Environmental Violations in the Power Sector: Accountability and Community Welfare

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Keywords: Environmental Violations · Stakeholder Theory · Electricity Prices · Community

JEL Classification: D60, H23, K32, Q48, Q50

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Abstract

This study investigates how U.S. power sector firms respond to environmental violations identified by the EPA. Following a violation, affected plants adopt mitigation strategies such as reducing electricity generation, improving fuel quality, lowering coal use, installing scrubbers, upgrading pollution controls, and investing in energy-efficient generators. These actions are supported by economies of scale and public subsidies. At the firm level, violations are associated with increases in assets, capital expenditures, long-term debt, operating revenue, and electricity prices. However, operating and net income remain stable, suggesting that firms pass much of the compliance cost to consumers. While these responses contribute to environmental improvement, the accompanying rise in electricity prices raises concerns about social equity, particularly for households least able to absorb higher energy costs. Overall, the findings highlight a broader ethical and policy dilemma: efforts to enforce environmental accountability may disproportionately burden vulnerable populations.

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Introduction

Firms are expected not only to pursue profits but also to comply with legal and regulatory frameworks designed to safeguard the public and the environment. When companies violate environmental regulations, they breach both statutory requirements and ethical norms, resulting in penalties and enforcement actions that jeopardize public health and ecosystems (Flannery and May, 2000; Xu et al., 2012). A critical question in business ethics is how violators fulfill their responsibilities following such misconduct: do they implement systemic organizational changes to prevent future violations, or merely adopt symbolic measures to restore reputation? While prior research suggests that companies often manage accountability through reputational strategies, less is known about whether these responses ensure enduring adherence to ethical standards or how they affect long-term economic and societal outcomes. This paper examines how environmental violators in one of the most polluting sectors in the U.S., the power industry, address accountability for ecological breaches and manage the financial burden of compliance. Our analysis highlights the significant economic and social implications of these actions.

Air pollution and its link to climate change have garnered increasing attention in the 21st century, particularly within high-pollution industries such as electricity.[1] The United States Environmental Protection Agency (EPA), responsible for setting environmental standards, monitoring pollution, and enforcing regulations, implements stringent measures and rigorous enforcement to mitigate the carbon footprints of major polluters. In 2021, the EPA allocated over \$2.5 billion to Environmental Programs and Management (EPA, 2022a), and its enforcement actions prompted facilities that failed to meet standards to invest over \$8.5 billion in compliance-related measures (EPA, 2022b). Depending on the severity of violations, affected facilities may face federal or state/local financial penalties, be required to implement

[1]Electricity producers account for about 65%, 35%, and 30% of total SO2, NOx, and CO2 emissions in the U.S. With the increasing electrification such as the adoption of electric vehicles, this percentage could potentially increase at least in short-run.

specific measures to return to compliance, and/or engage in Supplemental Environmental Projects (SEPs).[2] These environmental initiatives reflect the plants' ethical considerations in responsibly addressing their ecological impact (Cho et al., 2006; Newton, 2008).

We posit that, following environmental violations, firms adjust their operational practices to achieve regulatory compliance and mitigate future risks. These adjustments are motivated not only by the financial penalties associated with violations but also by the need to reduce harmful emissions and restore organizational legitimacy. Prior research (Lee and Xiao, 2018; Nadeem, 2021) highlights the role of governance in shaping firms' use of Supplemental Environmental Projects (SEPs), which serve as restorative actions that deliver societal benefits outside of core operations. In contrast, our study focuses on operational responses, specifically how noncompliant firms modify production processes and environmental controls within their core business to meet regulatory standards. Given the economic losses, reputational damage, and market value declines associated with regulatory breaches (Karpoff et al., 2005), firms have strong incentives to implement internal changes that signal accountability and reduce future exposure.

Alternatively, firms may not exhibit substantive improvements in environmental performance following violations. Instead, they might implement superficial or symbolic changes that create an appearance of compliance without significantly reducing harmful emissions or minimizing their ecological footprint. In such cases, corporate responses serve primarily reputational or regulatory purposes rather than reflecting a genuine shift toward sustainability. Prior research (Bansal, 2005; Shevchenko, 2021; Stafford, 2002) suggests that environmental penalties can sometimes exacerbate poor environmental performance, as firms treat them as routine costs of doing business rather than as catalysts for change. Some studies find that violators respond by increasing environmental disclosures (Patten, 1992), enhancing external communications (Cho, 2009), or selectively sharing favorable environmental information (De Villiers and Van Stadden, 2011; Deegan and Rankin, 1996). However, these actions are

[2] SEPs included in settlement agreements are authorized by the EPA.

often viewed as symbolic gestures lacking substantive follow-through or long-term commitment to environmental standards. Thus, whether noncompliant firms demonstrate credible accountability and improved practices remains an open empirical question.

We empirically examine how power plants respond to environmental violations, focusing on emissions of carbon dioxide (CO2), sulfur dioxide (SO2), and nitrogen oxides (NOx) between 2001 and 2020. Using nearby non-violating plants as a control group in a stacked difference-in-differences (DiD) framework, we find that violating plants significantly reduce emissions across all three pollutants. Emission intensities, defined as pollution per unit of electricity generated, also decline, suggesting that the observed reductions are not solely attributable to lower output but reflect operational improvements. These findings provide initial evidence that firms take substantive steps to reduce their environmental impact following regulatory enforcement.

To assess whether these improvements reflect short-term compliance or deeper organizational change, we analyze the operational and technological strategies firms voluntarily adopt in the aftermath of violations. These responses illustrate how firms exercise agency under regulatory pressure and may signal a broader orientation toward ethical conduct and environmental responsibility. Specifically, we find that (1) electricity production declines significantly; (2) firms reduce sulfur content in fuel, improving fuel quality and lowering SO2 emissions; (3) noncompliant plants shift away from coal toward cleaner fuels, particularly natural gas; and (4) firms invest in emissions-reduction technologies, including enhanced scrubbers, abatement systems, and new generators. While scrubbers and abatement technologies effectively reduce pollutants, new generators improve environmental performance by altering the fuel mix. Taken together, these results suggest that environmental violators do not simply internalize regulatory penalties as routine costs, but instead implement substantial strategic changes in operations, fuel sourcing, and emissions control. These efforts, often requiring significant capital investment, reflect a substantive response to regulatory pressure aimed at sustainably and responsibly reducing the firm's environmental footprint.

Next, we present evidence on two mechanisms that drive firms' pollutant-mitigation efforts following environmental violations: organizational structure and financial capacity. Our analysis shows that firms operating multiple facilities are more likely to leverage economies of scale, particularly when plants share similar fuel types, to coordinate compliance across sites. However, this effect weakens when compliance requires large, capital-intensive investments, such as the installation of emissions-control technologies. From the financial perspective, we find that U.S. government subsidies support short-term environmental improvements but are often insufficient to catalyze sustained, long-term investments in advanced technologies. These results underscore the critical role of both internal organizational capacity and external financial support in shaping the scale and durability of firms' environmental responses.

While these strategies, such as investing in cleaner generation technologies, adopting pollution controls, and transitioning to lower-emission fuels, reflect a commitment to environmental responsibility, they raise a critical ethical question: who ultimately bears the cost of compliance? Our analysis reveals significant post-violation increases in total assets, capital expenditures, long-term debt, operating revenues, production expenses, and electricity prices. The growth in total assets reflects large capital investments, while increased long-term debt indicates greater reliance on external financing. On average, production costs rise by $139 million, primarily due to higher fuel expenditures and added operating and maintenance costs. At the same time, operating revenues increase by $161 million, largely offsetting these expenses and leaving operating and net incomes unchanged. Importantly, the rise in revenues is partly attributable to higher electricity prices, suggesting that some portion of compliance costs may be passed onto consumers. This cost-shifting is especially pronounced among firms with limited subsidy access, operating in regulated markets with low competitive pressure, or located in regions with fewer independent power producers. While such strategies reduce environmental harm, they raise important concerns about equity and social welfare, underscoring the broader ethical challenge of equitably distributing the financial burden of environmental compliance.

Our baseline analysis exploits a quasi-natural experiment involving facilities that receive first-time environmental violations. A central concern, however, is that enforcement may be endogenous: regulators often target facilities based on observable characteristics, such as size, compliance history, or environmental risk, that may also correlate with emissions-reduction behavior independent of enforcement. To address this potential bias, we implement an instrumental variable (IV) strategy alongside a series of robustness checks. Our first IV measures the total number of air-related enforcement actions targeting power and manufacturing plants within a county, normalized by either the number of power plants or their share of county-level electricity generation capacity. The second IV captures the total penalties from air-related enforcement actions across all emission sources in a county-year, scaled by the number of power plants in that county-year. This instrument reflects both the frequency and severity of enforcement, thereby signaling regulatory intensity and credibility. Our core findings remain robust across both IV specifications and a range of alternative control groups defined by nameplate capacity, fuel mix similarity, generator age, and the presence or absence of coal- or oil-fired units.

Our research makes several significant contributions to the literature. First, our study enriches the business ethics literature by exploring corporate responses to environmental violations. Previous research suggests that companies often engage in symbolic activities, such as increasing environmental disclosures or enhancing external communication, to bolster their image or evade accountability (Cho, 2009; De Villiers and Van Stadden, 2011; Deegan and Rankin, 1996; Patten, 1992). Recent studies emphasize the role of stakeholders, including shareholders and corporate boards, in pressuring firms to extend restorative justice to the environment (Lee and Xiao, 2018; Nadeem, 2021). While this research illuminates symbolic gestures and stakeholder influence, it overlooks the specific, actionable changes businesses make after an environmental breach. Our study addresses this gap by detailing how companies alter their operations and assessing the broader consequences, offering significant insights into the effectiveness and sustainability of corporate responses to environmental violations.

Second, our work highlights the distributional consequences of environmental compliance costs. Previous research shows that increases in fuel and emissions costs are often passed on to consumers, driven by the inelastic demand for electricity and the low cost of adjusting prices (Sijm et al., 2006; Fabra and Reguant, 2014; Miller et al., 2017; Ganapati et al., 2020; Kim, 2022). Our study builds on this literature by demonstrating that consumers disproportionately bear the economic burden of environmental compliance through higher electricity rates, while firms maintain their operating income. This finding highlights how environmental transgressors shift financial responsibility onto consumers, exacerbating community economic and social challenges.

The remainder of this paper is structured as follows: the "Background and Hypotheses" section provides an overview of the U.S. power sector and develops the hypotheses we test. The "Research Design" section outlines the data, empirical model, variables, and summary statistics. The "Empirical Results" section presents our findings, and the "Conclusion" section offers final insights and implications."

Background and Hypotheses

Background Information

The U.S. electricity sector is shaped by a complex interplay of historical developments, resource availability, technological change, and evolving regulatory frameworks. Traditionally, electric utilities operated as vertically integrated monopolies, controlling generation, transmission, and distribution under state regulation. In the 1990s, however, many states restructured the sector to promote competition and reduce costs. This wave of deregulation led utilities to divest their generation assets, paving the way for independent power producers, while utilities retained control over transmission and distribution, which remain regulated. Regulated utilities typically operate under a cost-of-service model, which guarantees the recovery of prudently incurred costs and provides a regulated return on capital investment (Cicala, 2015). Major capital expenditures and rate changes require regulatory approval. In contrast, unregulated utilities operate in competitive electricity markets without guaranteed cost recovery, such that increases in operational costs or investments required for environmental compliance have a direct impact on profitability and market competitiveness. The creation of Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs) during the restructuring phase helped ensure grid reliability and nondiscriminatory access to transmission networks. Today, ISOs and RTOs serve roughly two-thirds of U.S. electricity demand, while vertically integrated utilities supply the remaining third. More recently, regulators have introduced performance-based incentive mechanisms to complement traditional cost-of-service regulation (Joskow, 2024). In deregulated markets, utilities and independent producers compete on cost and efficiency, adapting their strategies by shifting fuel mixes, retrofitting plants, or adopting pollution-control technologies.

Electricity generation in the U.S. primarily relies on fossil fuels, nuclear energy, and renewables.[3] As depicted in Figure 1, coal's share in electricity generation dropped from 50.9% in 2001 to 19.3% in 2020, while natural gas increased from 17.1% to 40.5%, and renewables rose from 7.7% to 19.5%. Despite the decline in coal-fired steam turbines due to environmental concerns, fossil fuels remain a significant part of the energy mix. The burning of these fuels releases pollutants like SO2, NOx, and CO2, which contribute to environmental and health issues. In 2019, the U.S. power sector was responsible for 65% of SO2 emissions, 35% of NOx emissions, and nearly 30% of CO2 emissions.[4] To curb these emissions, regulations such as the Clean Air Act and the 1990 Acid Rain Program have been implemented, with compliance monitored through Continuous Emission Monitoring Systems. Given this context, the electricity sector offers a unique opportunity to examine how market structures influence responses of utility violators to EPA enforcement actions

[3] https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php#: :text=Fossil%20fuels%20are%20the%20largest,U.S.%20electricity%20generation%20in%202022.

[4] https://www.epa.gov/newsreleases/epas-2019-power-plant-emissions-data-demonstrate-significant-progress.

across both deregulated and non-deregulated areas. Figure 2 illustrates the geographical spread of utilities across the U.S., enabling analysis of the EPA's impact on companies in varied locations, with a focus on CO2, SO2, and NOx emissions due to the availability of data on these pollutants.

Hypotheses Development

The debate between shareholder and stakeholder perspectives is central to modern business ethics. Milton Friedman's shareholder theory argues that a company's primary responsibility is to maximize shareholder value through profit generation (Friedman, 1970), a view that has long shaped corporate governance and strategic priorities (Jensen, 2010). In contrast, Edward Freeman's stakeholder theory broadens ethical considerations to include all parties affected by a company's operations, such as employees, customers, suppliers, and the community (Freeman and McVea, 2005). This approach advocates integrating stakeholder interests into decision-making to achieve long-term success and social responsibility (Harrison et al., 2015). Recent research finds that stakeholder-oriented firms are more likely to achieve sustainable success and foster innovation (Freudenreich et al., 2020; Alshukri et al., 2024). Balancing these perspectives reflects the evolving nature of corporate responsibility in addressing the broader impacts of business activities on society.

To safeguard community welfare from being compromised by profit-driven decisions, various external forces hold companies accountable for their actions. Consumers influence corporate behavior through choices and activism, while shareholders, especially institutional investors, push for transparency and long-term sustainability, often focusing on environmental, social, and governance (ESG) issues (Luchs and Miller, 2015; Dyck et al., 2019; Dimson et al., 2015). However, these pressures alone may not ensure full ethical compliance, which makes government regulation essential. Agencies like the EPA play a key role in protecting public health and the environment by enforcing standards and holding companies accountable (Bebbington et al., 2008; Gunningham, 2011). Yet the effectiveness of the EPA in reducing pollution and ensuring compliance is debated. Proponents argue that it significantly reduces violations and promotes sustainable practices through penalties and corrective measures (Gray and Shimshack, 2011; Konar and Cohen, 2001). Critics, however, contend that inconsistent monitoring, negotiated settlements, and political influences can weaken its impact (Shimshack, 2014; Grooms, 2015). Given this uncertainty, we propose the following hypothesis:

H1: EPA enforcement actions do not significantly reduce emissions at violating plants.

Even when companies respond to EPA enforcement by reducing pollution, some managers choose temporary, low-cost fixes over sustainable, long-term solutions. These short-term measures, such as cutting electricity generation or installing basic filtration systems, are designed to meet immediate EPA requirements without incurring significant financial costs. However, these token actions often fail to address the underlying causes of pollution, leading to recurring violations (Short and Toffel, 2010; Gray and Shimshack, 2011). As a result, the long-term effectiveness of EPA enforcement often depends on factors beyond its control. Companies driven by short-term financial goals and pressured by investors to meet quarterly earnings targets tend to resort to temporary compliance measures instead of committing to significant, long-term environmental solutions (Berrone et al., 2013). Whether environmental violators show long-term accountability and a sustained commitment to maintaining environmental standards remains an empirical question. This discussion leads to the following two competing hypotheses:

H2: Violating plants adopt only short-term, low-cost measures rather than comprehensive solutions to address pollution.

H2a: Violating plants adopt measures that extend beyond short-term fixes to address pollution effectively.

Access to capital, including subsidies as a form of financial support, and a company's organizational structure are key factors in determining how firms respond to enforcement actions. Firms with limited financial resources often struggle to comply, while those with greater access to capital, such as through subsidies, are more likely to invest in effective emission-reduction solutions (Kahle and Stulz, 2013; Dechezleprêtre et al., 2016; Wang and Zhang, 2020; Wenqi et al., 2022). Organizational structure also matters: decentralized firms may lack incentives to undertake costly improvements, while larger, centralized firms with strong leadership are typically better equipped to pursue sustainability initiatives (Drempetic et al., 2020). This leads to the following hypothesis:

H3: Access to financial resources and organizational structure enable effective remediation following environmental violations.

The EPA's efforts to curb emissions are critical for protecting public health and the environment. However, compliance with these regulations can significantly raise operational costs for electricity-generating facilities. Economic theory and prior evidence suggest that firms may respond by passing some of these costs onto consumers through higher electricity prices (Linn et al., 2014). This cost pass-through can have regressive effects, disproportionately burdening lower-income households and exacerbating social inequality, particularly in vulnerable communities (Fowlie, 2010). Beyond these direct consumer impacts, enforcement actions may have broader negative implications for local economic welfare. Rising compliance costs can prompt facilities to scale back production, delay expansions, or postpone infrastructure investments. These actions may reduce employment, suppress economic activity, and hinder regional growth. In communities dependent on emissions-intensive industries, such disruptions may also erode local business vitality and public revenues, deepening economic disparities. While EPA regulations deliver substantial environmental and public health benefits, they also impose economic burdens that can adversely affect social welfare, underscoring the complex trade-offs inherent in environmental policy enforcement. In light of these considerations, we test the following hypothesis:

H4: Violating utilities pass a portion of compliance costs to consumers through higher electricity prices.

Research Design

Data

This study draws on data from multiple sources. Emissions and enforcement action data come from the EPA. The EPA's Clean Air Markets Division (CAMD) continuously monitors and reports CO2, SO2, and NOx emissions from power plants with a nameplate capacity of over 25MW. For enforcement actions, we use formal administrative and judicial cases from the ICIS-Air dataset and Clean Air Act (CAA) cases from the ICIS-FE&C dataset, including only those with penalties exceeding $5,000. Our findings remain robust to this threshold. For high-priority violations (HPVs) in ICIS-Air, the 'Day Zero' date, recorded by state agencies and reported to the EPA, was obtained through a Freedom of Information Act request. The settlement date serves as the violation or enforcement action initiation date for non-HPV activities, which is otherwise unavailable. Finally, the EPA-EIA crosswalk, provided by Huetteman et al. (2021), links EPA data to the corresponding plants in the EIA database.

Power plant operations data are sourced from various U.S. EIA datasets: (1) EIA-860: provides characteristics of utility firms, power plants, and generators, including generator-level ownership. (2) EIA-923: offers data on fuel quantity, heat content, and net generation by fuel type. (3) Fuel sulfur content: sourced from EIA-767 (2001-2005) and EIA-923 (2008-2020). Since data for 2006 and 2007 are unavailable, sulfur content is extrapolated using the average sulfur percentage from 2005 and 2008. Remaining missing values are estimated based on data from nearby plants. (4) FERC Form 1: contains annual financial information of investor-owned utility firms. (5) EIA-861: includes electricity disposition, revenue, and sales to ultimate customers. (6) Electricity sales by non-utilities: from EIA-923 (2004-2020), with data for 2001-2003 unavailable. Missing values are estimated using median prices from nearby plants. Electricity sales and price data are taken from EIA-923 and EIA-861 for non-utilities, with gaps filled using median prices from nearby plants. For utilities, data comes from EIA-861. When both retail and wholesale sales are reported, the electricity sales price is calculated as a weighted average of wholesale and retail prices. We construct our sample from plants listed in EIA-860 between 2001 and 2020, focusing on those in the contiguous U.S. that operate primarily on fossil fuels for at least 50% of their capacity. Plants with missing emissions data are excluded, and the analysis is limited to investor-owned utilities and independent power producers. Finally, we obtain subsidy data from Good Jobs First's Subsidy Tracker database.

Empirical Model and Variables

We apply a stacked difference-in-differences (DiD) approach, consistent with the guidelines provided in Baker et al. (2022), to assess how facilities respond to their first environmental violation.[5] For each event, we construct cohort-specific treatment and control groups based on the timing of the initial violation, and then combine these cohorts into a unified empirical framework. The treatment group consists of plants that violated environmental regulations and received enforcement actions, with the initial incident marking the event time. The control group includes non-violating plants within a 60-miles radius of the treated plants during the sample period. Due to the localized nature of electricity markets, factors such as the stringency of environmental regulation, fuel procurement options, and costs (Cicala, 2015), market structure, and electricity prices are relatively stable within this area, making the treatment and control groups comparable in non-plant-specific characteristics.[6] We apply

[5] Our main finding remains robust when using the Callaway and Sant'Anna (2021) method for estimating the average treatment effect.

[6] Figure A1 demonstrates the robustness of our main findings with respect to the 60-miles distance used to construct the control group. Repeating the baseline analyses with distances ranging from 10 to 200 miles shows that the statistical and economic significance of the results remains largely unchanged.

the following model to analyze the impact of environmental violations:

$$y_{i,t,c} = \beta_0 + \beta_1 Post_{t,c} * Treated_i + \lambda_{i,c} + \omega_{t,c} + \epsilon_{i,t,c}, \tag{1}$$

where $y_{i,t,c}$ represents the outcome variable for plant i at time t in cohort c, where the outcome variables include pollution emissions such as CO2, SO2, and NOx. Emissions are measured as the natural logarithm of one plus the tons of pollutants emitted. $Treated_i$ is set to one for treated plants and zero otherwise. $Post_{t,c}$ is one after an enforcement action and zero otherwise. Each cohort, focused on an 11-year window around each event, includes one treated plant and the surrounding control plants. Eq. (1) also includes cohort-by-year ($\omega_{t,c}$) and cohort-by-plant ($\lambda_{i,c}$) fixed effects to control for time and time-invariant plant characteristics within each cohort. We cluster standard errors at the cohort-plant level.

Our analysis focuses on key indicators that reflect the strategies of noncompliant plants to improve environmental performance, including reduced production, changes in fuel mix, improvements in fuel quality, and investments in abatement technologies and new generators. Electricity production is measured as the natural logarithm of one plus the total GWh generated. Fuel quality improvements are assessed by analyzing sulfur content in fuel inputs (ln(Sulfur)) and sulfur intensity per unit of heat (ln(Sulfur Intensity)). Changes in fuel mix are measured by the proportions of coal and gas in electricity generation (Coal Share and Gas Share). Investment-related variables include the natural logarithm of one plus the number of operating scrubbers (ln(Scrubbers)), annual investments in abatement technologies (ln($ Abatement)), and newly installed generators (ln(New Generators)).

In our final analysis, we examine the impact of environmental violations on key financial metrics at the utility level. We begin by analyzing balance sheet data to identify changes in assets and liabilities, focusing on firm size (ln(Assets)), the capital expenditure ratio (Capex/Assets), and the long-term debt ratio (Long-term Debt/Assets). This approach helps us evaluate how violations might affect the overall financial structure and investment capacity of these firms. Next, we analyze income statements to assess shifts in revenue, costs, and profitability. We use indicators such as operating revenue relative to assets (Operating Revenue/Assets), production expenses relative to assets (Production Expenses/Assets), and operating income relative to assets (Operating Income/Assets) and net income relative to assets (Net Income/Assets) to gauge financial performance and efficiency following violations. Finally, we examine changes in electricity prices charged by violators (ln(Electricity Price)), offering insights into how these firms may pass compliance costs on to consumers. This comprehensive financial analysis reveals the broader economic implications of environmental non-compliance for utility firms.

Descriptive Statistics

Table **1** presents summary statistics for key variables in the study. On average, a power plant emits over 33.7 thousand tons of CO2,[7] 12.79 tons of SO2, and 124.21 tons of NOx annually. In terms of emission intensity, power plants emit an average of 208.56 tons of CO2, 0.41 tons of SO2, and 0.57 tons of NOx per GWh of electricity generated. Operationally, the average plant generates more than 396 GWh of electricity annually, with 11.62 tons of sulfur used as heat input and an average sulfur content of 0.18 pounds per MMBTU. On average, plants source 70.4% of their electricity from gas and 21.5% from coal. Furthermore, power plants typically have 0.19 installed scrubbers, spend about $461,000 on pollution abatement technologies, and install 0.05 new generators each year. For investor-owned utility firms, average total assets amount to $3.58 billion, with long-term debt making up 27.2% of this total. Annual capital expenditures represent 7.3% of assets. Operating revenue, production expenses, operating income, and net income account for 39.6%, 20.7%, 4.2%, and 3% of total assets, respectively. The average electricity price is $64.63 per MWh.

[7] All values reported here are in raw form, whereas the table presents them in log form. For example, $\exp(10.426) - 1 = 33,724$.

Empirical Results

In this section, we begin by evaluating the impact of EPA enforcement actions on reducing pollution emissions in the electricity sector. We then explore the various strategies utility firms employ to navigate and respond to these regulatory measures. Additionally, we investigate the mechanisms that enable violators to address environmental violations. Finally, we analyze the financial consequences of enforcement actions on violating utility firms.

Pollution Emissions

Panels A and B of Table **2** present estimates from Eq. 1. In Panel A, Columns 1-3 show that pollution emissions at violating plants decrease by 36% for CO2, 45% for SO2, and 27% for NOx.[8] To assess whether these reductions are due to decreased electricity generation, Panel B examines the impact of environmental violations on emissions intensities (pollution per unit of electricity generated). While CO2 intensity declines by 11%, the effect is statistically insignificant. In contrast, SO2 and NOx intensities significantly decline by 15% and 5%, respectively, following environmental violations. Results in Appendix Table A2 confirm the robustness of these findings using alternative penalty thresholds for defining enforcement actions. Collectively, these results reject hypothesis H1, which posits that environmental violations fail to reduce emissions. Instead, they suggest that emissions reductions reflect not only lower output but also efforts by violating plants to improve environmental compliance.[9] Given that enforcement could affect electricity production directly, the remainder of the analysis focuses on raw pollution emissions rather than intensities.

[8] $e^{-0.448} - 1 = -0.36$, $e^{-0.591} - 1 = -0.45$, and $e^{-0.318} - 1 = -0.27$.

[9] One potential explanation for the observed emission reductions is the strategic reallocation of electricity generation from violating plants to non-violating sibling plants within the same parent utility (Bartram et al., 2022). To assess this, we examine changes in *Plant Share*—a plant's share of total generation within its parent utility—following a violation. Appendix Table A3 shows no significant change in Plant Share, indicating limited evidence of intra-firm substitution. Instead, Table A3 documents a significant decline in the capacity factor (actual generation relative to maximum capacity), consistent with an intentional reduction in output to improve environmental compliance.

To capture the dynamics before and after events, we replace the *Post* dummy with indicator variables for each year surrounding the environmental violations, using the following regression specification:

$$y_{i,t,c} = \beta_0 + \sum_{\tau=-5}^{-2} \beta_\tau Treated_i * \mathbb{1}[t - t_{0,c} = \tau] + \sum_{\tau=0}^{5} \beta_\tau Treated_i * \mathbb{1}[t - t_{0,c} = \tau] + \lambda_{i,c} + \omega_{t,c} + \epsilon_{i,t,c} \tag{2}$$

In Eq. 2, $\tau \in [-5, +5]$ represents the time relative to the violation year, with $t_{0,c}$ denoting the year violations occur in each cohort. Figure 3 depicts the dynamics of β_τ coefficients for our focal plant's operations. Sub-figures (a)–(c) reveal no systematic pre-trends in CO2, SO2, or NOx emissions between treated and control plants prior to enforcement, supporting the parallel trends assumption. Following the enforcement actions, however, we observe a steady and sustained decline in emissions across all three pollutants. These post-treatment reductions indicate improved environmental performance at violating plants. Appendix Figure A2 provides additional robustness checks, confirming the persistence of these downward trends in the post-enforcement period.[10]

Corporate Strategic Responses

Utility firms adopt various strategies to improve environmental performance after violations. These strategies range from short-term measures, like reducing production, to medium-term actions, such as changing fuel types, and long-term investments in emission-reducing technologies or new generators. This section examines utility firms' operational decisions to lower emissions and enhance their environmental impact after violations.

Cutting production is the quickest way to reduce emissions after violations, but it risks market share loss if not paired with long-term sustainable strategies. A more sustainable approach involves changing the fuel mix and using cleaner energy sources, such as natural

[10] In Figure A2, alternative control groups are constructed by matching each violating plant with three controls of similar size (i.e., nameplate capacity), fuel mix similarity (i.e., cosine similarity of fuel inputs), age, and generation technology (i.e., use of coal- or oil-based steam generators).

gas instead of coal or petroleum. Table **3** shows that, following environmental violations, plants respond by promptly reducing electricity generation (column 1), total sulfur input (column 2), and sulfur intensity in the fuels used (column 3). Columns 4 and 5 suggest that the decline in total sulfur content is primarily due either to a shift in the fuel mix, such as replacing coal with natural gas (which has negligible sulfur content), or to improving coal quality, such as opting for subbituminous over bituminous coal. Moreover, the findings reveal a 2.7% decrease in coal dependency (12.4% relative to the sample average *Coal Share*) and a 3.5% increase in gas reliance (4.9% relative to the sample average *Gas Share*). Given the higher cost of natural gas compared to coal, this shift not only reduces emissions but also affects operational costs. Untabulated results support this, showing a 15.5% increase in fuel expenses following environmental violations.

We next examine whether firms respond to environmental violations by investing in pollution-abatement technologies or adopting cleaner electricity generation. Columns (6)–(8) highlight these shifts. Column 6 shows a 5.2% increase in the use of scrubbers, which are devices commonly installed in coal-fired generators to reduce SO2 emissions, following enforcement. Column 7 documents a 19.8% rise in broader abatement investments, including flue gas particulate collectors, continuous emissions monitoring systems, and NOx control technologies. Column 8 reveals a 3.1% increase in the installation of new generators, primarily gas turbines and combined cycle systems, which offer higher thermal efficiency and facilitate fuel switching.

To assess broader environmental investments, we also examine changes in utility-level green electricity generation. As shown in Appendix Table A4, enforcement actions lead to significant increases in electricity generation from wind, but not from solar or hydro, with statistically significant improvements in total green output. Together, these results suggest that firms respond to regulatory enforcement not only through immediate emission reductions but also by investing in longer-term measures to enhance environmental performance. These findings support Hypothesis H2a.

Factors Influencing Corporate Responses

Utility firms employ various emission-mitigation strategies, influenced by factors such as enforcement authority, organizational structure and access to financial resources, including government subsidies. This section explores the mechanisms that drive firms' pollutant-mitigation efforts and enhance the effectiveness of enforcement actions, highlighting the diverse ways in which violating power plants respond to regulatory measures.

Federal versus State Enforcement Impact

The EPA oversees national environmental policies but heavily relies on state governments for enforcement. The Office of Enforcement and Compliance Assurance within the EPA shapes national strategies and supervises state implementation, blending centralized policy with decentralized enforcement to ensure uniform standards while accommodating regional needs. While states manage environmental initiatives, the EPA provides crucial oversight to ensure these programs meet federal targets. The EPA also retains the authority to conduct independent inspections and intervene when states fail to act. This dual role balances state responsiveness with national goals. However, concerns about state agencies' effectiveness and leniency in enforcement persist (Woods, 2008; Blundell, 2020), with research by Glicksman and Earnhart (2007) suggesting that federal oversight offers stronger deterrence.

In light of these findings, our analysis examines whether a similar disparity exists between state and federal enforcement actions in the electricity sector. We divide the sample into two subsamples based on the enforcing agency's jurisdiction: state or federal. The results in Table 4 show that federal enforcement leads to a more significant reduction in emissions and power generation compared to state-level actions, suggesting that plants are more responsive to federal oversight. This comparison highlights differences in post-violation pollutant mitigation between state and federal monitoring and underscores the crucial role of federal intervention in driving environmental compliance and improving sector performance.

Panel B of Table 4 distinguishes corporate responses based on whether enforcement actions originate from federal or state agencies, indicating a stronger impact associated with federal enforcement.

The Organizational Structure of Utility Firms

The organizational structure of utility firms significantly influences their responses to environmental violations and their capacity to reduce emissions. Utility firms operating multiple plants across various locations often demonstrate greater operational flexibility in adhering to environmental regulations. The presence of multiple plants within a single firm allows them to leverage economies of scale in fuel procurement, making the transition to cleaner fuels more cost-effective when implemented across several plants rather than individually. To assess the impact of organizational structure, we revisit our baseline analyses in Table 5, examining violators within multi-plant utility firms separately from those in single-plant firms. Panel A indicates that the previously observed responses are primarily driven by plants within multi-plant utilities, while emissions and electricity production remain unchanged in single-plant utilities.

As discussed in the Corporate Strategic Responses section, changing the fuel mix, especially replacing coal with gas, is a key strategy for violating plants to regain compliance. We propose that economies of scale in fuel procurement and related investments contribute to the stronger responses observed in multi-plant utility firms. In Panel B, we focus on violating firms within multi-plant utilities to examine the impact of organizational structure. We divide these firms into two subsamples based on their siblings' coal reliance: the "High" subsample includes plants with above-median coal reliance among non-violating siblings, and the "Low" subsample includes those with below-median coal reliance. The results show that plants with siblings heavily reliant on coal exhibit significantly stronger reductions in SO2 and NOx emissions.

We also examine how organizational structure and coal dependence at non-targeted sibling facilities affect violators' operational responses to enforcement actions. Results in Panel C show that facilities with similar characteristics to their siblings are more likely to respond to EPA enforcement actions, particularly when they can exploit firm-wide economies of scale from the common use of similar fuels. However, this effect weakens when the necessary actions, such as acquiring new generators or investing in abatement technologies, become costly and are not primarily driven by cost efficiencies. Consistent with hypothesis H3, these findings underscore the significant influence of organizational structure in shaping decisions that enhance the environmental performance of violating plants.

To reinforce the importance of organizational structure in shaping utility firms' responses to environmental violations, we examine internal spillover effects across affiliated establishments. Specifically, we assess whether enforcement at one plant influences the environmental performance of non-violating sibling plants within the same corporate network. Prior studies have shown that internal firm networks can transmit shocks and responses across units (e.g., Duchin et al., 2017; Giroud and Mueller, 2019; Bena et al., 2021). Focusing exclusively on non-violating sibling plants, Appendix Table A5 employs a stacked DiD approach and finds a significant decline in emissions following a related plant's violation. These sibling plants adopt similar adaptive strategies, such as reducing output, improving fuel mix, increasing gas usage relative to coal, and installing new generators, indicating a coordinated shift toward regulatory compliance at the firm level.

Availability of Government Subsidies

Existing literature has underscored how financial constraints and access to capital shape firms' environmental performance (e.g., Bartram et al., 2022; Xu and Kim, 2022). Strategies that utility companies use to improve their environmental impact, such as upgrading generators, installing scrubbers, or altering fuel mixes, require substantial financial investment. Thus, a firm's ability to secure financing is critical for implementing these environmentally beneficial strategies. In this section, we assess the financial strength of utility firms by investigating their access to government subsidies. We specifically examine the impact of state- and local-level subsidies to utility and power generation firms, revealing how these critical financial resources influence their capacity to achieve environmental goals. Panel A of Table **6** reports results for violating plants split by above- and below-median access to government subsidies. Emission reductions are significantly larger among violators with greater subsidy access, suggesting that public financial support facilitates regulatory compliance and amplifies remediation efforts following environmental violations.

While pollution reduction efforts have shown measurable success, the effectiveness of government subsidies in fostering sustained environmental solutions remains uncertain. Critics argue that U.S. environmental subsidies, while helpful in promoting incremental improvements, are often too modest in scale to drive transformative change, particularly for smaller firms. Consequently, firms often adopt low-cost, limited-impact measures rather than invest in comprehensive environmental strategies. This tendency is especially pronounced among smaller or financially constrained firms, which often prioritize basic energy efficiency upgrades over capital-intensive projects such as advanced pollution control technologies or renewable energy transitions (Borenstein, 2012).

Panel B examines how subsidy access shapes violating plants' responses to enforcement. Results in Columns (1)–(10) show that in high-subsidy areas, plants are more likely to reduce electricity generation, improve fuel quality, and shift from coal to gas following violations. However, as shown in Columns (11) and (16), capital-intensive responses, such as investing in abatement technologies and installing new generators, are more common in low-subsidy areas, while high-subsidy regions see only modest increases in scrubber adoption. In high-subsidy areas, firms may rely on subsidized, lower-cost operational adjustments to meet compliance standards, reducing the incentive to pursue costly, long-term upgrades. By contrast, firms in low-subsidy areas may be more motivated to undertake deeper, self-financed investments to mitigate regulatory risk and sustain compliance in the absence of external assistance.

Financial Consequences

So far, we have analyzed utility companies' strategic adaptations following environmental regulation violations. These actions include installing pollution-control equipment, upgrading facilities, reducing production, and altering fuel mixes. This section examines whether these changes, which often require increased capital expenditures and operating costs, impact financial performance and energy prices.

Financial Performance

Using financial data disclosed by investor-owned utilities in FERC Form 1, we estimate the following regression model:

$$\text{Financial Indicator}_{p,t,c} = \beta_0 + \beta_1 Post_{t,c} * Treated_p + \lambda_{p,c} + \omega_{t,c} + \epsilon_{p,t,c} \tag{3}$$

where Financial Indicator$_{p,t,c}$ represents a financial outcome variable for parent utility firm p at time t in cohort c. Our study examines seven key financial indicators: total assets (in billions), capital expenditures, long-term debt, operating revenue, production expenses, operating income, and electricity price per megawatt-hour (MWh). We log-transform total assets and electricity prices and scale the remaining metrics by total assets. The treatment group consists of utility firms that have violated environmental regulations at least once, while the control group includes the three nearest utility firms to each treated firm that have not violated regulations during the study period. Our analysis spans an 11-year window around each enforcement action, grouping each treated utility with its nearest controls into cohorts. To account for temporal trends and firm-specific characteristics within each cohort, we include cohort-specific parent utility fixed effects ($\lambda_{p,c}$) and year ($\omega_{t,c}$). Standard errors are clustered at the cohort-firm level. Table 7 presents the results.

The table presents several key findings consistent with our earlier results. Firms with noncompliant establishments show significant increases in total assets, capital expenditures, long-term debt, operating revenue, and production expenses. For example, the 6.2% (or $221 million) increase in total assets (Column 1) aligns with the results in Table 3, suggesting that violators invest in new generators and additional scrubbers. Similarly, capital expenditures (Column 2) and long-term debt (Column 3) rise by $68 million and $93 million, respectively, following violations. While EPA violations are associated with concurrent increases in operating revenue (Column 4) and production expenses (Column 5), these effects partially offset one another, leaving operating and net income largely unchanged (Columns 6 and 7). Specifically, average operating revenue increases by $161 million, while production expenses, comprising the bulk of total expenses, rise by $139 million. The lack of a significant impact on profitability suggests that firms pass variable compliance costs on to consumers through higher electricity prices. Supporting this interpretation, Column 8 shows a 4.8% increase in the average electricity price, or $3.1 per MWh, following violations. While operating income reflects immediate financial impacts, such as fines, depreciation, and interest payments, it may not fully capture the longer-term costs of compliance-related investments prompted by enforcement actions. Nonetheless, our results support Hypothesis H4: plants reduce pollution following violations without short-term profitability declines. This outcome appears to be driven, in part, by firms passing compliance costs on to consumers through higher electricity prices. Still, the longer-run financial burden of sustained environmental investments may remain obscured in near-term accounting measures.

Electricity Prices

Utility firms' ability to transfer compliance costs to consumers depends on their regulatory status, financial resources, and market competition. Table 7 uses price data from FERC Form 1, which is limited to investor-owned utilities. To address this constraint, we supplement our analysis with electricity price data from Schedules 6 and 7 of the EIA-923 and EIA-861, which include both investor- and non-investor-owned utilities. We calculate prices as a weighted average of wholesale and retail rates. Using this broader dataset, we re-estimate the impact of environmental violations on electricity prices in Column (1) of Table 8 and find a 6.3% increase post-violation, consistent with the results from Table 7. We then examine how price responses vary by access to government subsidies in Columns (2) and (3). The results show that price increases are larger among firms with limited subsidy access, highlighting the role of public financial support in easing the cost burden passed on to consumers.

We further examine how market competition shapes utilities' ability to pass compliance costs to consumers, using three measures of competitive pressure. We hypothesize that firms with greater market power are more likely to raise prices following environmental violations. First, we distinguish between regulated and non-regulated utilities. Regulated firms, guaranteed a reasonable return on investment, face fewer constraints in passing abatement costs to electricity prices. In contrast, non-regulated firms operating in competitive markets have limited pricing power. Columns (4) and (5) show that price increases are concentrated among regulated utilities. Consistent with this, Appendix Figure A3 illustrates a gradual rise in electricity prices for these firms. Second, we use the state-level Herfindahl–Hirschman Index (HHI) as a measure of market concentration. As shown in Columns (6) and (7), electricity prices rise significantly in less competitive states (higher HHI values), further supporting the view that market power facilitates cost pass-through. Finally, we examine the share of state electricity generated by Independent Power Producers (IPPs), which operate outside of regulated utility structures and compete in wholesale markets. Columns (8) and (9) show that electricity prices rise by 16% in states with a low IPP share but remain unchanged in states with greater IPP presence.

In summary, the findings show that electricity market competition and utility market power critically shape the extent to which firms can pass the costs of environmental compliance onto consumers. In less competitive markets, utilities preserve profit margins by shifting the financial burden of cleaner production to consumers. This cost pass-through dynamic highlights the intersection of regulatory enforcement and market structure, revealing how firms leverage their pricing power to absorb compliance shocks with minimal impact on their bottom line.

Additional Tests

EPA investigations may appear to reduce emissions, but this relationship is likely confounded by endogeneity concerns, as regulators often target facilities that differ systematically from those not investigated. Enforcement is typically prioritized based on observable traits, such as facility size, compliance history, prior violations, or environmental risk, that also correlate with a firm's likelihood of independently improving environmental performance. In some cases, investigations are triggered by temporary emission spikes from operational disruptions or short-term shocks, after which emissions revert to baseline without regulatory intervention. Additional concerns stem from constructing control groups based on geographic proximity may bias results if time-varying or omitted factors jointly affect violations, emissions, and operations. As a result, observed reductions may reflect facility characteristics, mean reversion, or methodological artifacts rather than the causal effect of enforcement. To address these concerns, this section applies an IV strategy and refines control group selection. It also presents suggestive evidence on the broader applicability of the results across industries and examines how political factors, such as lobbying, influence firm responses to enforcement.

Instrumental Variable Analysis

We use an IV strategy to address endogeneity concerns and strengthen causal inference. A valid instrument must correlate with the likelihood of enforcement (relevance) but not directly affect plant outcomes (exclusion restriction). To construct our instrument, we measure regulatory exposure by analyzing the frequency and severity of air-related violations across all emission sources within a county, including manufacturing, oil and gas, refineries, and chemical, metal, and mineral production, rather than limiting analysis to the power sector.

The control group is restricted to power plants located within 60 miles of a violator but situated in different counties to isolate variation in regulatory exposure. For plant i in county j at time t, we compute (1) the number of enforcement actions ($\#Enforcement_{-i,j,t}$) and (2) the total penalties ($\$Penalty_{-i,j,t}$) applied to other emission sources in the same county-year. These values are then normalized by the number of operating plants in the county, providing county-level proxies for exposure to regulation and EPA targeting risk. The resulting instruments for plant i in county j at time t are defined as follows:

$$EnforceExposure_{i,j,t}\ (Frequency) = \frac{\#Enforcement_{-i,j,t}}{\#Plants_{j,t}}.$$

$$EnforceExposure_{i,j,t}\ (Penalty) = \frac{\$Penalty_{-i,j,t}}{\#Plants_{j,t}}.$$

Our identification strategy relies on the assumption that a higher frequency of enforcement actions in a given geographic area increases the likelihood that nearby power plants will be targeted by the EPA. At the same time, enforcement actions directed at other emission sources, particularly in different industries, are unlikely to directly influence a power plant's emissions or operational decisions, except through increased exposure to regulatory scrutiny.

Before estimating the 2SLS regressions, we assess the relevance of our instruments in predicting the likelihood of enforcement. Columns (1) and (2) of Table A6 report results from the full sample of U.S. power plants with available emissions data, examining the relationship between $Enforcement$ (a binary indicator equal to 1 if a plant is targeted within a given year) and our two instruments. A one-standard-deviation increase in $EnforceExposure_{i,j,t}$ $(Frequency)$ and $EnforceExposure_{i,j,t}$ $(Penalty)$ raises the probability of enforcement by 0.72% and 0.99%, respectively. Columns (3) and (4) repeat the analysis in our primary matched sample, where each violating plant is paired with control plants located within a 60-mile radius. In this setting, the instruments increase the likelihood of enforcement by 0.61% and 0.99%, respectively. These results confirm that both instruments are strongly correlated with enforcement probability, satisfying the relevance condition for valid instrument use. Using these instruments, we proceed to estimate the following 2SLS regressions:

$$Post_{t,c} * Treated_{i,j} = \beta_0 + \beta_1 Post_{t,c} * EnforceExposure_{i,j,t_0} + \lambda_{i,c} + \omega_{t,c} + \epsilon \tag{4}$$

$$y_{i,j,c,t} = \beta_0 + \beta_1 \widehat{Post_{t,c} * Treated_{i,j}} + \lambda_{i,c} + \omega_{t,c} + \epsilon \tag{5}$$

Eqs. (4) and (5) present the 2SLS framework. Eq. (4) specifies the first-stage regression, where $EnforceExposure_{i,j,t_0}$ serves as an instrument for the endogenous treatment variable, which indicates whether plant i in county j is targeted by enforcement at time t_0. Eq. (5) then regresses plant outcomes on the fitted values from the first stage to estimate the causal effect of enforcement. Panels A and B of Table **9** report the 2SLS results. Column (1) in both panels presents the first-stage estimates, with corresponding F-statistics of 12.36 and 13.60, respectively. These values exceed the conventional threshold of 10, indicating sufficiently strong instruments and alleviating concerns about weak instrument bias. Columns (2)–(4) show that the reductions in CO2, SO2, and NOx emissions from the baseline analysis persist after accounting for endogeneity, confirming that the effects are not driven by selection bias. Notably, the estimated emission reductions are even larger under the IV specification, strengthening the causal interpretation. However, consistent with earlier findings, we find no significant impact of enforcement on electricity generation, suggesting that the emission reductions stem from improved environmental practices rather than reduced output.

Validity of Instrumental Variables

Given potential concerns about internal validity, we clarify the key assumptions of our IV strategy and conduct a series of robustness checks to support its credibility. Panels A and B of Table A7 exclude enforcement actions with penalties under \$10,000 and \$20,000, respectively. Because larger penalties typically reflect more serious violations and stronger regulatory commitment, these specifications help identify more credible enforcement events.

Consistent with this interpretation, the estimated effects of enforcement become stronger when instruments are based on higher-penalty violations. Panel C further restricts the sample to High Priority Violations (HPVs), which the EPA designates as particularly severe. This restriction also amplifies the estimated effects, lending additional support to our main findings.

A key identification concern is that county-level enforcement may directly influence emissions at nearby power plants, thereby violating the exclusion restriction. To address this, Panel D excludes enforcement actions against other power plants when constructing the instrument. This helps mitigate the risk of correlated emissions driven by unobserved local factors shared across plants. The results remain robust to this adjustment. To further assess potential spillover effects, Panel E introduces a *Proximate Enforcement* indicator that flags whether enforcement occurred within five miles of a plant in the previous five years. Including this variable does not materially affect the IV estimates, indicating limited local spillovers. In untabulated analyses, we further test for spillovers using a stacked DiD approach, comparing non-violating plants located within three (five) miles of a violating facility to control plants located within a 60-mile radius of treated plants, but without any enforcement actions occurring within the corresponding three (five) miles proximity. We find no significant differences in emissions between these groups, further supporting the exclusion restriction.

Finally, in Table A8, we incorporate county-level time-varying covariates into the IV regressions. The results remain consistent, confirming that our instruments capture exogenous variation in regulatory exposure. While these checks bolster credibility, fully accounting for unobserved, time-varying county-level confounders remains challenging, and we acknowledge this limitation.

Generalizability Across Industries

A potential concern is whether our findings from the electricity sector generalize to other heavily polluting industries. Extending the analysis to chemicals, manufacturing, or energy extraction would strengthen external validity, but data limitations constrain this effort. Specifically, the detailed facility-level emissions and operational data necessary for rigorous empirical analysis are often unavailable or inconsistently reported outside the electricity sector.

To explore this concern, we provide supplementary evidence using the EPA's Toxics Release Inventory (TRI), which tracks toxic air emissions across a wide range of industrial facilities. Emissions are categorized as fugitive emissions (unconfined releases not routed through stacks or vents), stack emissions (controlled releases through stacks, ducts, or pipes), and total emissions, defined as the sum of fugitive and stack emissions. The control group consists of facilities located within a 60-mile radius of treated plants that did not receive enforcement actions during the study period. Leveraging this dataset, Appendix Table A9 implements a stacked DiD design to examine changes in these emission types following EPA enforcement actions. The results reveal qualitatively similar emission reductions to those observed in the electricity sector, suggesting that enforcement-induced improvements may extend to other industrial contexts. However, differences in pollutants, regulation, and processes may complicate direct extrapolation. Many TRI chemicals are tied to specific operations requiring distinct control and mitigation strategies. Thus, while the TRI-based analysis provides suggestive support for broader applicability, we remain cautious in generalizing beyond the power sector.

Political Influence and Enforcement

Corporate political activity can significantly influence the regulatory landscape, shaping both the likelihood and outcomes of enforcement actions. Politically connected firms may avoid investigations, negotiate reduced penalties, or delay compliance, thereby weakening regulatory impact. Recent research (e.g., Heitz et al., 2023) finds that politically connected firms face reduced regulatory scrutiny and lower penalties, suggesting that political influence systematically weakens enforcement intensity. Our empirical strategy addresses part of this concern by leveraging variation in enforcement actions targeting neighboring plants. This design aims to capture plausibly exogenous enforcement shocks that are less likely to reflect the treated firm's prior political engagement, particularly pre-violation lobbying activity.However, this approach does not fully capture post-enforcement lobbying, such as efforts to reduce penalties or alter compliance scope and timing, which may weaken regulatory effectiveness.

To more directly assess this dynamic, we conduct additional analyses presented in Appendix Table A10.[11] Specifically, we examine whether lobbying moderates the relationship between environmental enforcement and emissions outcomes by comparing utility firms that reported lobbying expenditures during the violation year to those that did not. The results indicate that lobbying firms show significantly weaker emissions reductions after enforcement, suggesting that post-violation political activity may dilute the intended impact of regulatory actions and allow politically connected firms to partially shield themselves from compliance pressure. Importantly, enforcement actions continue to yield statistically significant emissions reductions across both groups. These findings reinforce the overall effectiveness of environmental enforcement while highlighting how corporate political influence moderates regulatory outcomes.

Conclusion

The U.S. electricity sector remains a significant source of environmental pollution, largely due to continued reliance on coal and natural gas. Although regulatory efforts and a gradual tran-

[11] We obtain data on firms' lobbying activities from LobbyView (Kim, 2018) and manually match these data to utility firms by name.

sition toward cleaner energy have reduced emissions, critical questions remain about utilities' responses to enforcement, the operational consequences of compliance, and the distribution of costs. Our analysis shows that when power plants are cited for environmental violations, they reduce emissions through multiple channels: reducing output, upgrading equipment, installing pollution controls, and shifting from coal to cleaner fuels. These changes are often supported by economies of scale and public subsidies. Violating utilities also expand their asset base, increase capital expenditures and long-term debt, and generate more operating revenue. While production costs rise, operating income and profitability remain stable, suggesting that firms pass much of the financial burden to consumers in the form of higher electricity prices. The resulting cost shift raises serious concerns about social equity, particularly for vulnerable populations least able to absorb rising utility costs.

These findings underscore the ethical and policy challenges of aligning environmental enforcement with stakeholder and distributive justice. Although regulation is essential for reducing emissions and upholding environmental responsibility, it can unintentionally shift compliance costs to consumers, especially those with limited means. A just transition requires safeguards to ensure burdens are shared fairly between utilities and the communities they serve. Stronger oversight of rate-setting practices, combined with targeted subsidies or conditional incentives, can mitigate regressive impacts and reinforce firms' responsibility to internalize the social costs of environmental harm. Advancing sustainability paired with a commitment to fairness, ensuring progress does not come at the expense of the most vulnerable.

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Figure 1
U.S. Electricity Generation by Energy Source

This figure shows electricity generation in megawatt hours (MWh) using different types of energy sources during the 2001-2020 sample period.

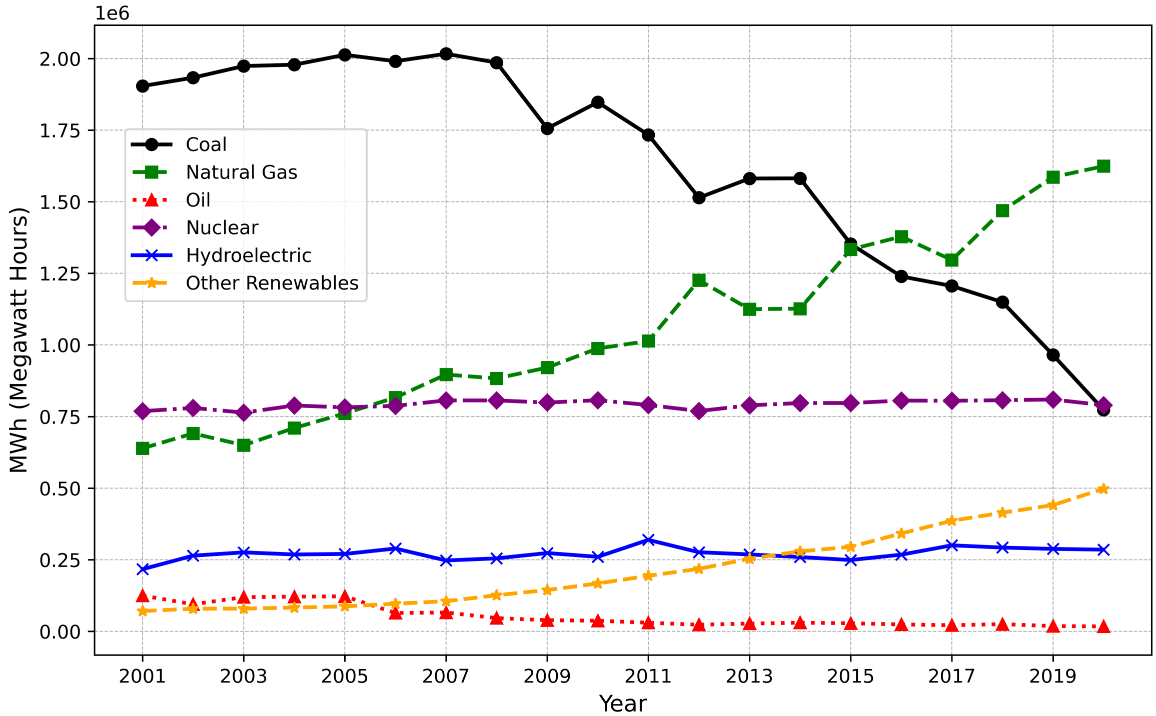


Figure 2
The Geographical Dispersion of U.S. Power Plants in 2020

This figure shows the geographical dispersion of all power plants across different U.S. counties in 2020.

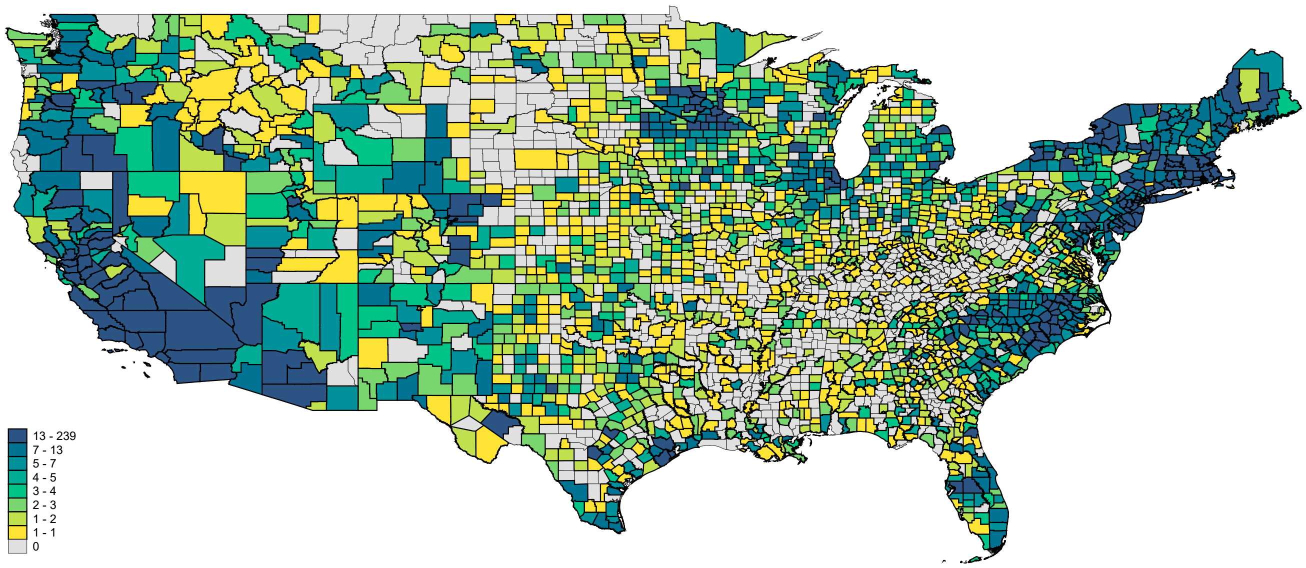
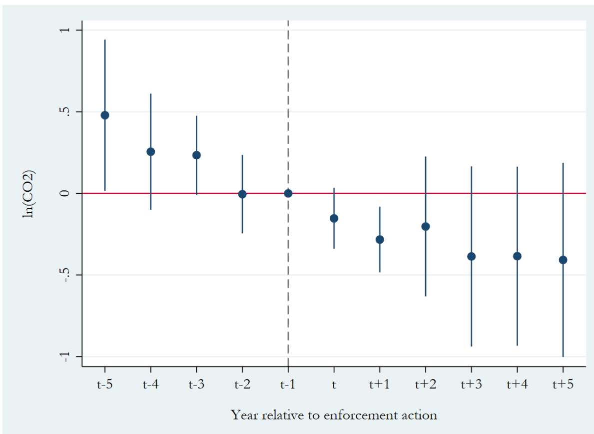
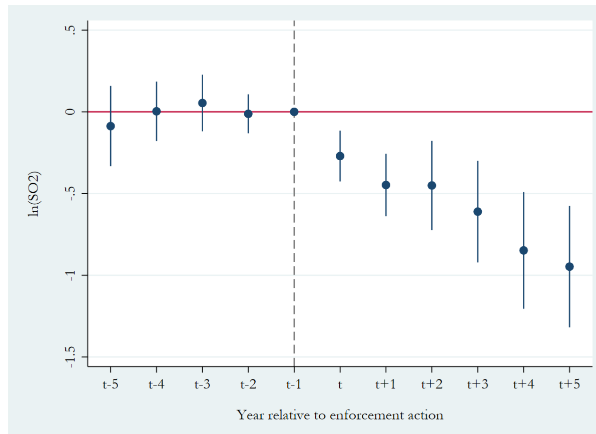


Figure 3
Dynamic Effects of Environmental Violations on Air Pollution

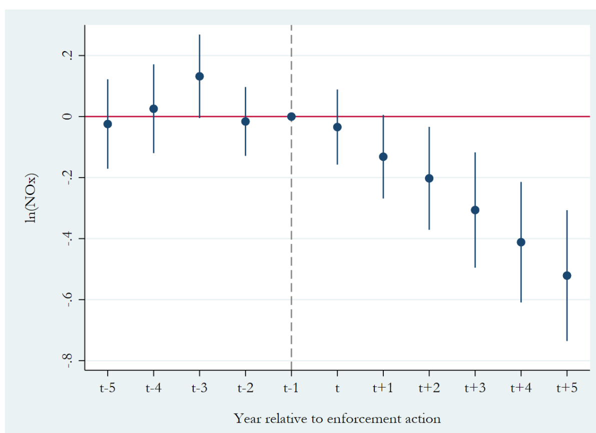
The figure illustrates the dynamic impacts of environmental violations on power plants' emissions. Specifically, Figures (a)-(c) depict the changes in CO2, SO2, and NOx emissions, respectively. Each subfigure presents estimated coefficients and their 95% confidence intervals, derived from regressing the outcome variables on dummy variables that indicate the distance (in years) relative to the event, as specified in Eq. 2.



(a) CO2 emissions



(b) SO2 emissions



(c) NOx emissions

Table 1
Summary Statistics

This table reports descriptive statistics of the main variables employed in our empirical analysis, including the number of observations (NObs), mean (Mean), standard deviation (Stdev), 25th percentile (25th), median (Median), and 75th percentile (75th) in the 2001-2020 period. Variable definitions are provided in Appendix Table A1. All continuous variables are winsorized at the 1st and 99th percentiles.

	NObs	Mean	Stdev	25th	Median	75th
	(1)	(2)	(3)	(4)	(5)	(6)
Pollution Emissions						
ln(CO2)	12296	10.426	5.21	9.618	12.302	13.941
ln(SO2)	12296	2.624	3.34	0.138	1.128	3.132
ln(NOx)	12296	4.830	2.16	3.392	4.682	6.091
ln(CO2/GWh)	12296	5.345	2.56	6.059	6.400	6.711
ln(SO2/GWh)	12296	0.342	0.71	0.002	0.003	0.111
ln(NOx/GWh)	12296	0.450	0.50	0.089	0.297	0.674
Corporate Responses						
ln(GWh)	12296	5.985	2.03	4.717	6.091	7.617
ln(Sulfur)	12296	2.535	3.79	0.000	0.000	4.853
ln(Sulfur Intensity)	12296	0.167	0.33	0.000	0.000	0.148
Coal Share	12269	0.215	0.40	0.000	0.000	0.000
Gas Share	12269	0.704	0.43	0.039	0.999	1.000
ln(Scrubbers)	7747	0.174	0.42	0.000	0.000	0.000
ln($Abatement)	5128	0.379	1.05	0.000	0.000	0.000
ln(New Generators)	12296	0.052	0.28	0.000	0.000	0.000
Utility-Level Financial Variables						
ln(Assets)	1869	1.521	0.78	0.799	1.463	2.100
Capex/Assets	1859	0.073	0.05	0.046	0.061	0.086
Longterm Debt/Assets	1869	0.272	0.10	0.233	0.288	0.324
Operating Revenue/Assets	1869	0.396	0.17	0.286	0.364	0.451
Production Expenses/Assets	1869	0.207	0.14	0.115	0.170	0.248
Operating Income/Assets	1869	0.042	0.02	0.033	0.042	0.050
Net Income/Assets	1869	0.030	0.02	0.022	0.029	0.037
ln(Electricity Price)	1868	4.184	0.37	3.967	4.228	4.449

Table 2
Emission Responses to Environmental Violations

This table reports the effects of environmental violations on the emission levels and emission intensity of violating power plants. Panel A presents results for different types of emissions, while Panel B focuses on emission intensity measures. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using the untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Emission Level		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.448**	-0.591***	-0.318***
	(-2.19)	(-4.19)	(-4.05)
Observations	12296	12296	12296
Adjusted R^2	0.857	0.903	0.917
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

	Panel B: Emission Intensity		
	ln(CO2/GWh)	ln(SO2/GWh)	ln(NOx/GWh)
	(1)	(2)	(3)
Post × Treated	-0.122	-0.165***	-0.053**
	(-1.16)	(-4.15)	(-2.02)
Observations	12296	12296	12296
Adjusted R^2	0.828	0.856	0.845
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

Table 3
Corporate Responses to Environmental Violations

This table reports the effects of environmental violations on corporate operational responses using stacked Difference-in-Differences (DiD) regressions. Column (1) presents the impact on electricity generation. Columns (2) and (3) report the effects on sulfur content and sulfur intensity. Columns (4) and (5) show changes in the share of different fuel types used. Columns (6) through (8) examine responses related to pollution control investments, including the installation of scrubbers, spending on pollution abatement, and the purchase of new generators. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using the untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	ln(GWh)	ln(Sulfur)	ln(Sulfur Intensity)	Coal Share	Gas Share	ln(Scrubbers)	ln($Abatement)	ln(New Generators)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Treated	-0.243***	-0.355***	-0.018*	-0.027**	0.034***	0.049**	0.194*	0.031***
	(-2.98)	(-3.49)	(-1.74)	(-2.54)	(2.91)	(2.13)	(1.93)	(2.65)
Observations	12296	12296	12296	12267	12267	7588	4833	12296
Adjusted R^2	0.908	0.958	0.959	0.982	0.967	0.864	0.541	0.073
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 4
Environmental Violations and Agency Heterogeneity

This table reports the differential effects of environmental violations by enforcing agency using stacked Difference-in-Differences (DiD) regressions. Odd-numbered columns present results for enforcement actions initiated by state agencies and recorded in ICIS-Air, while even-numbered columns correspond to actions led by the U.S. EPA and reported in ICIS-FE&C. Panel A examines the effects on emissions, and Panel B assesses corporate operational responses. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Emissions					
	ln(CO2)		ln(SO2)		ln(NOx)	
	State	Federal	State	Federal	State	Federal
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Treated	-0.313	-1.057*	-0.347**	-1.696***	-0.150*	-1.074***
	(-1.43)	(-1.93)	(-2.42)	(-4.27)	(-1.94)	(-4.92)
Difference (Federal - State)	-0.744		-1.349***		-0.924***	
Observations	10669	1627	10669	1627	10669	1627
Adjusted R^2	0.856	0.862	0.899	0.918	0.916	0.925
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 4 - Continued
Environmental Violations and Agency Heterogeneity

	Panel B: Corporate Response							
	ln(GWh)		ln(Sulfur)		ln(Sulfur Intensity)		Coal Share	
	State	Federal	State	Federal	State	Federal	State	Federal
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Treated	-0.066	-1.044***	-0.166*	-1.212***	-0.011	-0.047**	-0.005	-0.126***
	(-0.91)	(-3.88)	(-1.89)	(-3.27)	(-0.99)	(-2.17)	(-0.75)	(-2.67)
Difference (Federal - State)	-0.978***		-1.046***		-0.036		-0.121***	
Observations	10669	1627	10669	1627	10669	1627	10643	1624
Adjusted R^2	0.913	0.881	0.958	0.962	0.959	0.959	0.987	0.957
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Gas Share		ln(Scrubbers)		ln($ Abatement)		ln(New generator)	
	State	Federal	State	Federal	State	Federal	State	Federal
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Treated	0.024**	0.078**	0.047*	0.057	0.133	0.421*	0.036**	0.010
	(2.11)	(1.99)	(1.82)	(1.12)	(1.20)	(1.76)	(2.56)	(0.77)
Difference (Federal - State)	0.054		0.010		0.288		-0.026	
Observations	10643	1624	6634	954	4150	683	10669	1627
Adjusted R^2	0.969	0.954	0.864	0.864	0.523	0.541	0.079	0.108
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 5
Organizational Structure of Utility Firms and Post-Violation Responses

This table reports the effects of environmental violations on plant-level responses, conditional on the organizational structure of utility firms, using stacked Difference-in-Differences (DiD) regressions. Panel A presents results separately for single-plant and multi-plant utility firms. Panels B and C focus on multi-plant utility firms, further stratified by the coal share of their sibling plants—above-median (High) and below-median (Low), respectively. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Single-Plants versus Multi-Plants					
	ln(CO2)		ln(SO2)		ln(NOx)	
	Single	Multi	Single	Multi	Single	Multi
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Treated	-0.260	-0.581**	0.067	-1.057***	0.118	-0.625***
	(-0.80)	(-2.23)	(0.37)	(-5.50)	(1.32)	(-5.74)
Difference (Multi - Single)	-0.321		-1.124***		-0.743***	
Observations	5215	7081	5215	7081	5215	7081
Adjusted R^2	0.838	0.872	0.879	0.917	0.915	0.919
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes

	Panel B: Siblings Coal Share and Emissions					
	ln(CO2)		ln(SO2)		ln(NOx)	
	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Treated	-0.841**	-0.427	-0.646***	-1.298***	-0.254	-0.845***
	(-2.20)	(-1.21)	(-2.88)	(-4.67)	(-1.46)	(-6.31)
Difference (High - Low)	0.413		-0.652*		-0.591***	
Observations	3566	3515	3566	3515	3566	3515
Adjusted R^2	0.854	0.898	0.897	0.915	0.902	0.926
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 5 - Continued
Organizational Structure of Utility Firms and Post-Violation Responses

Panel C: Siblings Coal Share and Corporate Response

	ln(GWh)		ln(Sulfur)		ln(Sulfur Intensity)		Coal Share	
	Low	High	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Treated	-0.138	-0.642***	-0.160	-0.849***	-0.012	-0.050**	-0.032**	-0.068**
	(-0.94)	(-4.04)	(-0.87)	(-3.83)	(-0.57)	(-2.18)	(-1.99)	(-2.56)
Difference (High - Low)	-0.504**		-0.689**		-0.037		-0.036	
Observations	3566	3515	3566	3515	3566	3515	3560	3507
Adjusted R^2	0.916	0.889	0.915	0.971	0.938	0.944	0.983	0.975
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	Gas Share		ln(Scrubbers)		ln($ Abatement)		ln(New generator)	
	Low	High	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Treated	0.050**	0.066***	0.054*	0.040	0.055	0.353*	0.083***	0.038***
	(2.03)	(2.61)	(1.78)	(0.79)	(0.22)	(1.81)	(3.19)	(2.94)
Difference (High - Low)	0.016		-0.013		0.298		-0.045	
Observations	3560	3507	2116	1982	1222	1538	3566	3515
Adjusted R^2	0.958	0.963	0.920	0.811	0.344	0.528	0.077	0.005
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 6
Government Subsidies and Post-Violation Responses

This table reports the effects of environmental violations on utility firm responses, conditional on the availability of government subsidies, using stacked Difference-in-Differences (DiD) regressions. The sample is divided into two groups based on state subsidy levels allocated to utility firms. Odd-numbered columns correspond to plants in below-median subsidy states, while even-numbered columns represent those in above-median subsidy states. Panel A examines the impact on emissions, and Panel B focuses on corporate operational responses. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Emissions					
	ln(CO2)		ln(SO2)		ln(NOx)	
	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Treated	0.224	-1.289***	-0.331**	-0.917***	-0.093	-0.599***
	(0.74)	(-5.69)	(-1.97)	(-3.97)	(-1.01)	(-4.76)
Difference (High - Low)	-1.513***		-0.587**		-0.505***	
Observations	6952	5344	6952	5344	6952	5344
Adjusted R^2	0.860	0.854	0.907	0.898	0.917	0.917
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 6 - Continued
Government Subsidies and Post-Violation Responses

	Panel B: Corporate Response							
	ln(GWh)		ln(Sulfur)		ln(Sulfur Intensity)		Coal Share	
	Low	High	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Treated	-0.067	-0.463***	-0.004	-0.795***	0.000	-0.040**	0.002	-0.064***
	(-0.80)	(-3.17)	(-0.05)	(-4.03)	(0.00)	(-2.27)	(0.37)	(-2.89)
Difference (High - Low)	-0.396**		-0.791***		-0.040*		-0.066***	
Observations	6952	5344	6952	5344	6952	5344	6933	5334
Adjusted R^2	0.912	0.903	0.967	0.949	0.966	0.949	0.991	0.972
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Gas Share		ln(Scrubbers)		ln($ Abatement)		ln(New generator)	
	Low	High	Low	High	Low	High	Low	High
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Post × Treated	0.006	0.068***	0.042	0.058*	0.358**	0.022	0.050***	0.008
	(0.82)	(2.88)	(1.30)	(1.79)	(2.33)	(0.18)	(2.83)	(0.53)
Difference (High - Low)	0.062**		0.016		-0.336*		-0.043*	
Observations	6933	5334	4383	3205	2829	2004	6952	5344
Adjusted R^2	0.975	0.957	0.838	0.895	0.534	0.550	0.096	0.031
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 7
Financial Consequences of Environmental Violations

This table reports the effects of EPA enforcement actions on the financial outcomes of investor-owned utility firms, using stacked Difference-in-Differences (DiD) regressions. The analysis includes firms for which financial data are available from FERC Form 1. The Treated indicator equals 1 if the utility firm received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated utility firm and a set of geographically matched control firms that did not receive any enforcement action during the sample period. The control group is constructed using the three nearest untreated firms. All regressions include cohort by year and cohort by utility firm fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the firm-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	ln(Assets)	Capex/Assets	Long-term Debt/Assets	Operating Revenue/Assets	Production Expenses/Assets	Operating Income/Assets	Net Income/Assets	ln(Electricity Price)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Treated	0.060**	0.019***	0.026***	0.045**	0.039**	0.002	-0.000	0.047**
	(2.00)	(2.67)	(3.69)	(2.32)	(2.45)	(1.02)	(-0.03)	(2.24)
Observations	1850	1842	1850	1850	1850	1850	1850	1849
Adjusted R^2	0.977	0.273	0.781	0.727	0.748	0.667	0.448	0.904
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 8
Electricity Prices Post-Environmental Violations

This table reports the effects of EPA enforcement actions on utility-level electricity prices using stacked Difference-in-Differences (DiD) regressions. Column (1) presents the baseline estimate. Columns (2) and (3) examine heterogeneity by dividing utility firms into two groups based on state-level subsidy levels. Columns (4) and (5) split the sample by the regulatory status of the targeted utility firms. Columns (6) and (7) use the concentration of electricity generation within a state as a proxy for market competition, while Columns (8) and (9) use the share of electricity generated by independent power producers (IPPs) to capture competitive pressure. The Treated indicator equals 1 if the utility firm received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated utility firm and a set of geographically matched control firms that did not receive any enforcement action during the sample period. The control group is constructed using the three nearest untreated firms. All regressions include cohort by year and cohort by utility firm fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the firm-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Dependent Variable: ln(Electricity Price)								
				Electricity Market Competition					
		Government Subsidy		Regulatory Status		Generation HHI		IPP Share	
	Full Sample	Low	High	Regulated	Non-regulated	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Post × Treated	0.061*	0.114***	-0.003	0.189***	-0.016	-0.028	0.138***	0.148***	-0.043
	(1.93)	(2.82)	(-0.07)	(4.57)	(-0.39)	(-0.60)	(3.37)	(4.04)	(-0.86)
Difference		-0.117*		-0.205***		0.166***		-0.191***	
Observations	5126	2818	2308	1685	3441	2527	2566	2556	2537
Adjusted R^2	0.563	0.587	0.537	0.621	0.531	0.570	0.566	0.607	0.525
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 9
Instrumental Variable Analysis of Violation Effects

This table reports the results from instrumental variable (IV) regressions that estimate the causal effects of environmental violations using exogenous variation in enforcement exposure. Two instrumental variables are employed. *EnforceExposure (Frequency)* is defined as the number of air-related enforcement actions targeting all emission sources in a given county-year, divided by the total number of power plants in that county-year. *EnforceExposure (Penalty)* is defined as the total monetary penalties associated with such enforcement actions, divided by the number of power plants in the county-year. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: EnforceExposure (Frequency)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)
$\widehat{Post \times Treated}$		-8.346***	-2.936**	-1.284**
		(-2.66)	(-2.25)	(-2.22)
Post × EnforceExposure (Frequency)	0.157***			
	(3.52)			
Observations	11189	11189	11189	11189
Adjusted R^2		-0.912	-0.414	-0.290
F-Stat	12.36			
Cohort × Year FE	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes

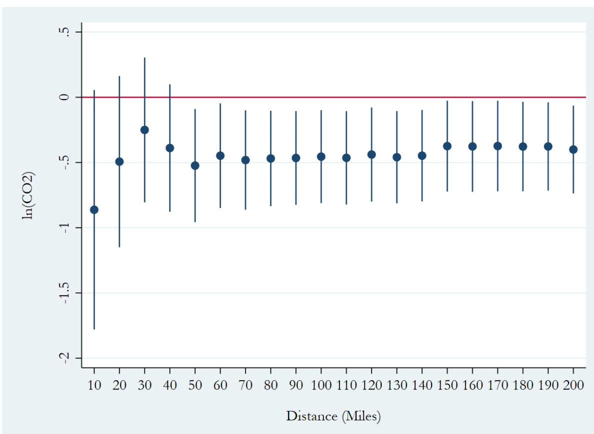
	Panel B: EnforceExposure (Penalty)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)
$\widehat{Post \times Treated}$		-4.459*	-3.042**	-1.723***
		(-1.94)	(-2.24)	(-2.92)
Post × EnforceExposure (Penalty)	0.011***			
	(3.69)			
Observations	11189	11189	11189	11189
Adjusted R^2		-0.380	-0.436	-0.411
F-Stat	13.6			
Cohort × Year FE	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes

Appendix

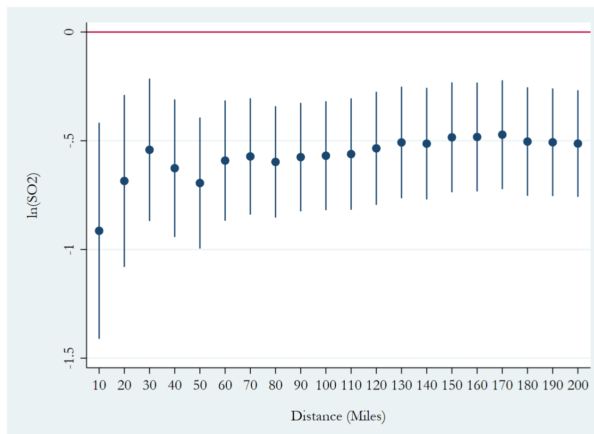
Figure A1

Robustness of Baseline Results to Geographical Distance of Control Group

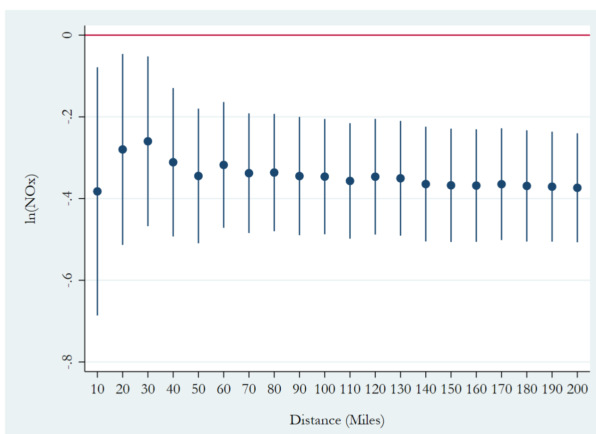
This figure depicts the robustness of baseline results to the choice of the geographical distance that is used to select the control group. Subfigures (a)-(c) show the robustness of results for CO2, SO2, NOx emissions, respectively. Each subfigure plots estimated coefficients and their 95% confidence intervals.



(a) CO2 emissions



(b) SO2 emissions

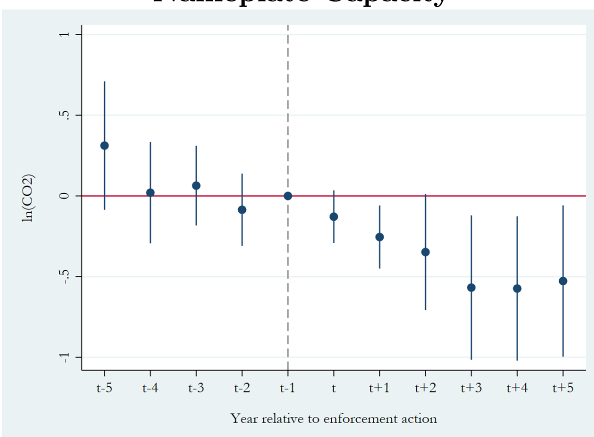


(c) NOx emissions

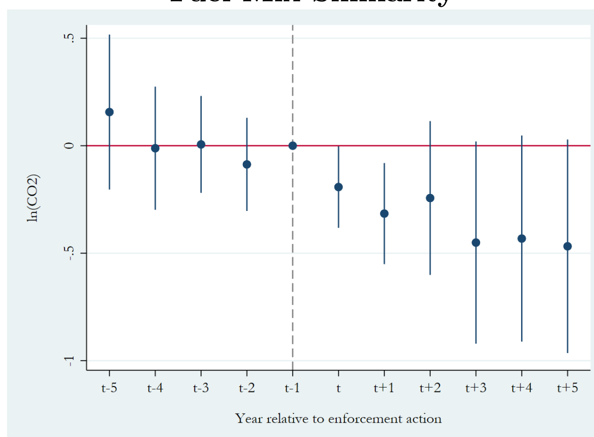
Figure A2
Emission Dynamics using Alternative Control Groups

This figure shows the dynamic impacts of environmental violations on power plant emissions, utilizing four distinct control groups. Subfigures (a), (c), and (e) use a control group based on nameplate capacity size; (b), (d), and (f) use one matched by fuel mix similarities; (g), (i), and (k) use an age-matched control group; and (h), (j), and (l) use a control group based on steam generator availability.

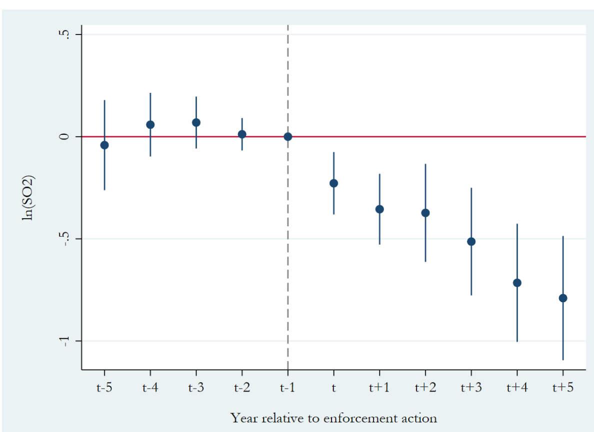
Nameplate Capacity | **Fuel Mix Similarity**



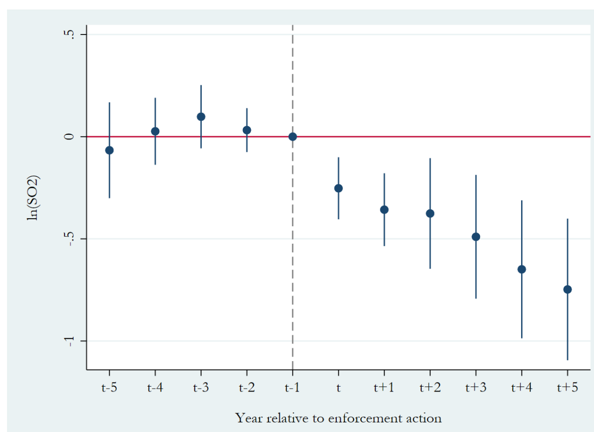
(a) CO2 emissions



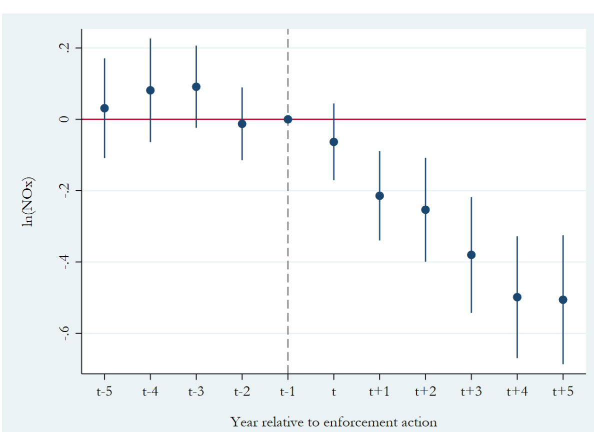
(b) CO2 emissions



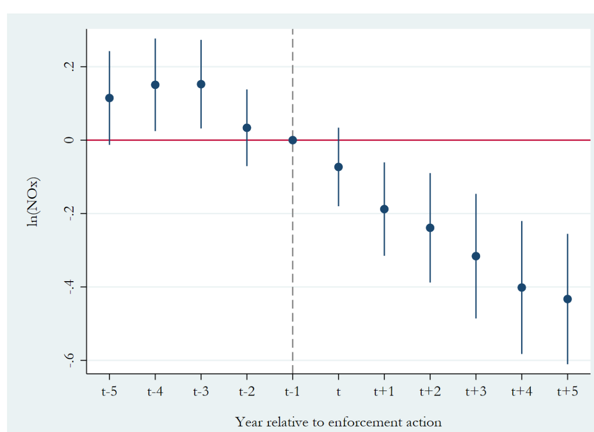
(c) SO2 emissions



(d) SO2 emissions



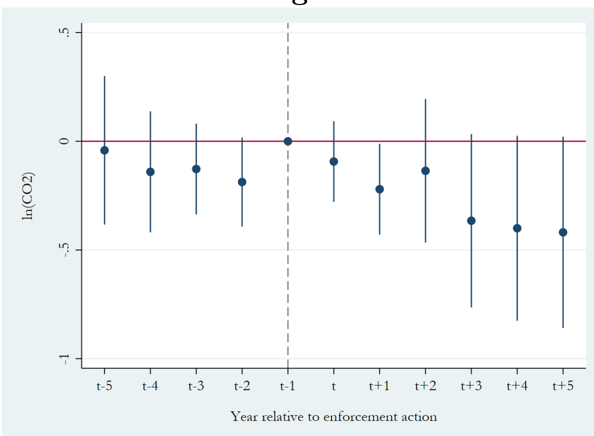
(e) NOx emissions



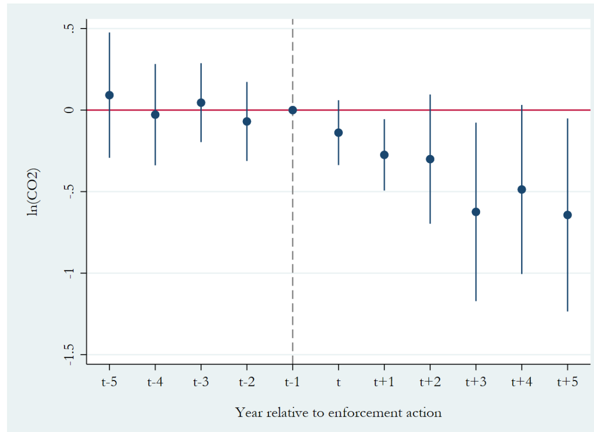
(f) NOx emissions

Figure A2 - Continued
Emission Dynamics using Alternative Control Groups

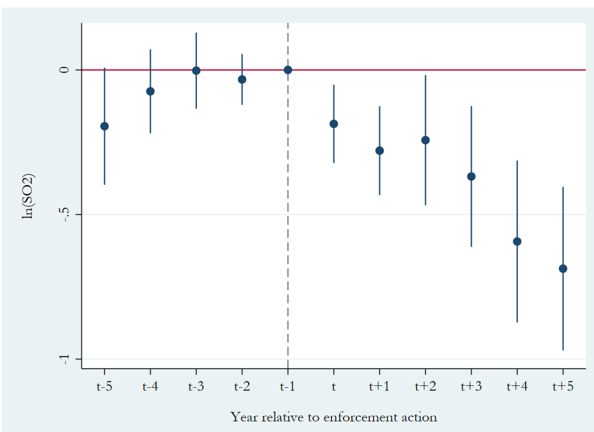
Age | **Steam Generation**



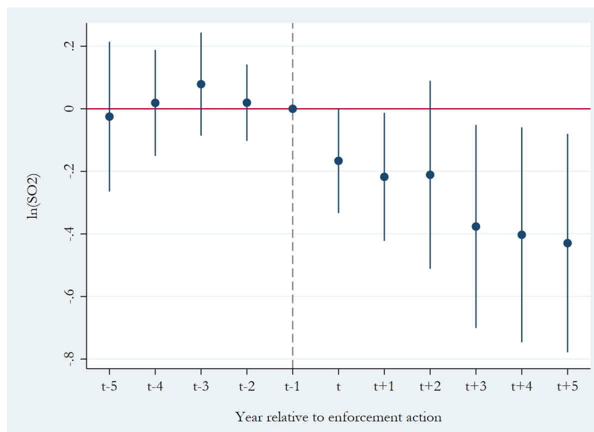
(g) CO2 emissions



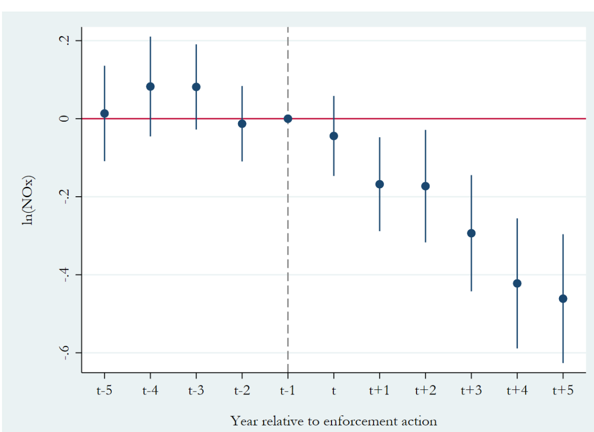
(h) CO2 emissions



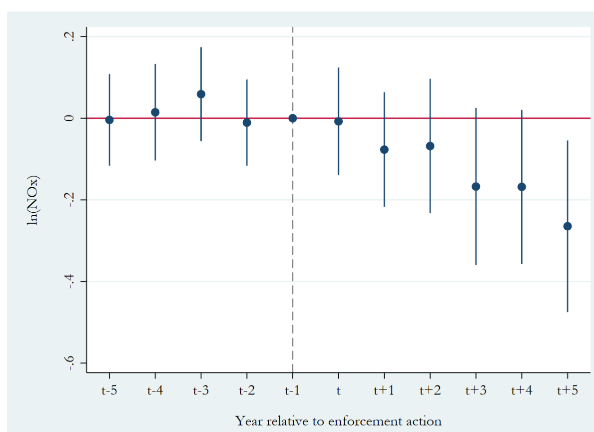
(i) SO2 emissions



(j) SO2 emissions



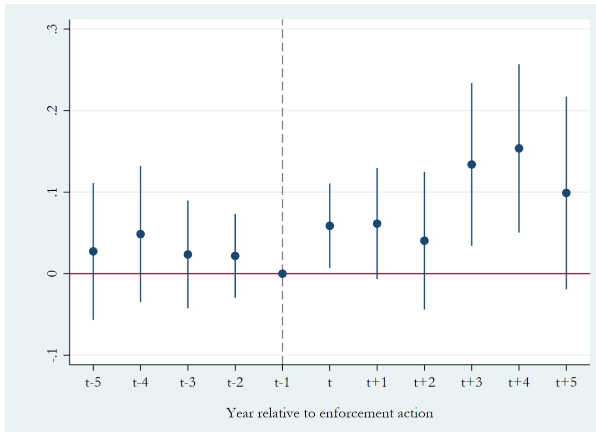
(k) NOx emissions



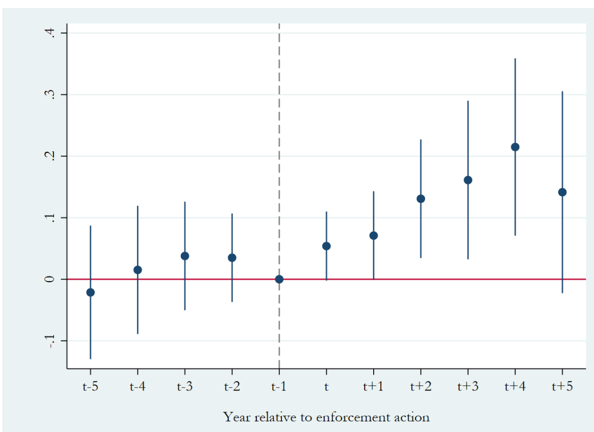
(l) NOx emissions

Figure A3
Electricity Price Dynamics

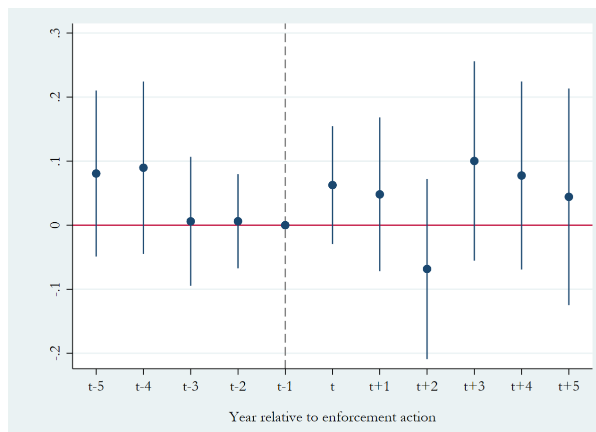
This figure depicts the dynamics of electricity price movements in the full sample and across subsamples with different levels of access to local subsidies and electricity market competition examined in Table 8.



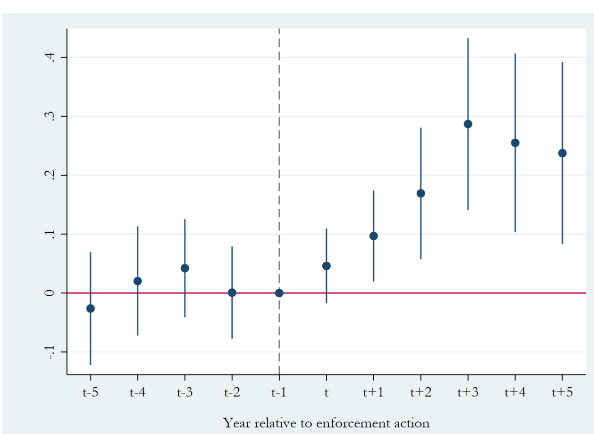
(a) Full Sample



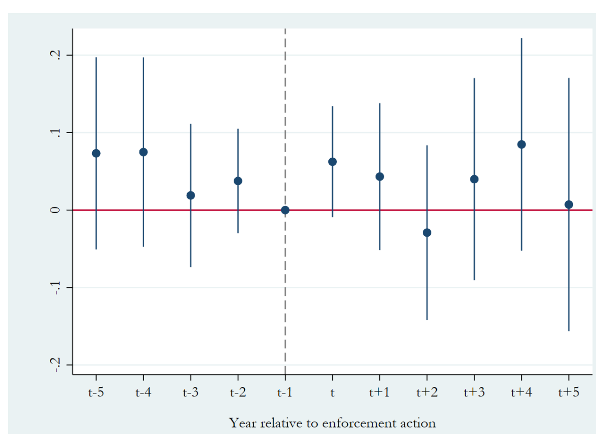
(b) Low Subsidy



(c) High Subsidy

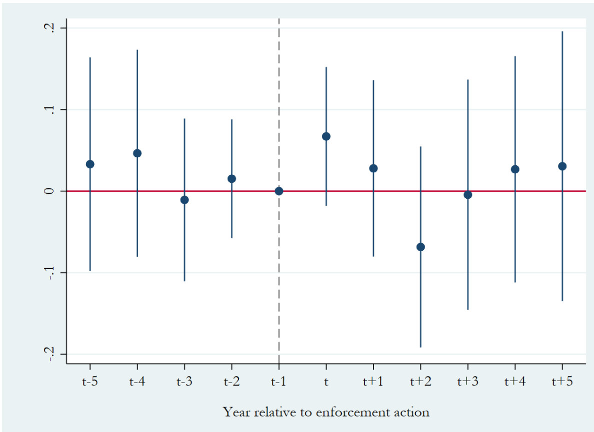


(d) Regulated

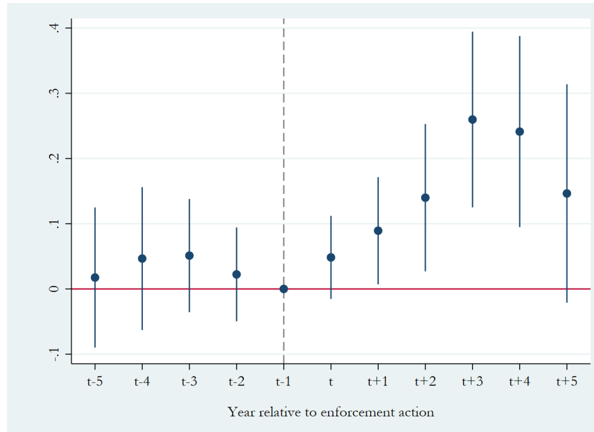


(e) Non-regulated

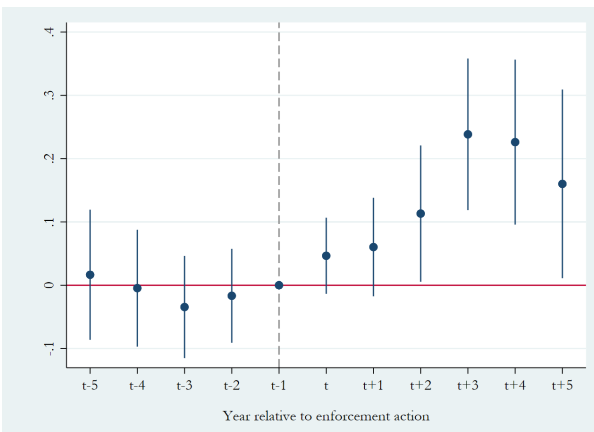
Figure A3 - Continued
Electricity Price Dynamics



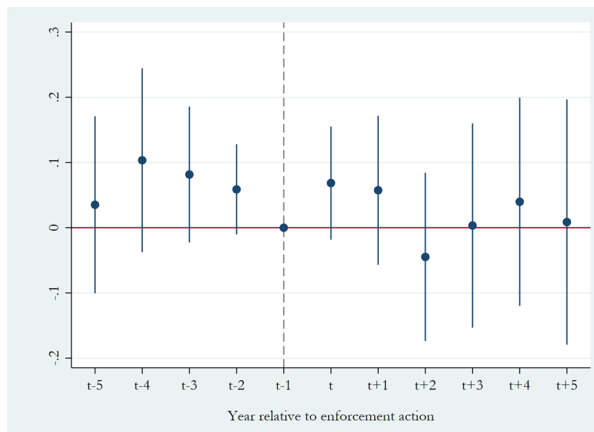
(f) Low HHI



(g) High HHI



(h) Low IPP Share



(i) High IPP Share

Table A1
Variable Definition

Variable	Definition and Data Source
ln(CO2)	Natural logarithm of 1 plus plant's total CO2 emissions in tons. (EPA's CAMD).
ln(SO2)	Natural logarithm of 1 plus plant's total SO2 emissions in tons. (EPA's CAMD).
ln(NOx)	Natural logarithm of 1 plus plant's total NOx emissions in tons. (EPA's CAMD).
ln(CO2/GWh)	Natural logarithm of 1 plus plant's tons of CO2 emissions per GWh of electricity generation. (EPA's CAMD).
ln(SO2/GWh)	Natural logarithm of 1 plus plant's tons of SO2 emissions per GWh of electricity generation. (EPA's CAMD).
ln(NOx/GWh)	Natural logarithm of 1 plus plant's tons of NOx emissions per GWh of electricity generation. (EPA's CAMD).
ln(GWh)	Natural logarithm of 1 plus the net electricity generation in GWh (EIA-923).
ln(Sulfur)	Natural logarithm of 1 plus the total tons of sulfur (EIA-923 and EIA-767).
ln(Sulfur Intensity)	Natural logarithm of 1 plus the total lb of sulfur per MMBTU of heat (EIA-923 and EIA-767).
Coal Share	The ratio of coal heat input divided by the total heat input from all types of fossil fuels. (EIA-923).
Gas Share	The ratio of gas heat input divided by the total heat input from all types of fossil fuels.
ln(Scrubbers)	Natural logarithm of 1 plus the number of scrubbers being used in power plants (EIA-860 and EIA-767). Data are only available for plants with steam-electric capacity of 10MW or more and the data are not available in 2006.
ln($Abatement)	Natural logarithm of 1 plus new structures and/or equipment purchased to reduce, monitor, or eliminate airborne pollutants during the year in million dollars (EIA-923). Data are only available for plants with steam-electric capacity of 10MW or more and the data are not available in 2006 and 2007.
ln(New Generators)	Natural logarithm of one plus the number of newly constructed generators during the year (EIA-860).
Federal	Cases undertaken by EPA and reported in ICIS-FE&C database.
State	Cases undertaken by state-level agencies and reported in ICIS-Air.
Government Subsidies	Total amount of subsidies granted by local or state-level governments to utilities and power generation companies within each state.
ln(Assets)	Natural logarithm of 1 plus total assets of utility firms in billion dollars (FERC Form 1).
Capex/Assets	Capital expenditure of utility firms divided by total assets (FERC Form 1).
Long-term Debt/Assets	Long-term debts of utility firms divided by total assets (FERC Form 1).
Operating Revenue/Assets	Operating revenue divided by total assets (FERC Form 1).
Production Expenses/Assets	Production expenses divided by total assets.
Operating Income/Assets	Operating income divided by total assets (FERC Form 1).
Net Income/Assets	Net income divided by total assets (FERC Form 1).
ln(Electricity Price)	Natural logarithm of 1 plus the average sales price of electricity. (FERC Form 1 in Table 6 as well as EIA-861 and EIA-923 in Table 7).
Regulatory Status	An indicator variable that is equal to 1 if the utility firm is regulated and zero otherwise (EIA-860).
Generation HHI	Sum of squares of plant-level electricity generation divided by total State-level electricity generation in a given year.
IPP Share	The proportion of the elecricity that is generated by Idependent Power Producers (IPP) in a given state-year.
EnforceExposure (Frequency)	For each power plant, it is calculated as the number of air enforcement actions that all other emission sources receive divided by the total number of operating power plants in each county-year.
EnforceExposure (Penalty)	For each power plant, it is calculated as the sum of the penalties of air enforcement actions that all emission sources receive divided by the total number of operating power plants in each county-year.

Table A2
Robustness to Violations' Penalty Size

This table reports the robustness of the baseline findings to the inclusion of enforcement actions with varying penalty sizes. In Panel A, we include all enforcement actions with total penalties greater than \$0, while Panel B restricts the sample to enforcement actions with penalties exceeding \$10,000. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Enforcement Actions with higher than \$0 Penalty		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.335*	-0.464***	-0.210***
	(-1.80)	(-3.61)	(-3.04)
Observations	13332	13332	13332
Adjusted R^2	0.840	0.898	0.921
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes
	Panel B: Enforcement Actions with higher than \$10,000 Penalty		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.396*	-0.611***	-0.379***
	(-1.75)	(-3.78)	(-4.36)
Observations	11196	11196	11196
Adjusted R^2	0.846	0.914	0.917
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

Table A3
Plant Share, Capacity Factor, and Environmental Violations

This table reports the effects of EPA enforcement actions on the Plant Share and Capacity Factor of targeted power plants. Plant Share is defined as a plant's electricity generation divided by the total generation of its parent utility. CapFactor measures the ratio of actual electricity generated to the maximum possible generation if the plant operated at full capacity year-round. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include plant and year fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Plant Share	CapFactor
	(1)	(2)
Post × Treated	-0.012	-0.042***
	(-0.80)	(-3.43)
Observations	12296	12296
Adjusted R^2	0.873	0.849
Cohort × Year FE	Yes	Yes
Cohort × Plant FE	Yes	Yes

Table A4
Green Electricity Generation and Environmental Violations

This table reports the impact of EPA enforcement actions on utility-level green electricity generation. Columns (1)–(3) examine changes in electricity generation from solar, wind, and hydro sources, respectively, following an environmental violation. Column (4) presents the corresponding change in total green electricity output. The Treated indicator equals 1 if the utility firm received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated firm and a set of geographically matched control firms that did not receive any enforcement action during the sample period. The control group is constructed using the three nearest untreated firms. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	ln(Solar)	ln(Wind)	ln(Hydro)	ln(Total Green)
	(1)	(2)	(3)	(4)
Post × Treated	0.125	0.591***	0.007	0.436**
	(1.17)	(3.21)	(0.13)	(2.51)
Observations	5210	5210	5210	5210
Adjusted R^2	0.561	0.827	0.985	0.942
Cohort × Year FE	Yes	Yes	Yes	Yes
Cohort × Firm FE	Yes	Yes	Yes	Yes

Table A5
Response to Environmental Violations in Sibling Plants

This table reports the effects of EPA enforcement actions on non-violating power plants that belong to the same parent company as the violating plants. The analysis excludes any plant that directly violated environmental regulations. Panel A presents the impact of sibling violations on pollution emissions. Panel B examines additional outcomes: Column (1) reports the effect on electricity generation, Columns (2) and (3) assess changes in sulfur content and sulfur intensity, while Columns (4) and (5) analyze the impact on the fuel mix, measured by the share of different fuel types employed. Columns (6) through (8) report post-violation changes in scrubber installation, pollution abatement expenditures, and the purchase of new generators. The Treated indicator equals 1 if a non-violating plant has at least one sibling plant receiving an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after a sibling receives the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that neither themselves nor their siblings received any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Emissions and Electricity Generation		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.327**	-0.749***	-0.350***
	(-2.20)	(-7.27)	(-5.71)
Observations	14036	14036	14036
Adjusted R^2	0.886	0.914	0.917
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

	Panel B: Operational Response							
	ln(GWh)	ln(Sulfur)	ln(Sulfur/MMBTU)	Coal Share	Gas Share	ln(Srubbers)	ln($Abatement)	ln(New Generators)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Treated	-0.216***	-0.330***	-0.017*	-0.024***	0.033***	-0.013	-0.046	0.055***
	(-3.48)	(-4.47)	(-1.90)	(-3.97)	(3.63)	(-0.56)	(-0.63)	(5.16)
Observations	14036	14036	13834	13973	13973	7832	5412	14036
Adjusted R^2	0.908	0.951	0.932	0.984	0.962	0.840	0.548	0.055
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A6
Validity of Instrumental Variables

This table tests the validity of two instruments, i.e., $EnforceExposure$ ($Frequency$) and $EnforceExposure$ ($Penalty$), used in the two-stage least squares (2SLS) regressions. For each power plant, $EnforceExposure$ ($Frequency$) is defined as the number of air enforcement actions received by other emission sources divided by the total number of operating power plants in the same county-year. Similarly, $EnforceExposure$ ($Penalty$) is defined as the sum of penalties associated with those air enforcement actions, divided by the number of operating power plants in the county-year. In this table, we regress a binary indicator, *Enforcement*, which equals 1 if the plant receives an enforcement action in a given year and 0 otherwise, on each of the instruments. Columns (1) and (2) include the entire sample of power plants with available emissions data, whereas Columns (3) and (4) contains a sample of targeted plants that receive an enforcement action and plants in the control group located in a different county but within 60 miles radius around targeted ones. The control group consists of plants outside of the county but within 60 miles radius around the treated ones, but the plants have neither received any enforcement action themselves nor experienced any in one of their siblings. Each cohort consists of one treated plant and the control plants surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. t-statistics are reported in parentheses. Standard errors are clustered at the plant level. Superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)
EnforceExposure (Frequency)	0.027***		0.023**	
	(4.01)		(2.46)	
EnforceExposure (Penalty)		0.002***		0.002***
		(4.68)		(2.81)
Observations	18955	18955	11189	11189
Adjusted R^2	0.125	0.125	0.284	0.284
Year FE	Yes	Yes		
Plant FE	Yes	Yes		
Cohort × Year FE			Yes	Yes
Cohort × Plant FE			Yes	Yes

Table A7
Robustness of Instrumental Variable Analysis

This table tests the robustness of the instrumental variable construction to alternative specifications. Panel A presents results excluding enforcement actions that target power plants. Panels B and C assess robustness to thresholds by including only enforcement actions with penalties greater than $10,000 and $20,000, respectively. Panel D restricts the sample to enforcement actions associated with High Priority Violations. Panel E includes *Proximate Enforcement* as an additional control, which equals 1 if an enforcement action occurred within 5 miles of the plant within the past five years. *EnforceExposure (Frequency)* is defined as the total number of air-related enforcement actions targeting all emission sources divided by the total number of operating power plants in each county-year. *EnforceExposure (Penalty)* is defined as the total penalties associated with such actions divided by the number of power plants in the county-year. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Excluding Enforcements with Penalty Less than 10K Dollars							
	EnforceExposure (Frequency)				EnforceExposure (Penalty)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\widehat{Post \times Treated}$		-1.733***	-1.330***	-0.689***		-1.637***	-1.411***	-0.910***
		(-2.93)	(-3.86)	(-4.49)		(-2.78)	(-3.89)	(-6.06)
Post × EnforceExposure (Frequency)	0.594***							
	(11.96)							
Post × EnforceExposure (Penalty)					0.033***			
					(12.17)			
Observations	11189	11189	11189	11189	11189	11189	11189	11189
Adjusted R^2		-0.211	-0.205	-0.198		-0.208	-0.210	-0.223
F-Stat	143.06				148.18			
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A7 - Continued
Robustness of Instrumental Variable Analysis

	Panel B: Excluding Enforcements with Penalty Less than 20K Dollars							
	EnforceExposure (Frequency)				EnforceExposure (Penalty)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\widehat{Post \times Treated}$		-2.916***	-1.417***	-0.677***		-1.683***	-1.520***	-0.836***
		(-4.25)	(-3.96)	(-4.06)		(-3.13)	(-4.54)	(-6.40)
Post × EnforceExposure (Frequency)	0.459***							
	(11.04)							
Post × EnforceExposure (Penalty)					0.038***			
					(14.63)			
Observations	11189	11189	11189	11189	11189	11189	11189	11189
Adjusted R^2		-0.264	-0.211	-0.197		-0.210	-0.218	-0.213
F-Stat	121.97				214.09			
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	Panel C: High Priority Violations							
	EnforceExposure (Frequency)				EnforceExposure (Penalty)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\widehat{Post \times Treated}$		-1.896*	-1.713***	-0.997***		-4.226***	-2.472***	-1.646***
		(-1.76)	(-3.46)	(-3.77)		(-2.65)	(-3.61)	(-4.06)
Post × EnforceExposure (Frequency)	0.595***							
	(7.29)							
Post × EnforceExposure (Penalty)					0.016***			
					(5.52)			
Observations	11189	11189	11189	11189	11189	11189	11189	11189
Adjusted R^2		-0.217	-0.235	-0.236		-0.359	-0.332	-0.387
F-Stat	53.15				30.49			
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A7 - Continued
Robustness of Instrumental Variable Analysis

	Panel D: Excluding Power Plants							
	EnforceExposure (Frequency)				EnforceExposure (Penalty)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\widehat{Post \times Treated}$		-8.897**	-3.382**	-1.368**		-7.207**	-1.368**	-7.207**
		(-2.55)	(-2.33)	(-2.17)		(-2.37)	(-2.17)	(-2.37)
Post × EnforceExposure (Frequency)	0.166***							
	(3.21)							
Post × EnforceExposure (Penalty)					0.010***			
					(3.40)			
Observations	11189	11189	11189	11189	11189	11189	11189	11189
Adjusted R^2		-1.015	-0.510	-0.310		-0.721	-0.310	-0.721
F-Stat	10.29				11.55			
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	Panel E: Controlling for Proximate Enforcement							
	EnforceExposure (Frequency)				EnforceExposure (Penalty)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\widehat{Post \times Treated}$		-8.967***	-2.780**	-1.246**		-5.046**	-2.816**	-1.707***
		(-2.59)	(-2.08)	(-2.06)		(-1.96)	(-1.98)	(-2.73)
Post × EnforceExposure (Frequency)	0.149***							
	(3.31)							
Post × EnforceExposure (Penalty)					0.010***			
					(3.43)			
Proximate Enforcement	0.079***	0.967**	-0.243	-0.058	0.072***	0.623**	-0.240	-0.018
	(3.00)	(2.47)	(-1.35)	(-0.76)	(2.79)	(2.26)	(-1.32)	(-0.24)
Observations	11189	11189	11189	11189	11189	11189	11189	11189
Adjusted R^2		-1.020	-0.383	-0.282		-0.435	-0.389	-0.406
F-Stat	10.98				11.76			
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A8

Instrumental Variable Analysis Controlling for County-Level Economic and Financial Status

This table reports the results from instrumental variable (IV) regressions controlling for county-level economic and financial characteristics. The control variables include county-level personal income per capita (in thousands of dollars), population (in millions), the share of personal income derived from farming, total deposits in FDIC-approved banks (in billions of dollars), and total SBA loan volume (in billions of dollars). Two instrumental variables are employed. *EnforceExposure (Frequency)* is defined as the number of air-related enforcement actions targeting all emission sources in a given county-year, divided by the total number of power plants in that county-year. *EnforceExposure (Penalty)* is defined as the total monetary penalties associated with such enforcement actions, divided by the number of power plants in the county-year. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: EnforceExposure (Frequency)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)
$\widehat{Post \times Treated}$		-9.790***	-2.816**	-1.335**
		(-2.68)	(-2.08)	(-2.12)
Post × EnforceExposure (Frequency)	0.151***			
	(3.36)			
Personal Income	-0.002	-0.088***	-0.025**	-0.014**
	(-1.41)	(-4.12)	(-2.50)	(-2.40)
Population	-0.277	-4.433	-4.939***	-1.847***
	(-0.87)	(-1.29)	(-3.85)	(-3.06)
Percent Farm Income	-1.427	-0.787	0.004	2.429
	(-1.43)	(-0.08)	(0.00)	(0.96)
Total Bank Deposits	0.148	14.947*	1.459	0.996
	(0.13)	(1.88)	(0.38)	(0.52)
Total SBA Loans	-0.027	-2.795	2.057*	1.113
	(-0.10)	(-1.18)	(1.81)	(1.40)
Observations	11103	11103	11103	11103
Adjusted R^2		-1.192	-0.382	-0.298
F-Stat	11.31			
Cohort × Year FE	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes

Table A8 - Continued
Instrumental Variable Analysis Controlling for County-Level Economic and Financial Status

	Panel B: EnforceExposure (Penalty)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)
$\widehat{Post \times Treated}$		-4.846*	-3.102**	-1.833***
		(-1.91)	(-2.13)	(-2.82)
Post × EnforceExposure (Penalty)	0.010***			
	(3.44)			
Personal Income	-0.003**	-0.072***	-0.026***	-0.016***
	(-2.03)	(-4.53)	(-2.64)	(-2.65)
Population	-0.213	-3.646	-4.984***	-1.926***
	(-0.67)	(-1.57)	(-3.73)	(-2.77)
Percent Farm Income	-1.437	6.028	-0.390	1.742
	(-1.45)	(0.99)	(-0.11)	(0.66)
Total Bank Deposits	0.378	12.149**	1.621	1.278
	(0.30)	(2.58)	(0.39)	(0.57)
Total SBA Loans	-0.074	-2.542	2.043*	1.087
	(-0.27)	(-1.64)	(1.74)	(1.30)
Observations	11103	11103	11103	11103
Adjusted R^2		-0.414	-0.438	-0.443
F-Stat	11.86			
Cohort × Year FE	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes

Table A9
Toxic Emissions and Environmental Violations

This table examines the impact of environmental violations on toxic emissions. Data on toxic emissions are obtained from the EPA's Toxics Release Inventory (TRI) Program for the period 2001-2020. Using a stacked Difference-in-Differences (DiD) approach, we analyze how toxic air emissions—categorized as fugitive emissions (i.e., releases to air that do not occur through a confined air stream), stack emissions (i.e., releases through confined air streams such as stacks, ducts, or pipes), and total toxic emissions—change following environmental enforcement actions. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed using untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the cohort-firm level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	ln(Fugitive Air)	ln(Stack Air)	ln(Toral Air)
	(1)	(2)	(3)
Post × Treated	-0.098**	-0.163***	-0.174***
	(-2.51)	(-4.28)	(-4.78)
Observations	4782959	4782959	4782959
Adjusted R^2	0.847	0.887	0.888
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

Table A10
Lobbying Activities and Environmental Violations

This table examines how lobbying activities influence the effect of environmental violations on pollution emissions. The sample is restricted to utility firms that report any lobbying expenditures during the sample period. For this analysis, the sample is divided into two subsamples based on whether the utility firm engaged in lobbying activities in the year of the enforcement action. The Treated indicator equals 1 if the plant is in environmental violation, and 0 otherwise. The Treated indicator equals 1 if the plant received an environmental enforcement action by the EPA, and 0 otherwise. The Post indicator equals 1 for observations after the first enforcement action. Each cohort includes one treated plant and a set of geographically matched control plants that did not receive any enforcement action during the sample period. The control group is constructed usin untreated plants operating within a 60-mile radius. All regressions include cohort by year and cohort by plant fixed effects. t-statistics are reported in parentheses, and standard errors are clustered at the plant-cohort level. Variable definitions are provided in Appendix Table A1. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	ln(CO2)		ln(SO2)		ln(NOx)	
	Not Lobby	Lobby	Not Lobby	Lobby	Not Lobby	Lobby
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Treated	-1.814**	-0.458*	-1.236***	-0.815	-0.924***	-0.310
	(-2.55)	(-1.77)	(-3.67)	(-1.66)	(-3.56)	(-1.18)
Difference (Lobby - Not Lobby)	1.356*		0.420		0.614*	
Observations	1988	650	1988	650	1988	650
Adjusted R^2	0.831	0.871	0.902	0.909	0.885	0.930
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes

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ECGI is an international non-profit membership organisation that provides a platform for debate and dialogue among academics, policymakers, and business leaders, with a focus on major corporate governance, ESG, and stewardship issues.

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