2.5% from the baseline level. These results suggest that potential changes in regulatory attention are not a major driver of the findings in the main analysis.[6]

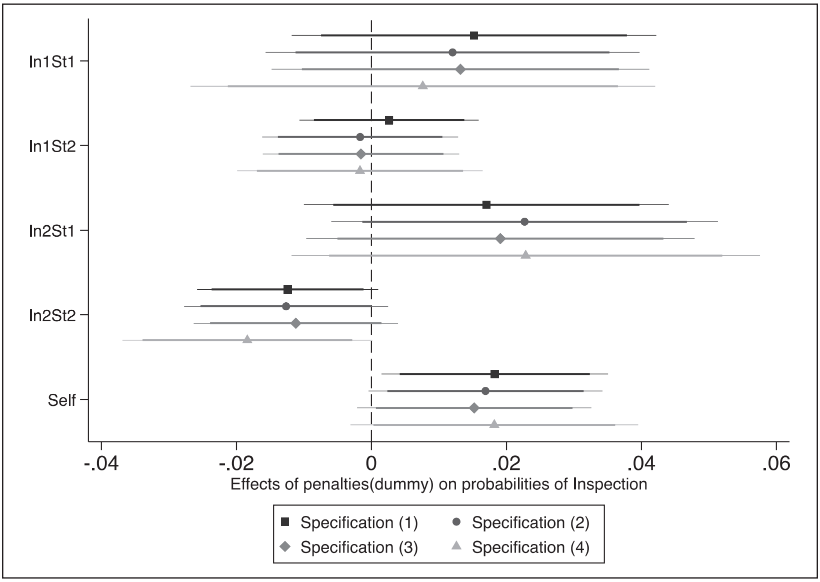

Figure 2. Intra-Firm Spillover of Regulatory Attention From Penalties.
Note. This figure presents the estimates for the intra-firm spillover of regulatory attention from penalties. The dependent variable is a dummy variable that indicates whether a facility receives inspection in a year (1 = yes; 0 = no). All penalty measures (on the *y*-axis) are measured as 1-year lagged dummy for penalties (1 = penalized; 0 = not penalized). In1St1 = same-industry-same-state; In1St2 = same-industry-different-state; In2St1 = different-industry-same-state; In2St2 = different-industry-different-state. Specification (1) = year fixed effects + facility-fixed effects + facility time trends; Specification (2) = specification (1) fixed effects + industry-year fixed effects; Specification (3) = specification (2) fixed effects + state-year fixed effects; and Specification (4) = specification (3) fixed effects + county-year fixed effects. All standard errors are clustered at facility level.

The main analysis also relies on the assumption that variations in penalties on sibling facilities are plausibly exogenous, conditional on the covariates and fixed effects. As discussed in the empirical model section, a major concern is that the identified spillover among sibling facilities might be driven by omitted, serially correlated common shocks among sibling facilities. If a focal facility experiences abnormally low or high levels of violation preceding the penalties on its sibling facilities, our model may mistakenly attribute mean reversion (a natural tendency for the environmental performance of the focal facility to return to a normal level) to the effects of penalties levied on sibling facilities. We investigate the issue by adding 4 years of leading measures of penalties levied on siblings and self to the right-hand side of the main

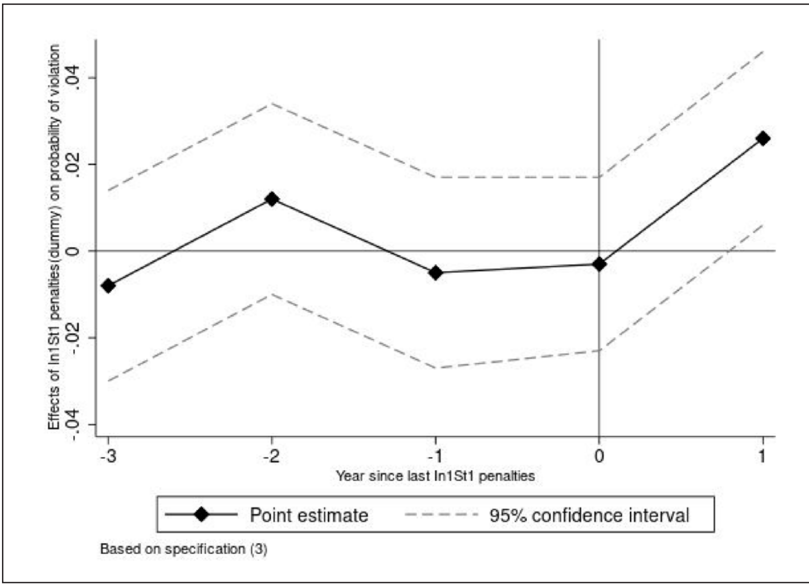

Figure 3. Intra-Firm Spillover of Environmental Performance From Penalties on In1St1 Siblings (With Leading Measures of Penalties Included in the Model).
Note. This figure presents the estimates for the intra-firm spillover effect of environmental performance from penalties when leading measures of penalty measures are added to the main model (based on specification (3)). This figure shows the estimates for leading penalties on same-industry-same-state siblings. Full estimates are presented in Table A9 in the Supplemental Appendix. The outcome variable is a dummy variable that indicates whether a facility incurs violation in a year. Leading penalty measures (on the *x*-axis) are measured as dummy variables (1 = penalized; 0 = not penalized). All standard errors are clustered at facility level.

model, and key results are reported in Figure 3 (full results in Table A9 in the Supplemental Appendix).

Figure 3 plots the coefficients for measures of penalties levied on In1St1 siblings, which is the group of sibling facilities from which we find a spillover effect in the main analysis, and there are two takeaways. First, the estimated spillover effect from In1St1 penalties (the point at the label "1" of the *x*-axis), which is the primary focus of our main analysis, is not sensitive to the inclusion of leading penalty measures. The estimated spillover effect is still positive, significant, and slightly larger compared with what we find in the main analysis. Second, the first four points in the graph demonstrate the changes in a focal facility's probability of violation in the years leading up to In1St1 penalties. The point estimates are close to zero and statistically insignificant. They indicate that a focal facility has no abnormally high or low levels of violation before the treatment (penalties on In1St1 sibling facilities), contradicting the scenario of mean reversion. Together, these results alleviate the concern that the main findings of the study are driven by omitted, serially correlated common shocks.

Finally, we investigate how long the spillover effect lasts by including earlier lagged penalty measures in the main model. The results (Table A10 in the Supplemental Appendix) show that the "leaking" effect only lasts for 1 year as the coefficients on 2-year lagged penalties become close to zero. The results make intuitive sense as the demand to shift resources to penalized siblings is probably most urgent in the first year as penalized facilities are often required to take immediate action to address their problems.

Additional Analyses

Besides the main analysis, we conduct several additional analyses to provide more clarity on the spillover effects and its implications for the environmental performance of multi-unit firms.

P2 Status as a Moderating Factor

Results from the main analysis are consistent with the prediction of intra-firm resource redeployment, which argues that a focal facility's environmental performance worsens due to inadequate compliance resources, which are prioritized and redeployed for sibling facilities targeted by enforcement actions. Following this reasoning, if a focal facility has adequate compliance resources, we would not expect its environmental performance to be affected by enforcement actions on its sibling facilities, and we test the scenario here.

We conduct the test by modifying the model in the main analysis. Specifically, we first generate an indicator for a focal facility's adequacy of environmental compliance resources in a year. We measure resource adequacy with whether a facility took voluntary pollution–prevention (P2) actions in a year.[7] P2 actions are practices that reduce, eliminate, or prevent pollution at its sources. Implementing them requires resources but is fully voluntary. Because of the voluntary nature of P2, participation in it is a good indicator that a facility has adequate resources. We add to the main model interaction terms between the P2 indicator and measures of penalties on sibling facilities. This allows us to compare the intra-firm spillover effects for P2 and non-P2 facilities.

Figure 4 presents the results. For non-P2 facilities, the spillover pattern is the same as in the main analysis. For P2 facilities, which are less likely to

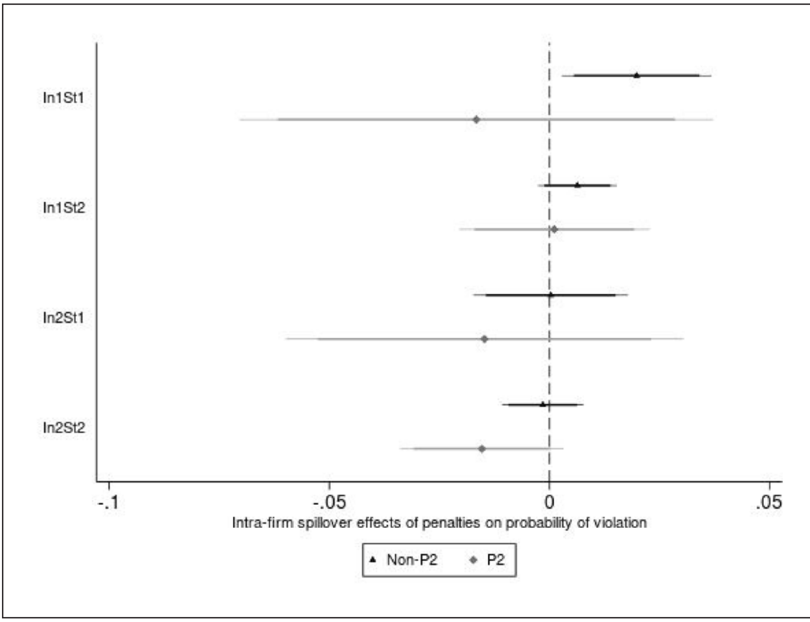

Figure 4. Intra-Firm Spillover of Environmental Performance From Penalties by P2 Status.
Note. This figure presents the estimates for the intra-firm spillover of environmental performance from penalties based on the main model (specification (3)), separately for P2 facilities and non-P2 facilities. The outcome variable is a dummy variable that indicates whether a facility incurs violation in a year (1 = yes; 0 = no). All penalty measures (on the *y*-axis) are measured as 1-year lagged dummy variables (1 = penalized; 0 = not penalized). In1St1 = same-industry-same-state; In1St2 = same-industry-different-state; In2St1 = different-industry-same-state; In2St2 = different-industry-different-state. All standard errors are clustered at facility level.

experience compliance resource constraints, the intra-firm spillover effect is gone. We do observe wide confidence internals for the estimates, primarily because there are relatively few P2 facilities. Roughly 12% of the observations in the sample are P2 facilities. But the point estimates are interesting. They are always to the left of those for non-P2 facilities, meaning that negative environmental performance spillover is less likely, and this provides some support for the intra-firm resource redeployment mechanism.[8]

Private versus Public Firms

As mentioned earlier, we conducted additional regressions using financial control variables that are only available for publicly traded firms (Table A5 in the Supplemental Appendix). The financial variables added no explanatory power, and results for public firms with and without the financial variables differed very little (Tables A5 and A6 in the Supplemental Appendix). However, restricting the sample to just public firms caused the compliance leakage effect to become insignificant, and restricting the sample to just private firms found an even stronger and more significant compliance leakage effect (Table A7 in the Supplemental Appendix). This finding is consistent with the resource redeployment hypothesis, since privately held firms lack access to public capital markets and are more likely to be capital-constrained. Moreover, this finding is consistent with recent research showing that joining the United Nations Global Compact had no impact on the environmental performance of public firms but significantly improved the performance of private firms (Li and Wu, 2020).

To better understand the results, we also interviewed several environmental compliance managers, and their accounts of firms' compliance strategies corroborate with the results. One manager at a Fortune 500 company said, "My experience has been. . . that when you get a violation, the first thing you do is, number one, validate that it is really a violation, and number two, look for preventive action anywhere else in your fleet. We did not see NOVs (notice of violations) increase at our other facilities because of these actions we were taking as a company." Other interviewees echoed this perspective. However, all our interviewees have "always worked for well-resourced companies." Their comments support our finding of insignificant leakage within publicly traded firms. We were unable to interview compliance managers from smaller firms, but all interviewees highlighted that compliance is complicated and that even large public firms sometimes hire consultants to help them understand how to comply. For companies that do not have adequate compliance resources, our interviewees acknowledged that it can be very difficult for such firms to understand their compliance obligations.

General Deterrence Across Nonsiblings

The general deterrence effect suggests that a facility may respond to enforcement actions targeted at other facilities facing the same regulator because all regulated facilities update their beliefs about the "toughness" of the regulator from its enforcement actions (Shimshack & Ward, 2005). We test the general deterrence effect by investigating how a facility's environmental performance is affected by penalties on nonsibling facilities in the same state. We modify the main model for the test. Specifically, we replace the four penalty measures for sibling facilities with two penalty measures for In1St1 nonsibling facilities and In2St1 nonsibling facilities.

Results from the analysis are included in Table A12 in the Supplemental Appendix, and they show that penalties on nonsibling facilities in the same state, either in the same or different industries, have no statistically significant impact on a focal facility's violation of the CAA. The results suggest general deterrence does not play a large role in the spillover of environmental performance from enforcement in our context.

Production Shifting

A number of studies show that environmental regulations may induce multi-unit firms to shift production (R. Hanna, 2010), and some previous work also attributes intra-firm spillovers of pollution to production shifting (Rijal & Khanna, 2020). Here, we directly test how a facility changes its production level following penalties on its sibling facilities by using the production index as a dependent variable. Results from the analysis are presented in Table A13 in the Supplemental Appendix, and they show that the impact of penalties on production is minimal, if any, suggesting that production shifting does not play a major role in the spillover of environmental performance from enforcement in our context.[9]

Discussion and Conclusion

In this study, we examine how a facility's environmental performance is affected by enforcement actions on its sibling facilities. We identified two mechanisms with opposite effects: (*a) Intra-firm learning*, which should lead a facility's environmental performance to improve as it benefits from enforcement-induced knowledge developed at its sibling facilities that have been targeted by enforcement actions; and (b) *intra-firm compliance resource redeployment*, which should lead a facility's environmental performance to worsen as its compliance resources, such as environmental budget and time and attention of management, are redeployed to sibling facilities targeted by enforcement actions.

The empirical results support intra-firm resource redeployment as the dominant mechanism, since a facility's probability of violation increases following penalties on In1St1 siblings. The identified spillover uniquely occurs among sibling facilities, as there is no spillover to facilities in the same state belonging to different companies. The spillover is also not due to production shifting or change in regulatory attention/scrutiny, as a facility's production level and its chances of being inspected are not impacted by penalties on its sibling facilities. Moreover, if a focal facility has adequate compliance resources, as proxied either by its pollution prevention investments or its access to public capital markets, its environmental performance is not affected by penalties on its siblings, which provides further evidence for the intra-firm resource redeployment mechanism.

The fact that we find no evidence of general deterrence effects is striking, especially since it contrasts with a number of prior studies. One important difference is that some of these other studies use data from Clean Water Act enforcement, which involves a much smaller number of regulated facilities (Evans et al., 2018; Gray & Shadbegian, 2007; Shimshack & Ward, 2005). For example, Evans et al. (2018) studied 489 facilities and Gray and Shadbegian (2007) studied 521 plants, while we studied 4,138, nearly an order of magnitude greater. It is entirely plausible that it is easier to draw inferences about regulator behavior when there are fewer facilities to monitor. Nevertheless, the difference in results suggests that further research on general deterrence across regulatory contexts is worthwhile.

This study contributes to the understanding of the efficacy of environmental enforcement and environmental performance of multi-unit firms. Building on the large body of literature on specific and general deterrence of enforcement, it explores the implications of common ownership (being sibling facilities) for the deterrent effect of enforcement. Unlike previous studies that mostly attribute intra-firm spillover of environmental performance to production shifting, this study suggests that the very common phenomenon of intra-firm resource redeployment in multi-unit firms may also play a significant role in the intra-firm spillover effect.

Our analysis also contributes to the discussion about the use of different regulatory approaches to improve business's environmental performance. Although a traditional enforcement approach that emphasizes sanctions remains one of the most powerful motivators for compliance (Delmas & Toffel, 2008), it has become more controversial over time. Scholars and policymakers increasingly advocate the use of tools such as compliance assistance (Stafford, 2012), voluntary regulations (Potoski & Prakash, 2005), information disclosure (Li, 2023, 2024; Lyon & Maxwell, 2007; Lyon & Shimshack, 2015), and management-based approaches (Bennear, 2007). This study illustrates a negative spillover of enforcement actions within multi-unit firms and suggests this is due to redeployment of inadequate compliance resources. The findings underscore the importance of balancing the imposition of strong enforcement actions with other regulatory approaches that aim at capacity building, to avoid pollution leakage and facilitate better environmental performance.

Our findings have important implications for both policymakers and business managers. For policymakers, the findings show how the leaking effect of environmental enforcement in under-resourced multi-unit firms can undermine the efficacy of environmental regulation. Regulators may need to adopt new enforcement strategies that discourage that leakage. For instance, regulators can take a more holistic approach to the environmental performance of multi-unit firms. That is, their enforcement programs could consider not only the performance of a specific facility but also its siblings' performance. Of course, this strategy if implemented should be communicated to business managers so that they can adapt accordingly to avoid the unwanted leakage effect. In addition, regulators may also supplement enforcement actions with assistance and other tools that enhance learning across facilities. Our findings suggest that limited learning occurs, either between or within firms. Measures to strengthen the learning mechanism will improve the efficacy and efficiency of enforcement. For example, regulators can publish more detailed information on violations and guidelines for compliance so that organizations can learn from the mistakes of others. Instead of solely relying on penalties, they can also increase the use of compliance assistance programs and require firm-wide education and training programs as parts of the enforcement process to spur learning across facilities.

For business managers, the findings highlight the importance of managing environmental knowledge and resources across affiliated facilities. The practice of redeploying resources for environmental compliance across units may lead to subpar environmental performance, causing significant financial and reputational damages. Instead of redeploying resources, firms should consider devoting more resources to improving their environmental compliance capacity, so that each facility has the needed resources to deal with environmental problems. When firms do redeploy resources, it is important to be aware of how doing so is likely to affect sibling facilities. In addition, multi-unit firms should also strengthen the learning across their facilities. Instead of having a negative spillover from resource redeployment, facilitating learning across units could generate positive spillovers.

There are a few caveats to note in the interpretation of the results. First, the regulatory pressure we examine in this study—environmental enforcement actions—can be very different from other types of pressure, and caution needs to be exercised when applying the results to other contexts. In the enforcement context, firms' assessment or expectation about the requirements of the regulation is relatively constant. Enforcement actions, while demanding corrections to facilities' current practices, are relatively small shocks to their operational environment (e.g., cost of production) compared with other potentially large changes in the institutional environment, such as adoption of new laws (Fremeth & Shaver, 2014; R. Hanna, 2010) or long-term changes in regulatory stringency (Gibson, 2019). The differences in the nature of institutional/regulatory pressure can potentially explain why some of our results differ from previous studies.

Second, the analyses are based on CAA facilities that are also subject to the reporting requirements of the TRI, to take advantage of the rich information that the TRI data sets provide, such as production level and parent company information. While the TRI covers major polluters in the United States, our analysis does not include the smaller facilities and industries beyond the coverage of the TRI.

Third, since the intra-firm learning and resource redeployment mechanisms happen simultaneously but in opposite direction, our analyses show resource redeployment to be the dominating mechanism but cannot rule out that intra-organization learning does exist. In fairness, even our publicly traded firm sample does not provide any evidence of intra-firm learning, but future research would be useful to further isolate the two mechanisms.

Fourth, this study has not pinpointed exactly what kind of resources have been redeployed and the processes that affect a facility's ability to comply with environmental regulations. A facility's environmental performance involves inputs of various resources—such as financial assets, equipment, personnel, and management—and complex processes that are deeply integrated into almost every aspect and function of corporate decision-making (Hart, 1995; Xu & Kim, 2022). Future research that uses different methods such as survey of environmental compliance managers as well as ethnographic studies is needed to understand what kind of resources are redeployed when faced with enforcement and how the redeployment leads to worse environmental performance. These insights will provide valuable lessons to prevent the leakage effects we have uncovered.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

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Supplemental Material

Supplemental material for this article is available online.

Notes

1. We do not have information on compliance managers for the Clean Air Act, the context of the research. Instead, this calculation is based on compliance managers for the Toxics Release Inventory (TRI), a major environmental information disclosure program that requires facilities to report their management of listed toxic chemicals. We have identified the compliance manager who is responsible for each facility's compliance with the TRI from their reporting forms.
2. We also conducted analysis with industry match based on four-digit and two-digit NAICS codes, which define the same industry more broadly. Results with alternative definitions of industry match are reported in Figures A2 and A3 in the Supplemental Appendix.
3. Because of potential endogeneity, we did not include regulatory attention as a control in the main model. But the inclusion of it does not affect the results (Table A14 in the Supplemental Appendix). We also estimate equation (1) with a sample of observations (facility-year) that have been inspected to rule out the concern that a higher likelihood of being inspected may drive the spillover. Again, we find evidence of spillover using this restricted sample (Figure A1 in the Supplemental Appendix).
4. Table 3 reports results when penalties are operationalized as dummies. Results based on dollar amounts of penalties (Table A1 in the Supplemental Appendix) and for other types of enforcement actions (Tables A3 and A4 in the Supplemental Appendix) are substantively similar.
5. Results based on broader definitions of same industry (four-digit and two-digit NAICS codes instead of six-digit NAICS codes) are reported in Figures A2 and A3 in the Supplemental Appendix. The spillover effects become smaller compared with the main model, which suggest that the spillover primarily occurs between sibling facilities that are similar.
6. In another estimation, we included whether a facility has been inspected in a given year as a control variable, and the results are very similar to those from the main model (Table A14 in the Supplemental Appendix). In an additional robustness check, we estimated the main model with a sample of observations (facility-year) that have been inspected in a given year to rule out the concern that a higher likelihood of being inspected may drive the spillover. Again, we find evidence of spillover using this more stringently constructed restricted sample (Figure A1 in the Supplemental Appendix).
7. Facilities report information about their P2 actions in the TRI.
8. We also examined the intra-firm spillover effect on P2 actions from penalties by using whether a facility takes voluntary P2 actions in a year as the outcome variable. The logic is that if a facility is facing compliance resources constraints due to the redeployment of the resources to penalized siblings, it will probably at least not increase the level of voluntary P2 actions following penalties on siblings. The results (Table A11 in the Supplemental Appendix) in general show that a facility tends to maintain or reduce the level of their voluntary P2 actions

following sibling facilities' penalization, which do not contradict the resource redeployment mechanism.

9. Because of potential endogeneity, we did not include the production index as a control in the main model. But the inclusion of it does not affect the results (Table A14 in the Supplemental Appendix).

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