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Environmental Violations in the Power Sector: Accountability and Community Welfare

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Abstract

This study examines how U.S. power sector firms respond to environmental regulation violations, focusing on facilities flagged by the EPA for non-compliance. In response, these plants implement various strategies to reduce air pollution and prevent future violations, including cutting electricity generation, improving fuel quality, reducing coal use, installing scrubbers, enhancing pollution controls, and investing in energy-efficient generators. Organizational efficiencies and government subsidies further strengthen these efforts. While these actions aid environmental recovery, the costs of compliance are often passed on to local communities through higher electricity prices, raising concerns about social equity. Following a violation, firms generally experience increases in assets, capital expenditures, debt, revenues, and electricity prices, yet operating income remains unaffected. Our findings highlight that while market competition and government subsidies can help alleviate some of the financial burden on consumers, these subsidies often fall short in promoting the long-term investments in advanced technologies necessary for sustained environmental progress.

Keywords: Environmental Violations, Stakeholder Theory, Electricity Prices, Community Welfare

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

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Abstract

This study examines how U.S. power sector firms respond to environmental regulation violations, focusing on facilities flagged by the EPA for non-compliance. In response, these plants implement various strategies to reduce air pollution and prevent future violations, including cutting electricity generation, improving fuel quality, reducing coal use, installing scrubbers, enhancing pollution controls, and investing in energy-efficient generators. Organizational efficiencies and government subsidies further strengthen these efforts. While these actions aid environmental recovery, the costs of compliance are often passed on to local communities through higher electricity prices, raising concerns about social equity. Following a violation, firms generally experience increases in assets, capital expenditures, debt, revenues, and electricity prices, yet operating income remains unaffected. Our findings highlight that while market competition and government subsidies can help alleviate some of the financial burden on consumers, these subsidies often fall short in promoting the long-term investments in advanced technologies necessary for sustained environmental progress.

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Introduction

Firms have a moral obligation to respect the public and the environment, considering their broader impact and ensuring their operations contribute positively and sustainably (Freeman, 1984; DesJardins, 1998). However, many fall short, engaging in unethical practices that compromise their integrity (Goodstein and Butterfield, 2010). Environmental violations not only result in penalties and enforcement actions but also jeopardize public health and ecosystems, raising serious concerns about corporate behavior (Flannery and May, 2000; Xu et al., 2012). A pivotal question in business ethics concerns how violators fulfill their moral responsibilities after such misconduct. Do they implement systemic changes within their organizations to prevent future unethical actions? While prior research suggests that companies use various strategies to restore their reputations and address accountability, the extent to which firms ensure enduring adherence to ethical standards and the long-term economic and societal impacts of these actions remain largely unexplored. This paper, therefore, examines how environmental violators in one of the most polluting sectors in the U.S.—the power industry—address their accountability for ecological breaches and manage the financial burden of compliance. Our analysis highlights the significant economic and social implications of these activities.

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

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

billion to align with regulations (EPA, 2022b). Depending on the severity of violations, affected facilities may face federal or state/local financial penalties, be required to implement 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, 2005).

We posit that, following violations, firms adjust their operational practices to comply with environmental regulations. These firms incur financial penalties and actively work to reduce harmful emissions, thereby minimizing their ecological footprint. Prior studies (Lee and Xiao, 2018; Nadeem, 2021) suggest that governance structures influence firms' use of Supplemental Environmental Projects (SEPs) as restorative actions to demonstrate accountability. Unlike SEPs, which provide societal benefits outside core operations, our study focuses on how non-compliant firms adjust their operations to meet regulatory standards. Given the economic losses, reduced legitimacy, and market value declines associated with regulatory breaches (Karpoff et al., 2005), firms are motivated to comply and restore legitimacy post-violation.

Alternatively, there may be no significant improvements in corporate environmental performance following violations. Firms might implement only superficial changes to appear compliant without substantially reducing harmful emissions or minimizing their ecological footprint. Consequently, any adjustments are mainly symbolic and do not lead to meaningful environmental benefits or adherence to ethical standards. Prior studies suggest that penalties for environmental violations often lead to a further decline in firms' environmental performance (Bansal, 2005; Shevchenko, 2021; Stafford, 2002). Instead of motivating improvements, penalties may be seen as mere costs of doing business. Some studies show that companies responsible for violations increase transparency through disclosures (Patten, 1992), improve external communications (Cho, 2009), and share favorable environmental information (De Villiers and Van Stadden, 2011; Deegan and Rankin, 1996). However, these actions are often token gestures, lacking a genuine commitment to long-term societal benefits

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

(Cho, 2009). Thus, whether environmental transgressors demonstrate long-term accountability and commitment to adhering to environmental standards remains an empirical research question.

Our analysis explores the operations of power plants that violated EPA regulations between 2001 and 2020. We investigate their compliance actions, focusing on emissions of carbon dioxide (CO2), sulfur dioxide (SO2), and nitrogen oxides (NOx). Using nearby power plants as a control group in our stacked difference-in-differences (DiD) regression analysis, we find that violating plants significantly reduce their CO2, SO2, and NOx emissions. Emission intensities, measured as pollution emitted per unit of electricity generation, also significantly decline, indicating that the reductions in pollution are not solely attributable to decreased electricity production.

We analyze the strategies power plants voluntarily implement to address environmental damage, assessing whether they are short-term compliance measures or reflect a commitment to long-term sustainability and corporate responsibility. Our analysis yields several significant findings: (1) Electricity production decreases significantly following environmental violations. (2) Violating power plants reduce sulfur in fuel, with sulfur content—a key component of environmental impact and fuel quality—directly influencing SO2 emissions. (3) Non-compliant plants shift away from coal toward cleaner fuels like natural gas, reflecting a broader move toward environmentally friendly energy sources. (4) Violating facilities invest in various emissions-reduction measures, including enhancing scrubber use, adopting pollution abatement technologies, and installing new generators. Scrubbers and abatement technologies effectively lower emissions, while new generators improve environmental performance by adjusting the fuel mix. Overall, these findings indicate that environmental violators not only face monetary penalties but also implement significant strategic changes in operations, fuel utilization, and emission reduction technologies. These efforts, often involving substantial investment costs, reflect a commitment to sustainably and responsibly reducing their environmental footprint.

Next, we explore two mechanisms that drive firms' pollutant-mitigation actions after breaching environmental regulations: organizational structure and financial resources. Our analysis reveals that firms with multiple facilities often leverage economies of scale, especially when these facilities share similar fuel dependencies, to improve compliance across all plants. However, this effect weakens when compliance requires costly, capital-intensive measures. Additionally, while U.S. government subsidies can support short-term environmental improvements, they frequently lack the scale to spur significant, long-term investments in advanced technologies. These findings highlight the crucial roles that organizational structure and financial resources play in shaping a firm's environmental strategy.

While firms' strategies in response to environmental regulations—such as investing in new generators, adopting pollution control technologies, and shifting to cleaner, costlier fuels—are essential for upholding environmental responsibility, they raise an ethical question: who should bear the financial burden 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 increase in total assets reflects higher capital investments, while the rise in long-term debt indicates greater reliance on external financing. On average, production expenses grow by $139 million, driven primarily by higher fuel costs and additional operating and maintenance expenditures, which make up the main component of total expenses. Despite these increased costs, operating revenues also rise by $161 million, largely offsetting the expenses and leaving operating income unchanged. Notably, the rise in revenues is largely attributed to higher electricity prices, as firms shift compliance costs onto consumers. This effect is especially pronounced for firms with limited access to subsidies, operating in regulated markets with low competition, or located in regions with fewer independent power producers. Although these strategies help reduce environmental impact, passing the costs onto communities raises concerns about social welfare, underscoring the ethical challenge of equitably distributing the burden of compliance.

Our baseline results are based on a quasi-natural experiment involving facilities that receive first-time environmental violations. However, time-varying plant characteristics and exposure to EPA enforcement actions could influence our findings. To address potential endogeneity, we use propensity score matching and instrumental variable (IV) analysis. Our instruments include the total number of air enforcement actions in the county from power and manufacturing plants, adjusted by the number of power plants or their share of the county's total generation capacity. Our core findings remain robust and materially unaffected by these tests, and they also hold across control groups formed based on various factors such as nameplate capacity, fuel mix similarity, generator age, and the presence or absence of coal- or oil-fired generators.

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 a complex landscape shaped by historical evolution, resource availability, technological advancements, and regulatory shifts. Traditionally, electric utilities operated as regulated, vertically integrated monopolies that controlled energy delivery. However, in the 1990s, many states began deregulating the sector to foster competition and reduce costs. This restructuring led utilities to divest their generating assets, giving rise to independent energy suppliers, while utilities retained control over transmission and distribution, which remain regulated. Additionally, the creation of Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs) helped oversee transmission systems and ensure fair market access. Today, about two-thirds of U.S. electricity demand is met by regions governed by ISOs and RTOs, while vertically integrated utilities supply the remaining third. In deregulated markets, utility firms and independent producers compete, shaping their strategies based on competition and production costs. These strategies often include adjusting fuel mixes, retrofitting generators, or adopting pollution-reduction 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 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 duty is to maximize shareholder value through profit generation (Friedman, 2007), a view that has significantly influenced corporate strategies and governance (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 for integrating stakeholder

[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.

interests into decision-making for long-term success and social responsibility (Harrison et al., 2015). Recent studies show that companies adopting stakeholder-focused ethics often achieve sustainable success and foster innovation (Eccles et al., 2017; Freudenreich et al., 2020). 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, making 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 pollution 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; Eccles et al., 2017). 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 implement only short-term, cost-effective measures rather than comprehensive solutions to address pollution issues.

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

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). Furthermore, decentralized companies may lack the motivation to pursue costly initiatives, whereas centralized organizations with strong leadership are typically better positioned to make significant sustainability investments (Eccles et al., 2017). Therefore, the following hypothesis arises:

H3: The availability of financial resources and the organizational structure of a company facilitate effective remediation following breaches of environmental regulations.

The EPA's efforts to reduce emissions are essential for safeguarding public health and protecting the environment. However, complying with these regulations often leads to increased operational costs for electricity facilities, which are typically passed on to consumers in the form of higher prices (Linn et al., 2014). This cost-shifting disproportionately affects lower-income households, exacerbating social inequality, especially in vulnerable communities (Fowlie, 2010). While EPA regulations deliver substantial environmental and public health benefits, they also create economic challenges that can negatively impact social welfare, underscoring the complex trade-offs inherent in environmental policy enforcement. In light of these considerations, we test the following hypothesis:

H4: Utility firms that violate environmental regulations are likely to pass the costs of compliance onto consumers by increasing 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 with 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 is used 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 is 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 is 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 use a stacked DiD approach to assess the impact of environmental violations on violators' responses. 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 100-kilometer radius of the treated plants during the sample period. Due to the localized nature of the electricity market, factors such as environmental regulation stringency, 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.[5] We apply 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 non-compliant 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

[5] Figure A1 demonstrates the robustness of our main findings with respect to the 100-kilometer (KM) distance used to construct the control group. Repeating the baseline analyses with distances ranging from 20 to 200KM shows that the statistical and economic significance of the results remains largely unchanged.

(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) 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 34.3 thousand tons of CO2,[6] 12.56 tons of SO2, and 122.84 tons of NOx annually. In terms of emission intensity, power plants emit an average of 210.66 tons of CO2, 0.4 tons of SO2, and 0.56 tons of NOx per GWh of electricity generated. Operationally, the average plant generates more than 398 GWh of electricity annually, with 11.35 tons of sulfur used as heat input and an average sulfur content of 0.18 pounds per MMBTU. On average, plants source 70.5% of their electricity from gas and 21.3% from coal. Furthermore, power plants typically have 0.19 installed scrubbers, spend about $450,000 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% of this total. Annual capital expenditures represent 7.3% of assets. Operating revenue, production expenses, and operating income account for 39.6%, 20.7%, and 4.2% of total assets, respectively. The average electricity price is $64.63 per MWh.

[6] All values mentioned here are in raw form, whereas those reported in the table are in the log form. E.g., $\exp(10.443) - 1 = 34,302$.

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 the estimates from Eq. 1. In Panel A, Columns 1-3 show that pollution emissions at violating plants decrease by 38% for CO2, 45% for SO2, and 28% for NOx.[7] To determine whether these reductions are due to decreased electricity generation, Panel B examines the impact of environmental violations on emissions intensities (pollution emitted per unit of electricity generated). The results indicate a 12% decrease in CO2 intensity, albeit statistically insignificant. However, SO2 and NOx intensities significantly decline by 15% and 6%, respectively, following environmental violations. These findings reject hypothesis H1, which posits the ineffectiveness of environmental violations in reducing emissions, and suggest that the reductions in emissions are not merely a consequence of lower electricity production but also reflect violating plants' efforts to enhance compliance with environmental regulations.[8] Since reductions in electricity production could independently result from enforcement actions, we conduct the remainder of our analyses using raw pollution emission levels rather than emission intensities.

[7] $e^{-0.481} - 1 = -0.38$, $e^{-0.595} - 1 = -0.45$, and $e^{-0.335} - 1 = -0.28$.

[8] The observed emission reductions may result from strategically shifting electricity generation and emissions from violating plants to non-violating sibling plants within the same parent utility company (Bartram et al., 2022). To investigate this, we analyze the effect of enforcement actions on *Plant Share*, defined as a plant's electricity generation relative to the parent utility's total output. Table A3 of the Appendix shows no significant shifts in *Plant Share* post-violation. Furthermore, Table A2 reveals a significant decrease in the capacity factor (the ratio of actual electricity generation to maximum possible generation), suggesting that the production reduction is aimed at improving environmental performance.

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) show no consistent differences in pollution emissions between the treatment and control groups before violations. However, a gradual decline in CO2, SO2, and NOx emissions is observed after enforcement actions.

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 **3** 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 the 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.

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 environmental violations, but it risks market share loss if not paired with sustainable, long-term strategies. A more sustainable approach involves changing the fuel mix and using cleaner energy sources, such as natural gas instead of coal or petroleum. Table 4 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 to either a shift in the fuel mix, such as replacing coal with natural gas (which has negligible sulfur content), or improving the quality of coal used, like opting for Subbituminous over Bituminous coal. Moreover, the findings reveal a 2.7% decrease in coal dependency (12.5% 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 impacts operational costs. Untabulated results support this, showing a 16% increase in fuel expenses following environmental violations.

We then examine whether firms invest in pollution abatement technologies or adopt more eco-friendly electricity generators following environmental violations. Columns (6)-(8) highlight shifts in these investments. Scrubbers, often integrated into coal-fired generators to capture SO2 emissions, are a strategic choice for improving environmental performance.

Column 6 shows a 5.2% increase in scrubber usage after violations. Column 7 reveals a 19.8% rise in investments in abatement technologies, such as flue gas particulate collectors, scrubbers, continuous emissions monitoring equipment, and nitrogen oxide control devices, following EPA enforcement. Finally, we explore the installation of new generators, primarily gas turbines or combined cycle generators, which typically offer higher thermal efficiency and support fuel switching. Column 8 indicates a 3.1% increase in new generator installations at violating plants compared to non-violating counterparts. Overall, these findings support hypothesis H2a by showing that violators employ measures that extend beyond short-term fixes to curb emissions and improve environmental performance.

Factors Influencing Corporate Responses

Utility firms employ various emission mitigation strategies, influenced by factors such as 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.

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 significance of organizational structure in shaping utility firms' responses to environmental violations, we examine the internal spillover effects across affiliated establishments. Specifically, we assess whether the impact of violations and subsequent enforcement extends beyond the violating plants to improve the environmental performance of non-violating plants within the same network. Previous research has demonstrated how internal networks transmit shocks within firms (e.g., Duchin et al., 2017; Giroud and Mueller, 2019;

Bena et al., 2021). Excluding the violators and focusing on their non-violating counterparts, Table A3 in the Appendix, using a stacked DiD methodology, shows that pollution emissions decrease following violations. Non-violating plants adopt similar adaptive strategies, such as reducing production, improving fuel quality, increasing reliance on gas over coal, and integrating new generators. These actions reflect a broader strategic shift towards regulatory compliance across the violating firms' networks.

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 crucial 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 target the impact of state-level and local subsidies granted to utility and power generation firms, revealing how these critical financial resources influence their capacity to achieve environmental goals.

Panel A of Table **6** presents the main results for the subsamples of violating plants with above- and below-median access to government subsidies. The findings indicate that emission reductions are significantly greater among violators with higher access to subsidies, suggesting that government financial support not only facilitates compliance with environmental regulations but also enhances remediation efforts following environmental violations.

While pollution reduction efforts have yielded significant results, the effectiveness of subsidies in promoting long-term solutions remains uncertain. Critics argue that U.S. government environmental subsidies, though beneficial in encouraging sustainable practices, are often too modest to drive substantial change, particularly for smaller-scale company actions. The limited size of these subsidies typically leads firms to focus on less impactful, cost-effective measures rather than investing in comprehensive environmental strategies. Smaller firms, or those with tighter budgets, are especially likely to prioritize low-cost initiatives, such as incremental energy efficiency improvements, over capital-intensive projects like advanced pollution control technologies or transitioning to renewable energy sources (Borenstein, 2012). Panel B examines how access to government subsidies influences violators' responses to environmental violations. The results in columns (1)-(10) indicate that reductions in electricity generation, improvements in fuel quality, and increased reliance on gas over coal are more common among violating plants in areas with higher subsidies. However, these subsidies do not drive the adoption of capital-intensive strategies such as investments in abatement technologies or new generators. In summary, while subsidies can facilitate short-term environmental improvements, they often fall short of promoting long-term, transformative investments. Consistent with hypothesis H3, these findings suggest that availability of financial resources in the form of government subsidies facilitates remediation actions following environmental violations.

Financial Consequences

So far, we have thoroughly analyzed utility companies' strategic adaptations following environmental regulation violations. These actions have led to significant changes, including 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

Leveraging the financial data disclosed by investor-owned utilities in FERC Form 1, we perform the following regression analysis at the parent utility firm level:

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

where Financial Indicator$_{p,t,c}$ represents a financial outcome variable of a 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 apply a natural logarithm transformation to 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 firm with its closest controls into cohorts. To account for temporal trends and firm-specific characteristics within each cohort, we introduce cohort-specific fixed effects for parent utility firms ($\lambda_{p,c}$) and year ($\omega_{t,c}$). Standard errors are clustered at the cohort-firm level. Table 7 presents the results.

The table highlights several key findings consistent with our earlier results. Firms with non-compliant establishments show significant increases in total assets, capital expenditures, long-term debt, operating revenue, and production expenses. example, the 6.2% (or $221 million) rise in total assets (column (1)) aligns with our previous results in Table 4, suggesting that violating firms are investing in new generators and additional scrubbers. Similarly, these firms experience substantial increases in capital expenditures (column (2)) and long-term debt (column (3)) following environmental violations and enforcement actions, with average increases of $68 million and $93 million, respectively. While EPA violations lead to concurrent increases in operating revenue (column (4)) and production expenses (column (5)), these tend to offset each other, leaving operating income largely unaffected (column (6)). Specifically, operating revenues rise by approximately $161 million, while production expenses, comprising the main component of total expenses,[9] increase by $139 million post-violation. The lack of a significant impact on operating income suggests that firms pass the

[9]Untabulated results show that total expense increase by $167 million post-violations.

additional compliance costs on to consumers through higher electricity prices. This is further supported by column (7), which shows a 4.8% increase in the average electricity price, or $3.1 per MWh, post-violation.

Overall, our results support hypothesis H4, indicating that plants effectively reduce pollution levels following environmental violations without experiencing negative financial impacts. This outcome is achieved by passing the costs of compliance onto consumers through higher electricity prices.

Electricity Prices

The ability of utility firms to pass costs to consumers depends on regulatory status, financial resources, and market competition. Since the FERC Form 1 database in Table 7 only includes price data for investor-owned utilities, we address this limitation by using electricity price data from Schedules 6 and 7 of the EIA-923 and EIA-861, which cover both investor- and non-investor-owned utilities. We calculate electricity prices as a weighted average of wholesale and retail prices. Using this data, we re-examine the impact of environmental violations on electricity prices in column (1) of Table 8, showing a 6.3% price increase post-violation, consistent with Table 7. Next, we analyze the role of government subsidies, splitting the sample by subsidy availability in columns (2) and (3). The results indicate that price increases are more pronounced among firms with limited access to subsidies, underscoring the importance of government support in reducing the cost burden on consumers.

We further examine how market competition influences utility firms' ability to pass remediation costs to consumers, using three proxies for competition. We expect lower competition and greater market power to enable firms to raise prices after violations. First, utilities in regulated markets, assured of a reasonable return on investment, can more easily pass pollution mitigation costs onto electricity prices. In contrast, non-regulated utilities operating in competitive markets have limited ability to pass post-violation costs to customers. The results in columns (4) and (5) show that price increases primarily occur among regulated utilities. Second, we use the state-level Herfindahl–Hirschman Index (HHI) as a proxy for market competition. As shown in columns (6) and (7), the findings indicate that prices increase and costs are passed to consumers in areas with lower competition (higher HHI). Lastly, we use the proportion of state electricity generated by Independent Power Producers (IPPs) as a third competition proxy. Lastly, we use the proportion of state electricity generated by Independent Power Producers (IPPs) as a third proxy for competition. IPPs are independent entities outside regulated utilities focused on generating profit for shareholders. Columns (8) and (9) reveal that electricity prices increase by 15.9% in areas with low IPP share but show no significant change in more competitive regions with higher IPP presence.

In summary, the findings reveal that electricity market competition and utility market power play a critical role in enabling firms to shift the financial burden of adopting cleaner production practices onto consumers. This dynamic of cost pass-through underscores how utilities leverage their market position to protect profits while complying with environmental regulations.

Additional Tests

There may be concerns about the suitability of using geography to construct the control group, as well as potential issues with time-varying characteristics or omitted variables that could simultaneously influence plants' environmental violations and their emissions and operational strategies. This section addresses these concerns by applying instrumental variable analysis and using alternative methods, such as propensity score matching, to refine the selection of the control group.

Propensity Score Matching

To ensure the robustness of our results, we relax the 100-kilometer radius condition and use propensity score matching (PSM) to construct the control group. This method allows us to match non-violating plants with a similar likelihood of violating environmental regulations as the violating ones. Propensity scores are calculated using plant size, age, coal share, regulatory status, and capacity factor. Each violating plant is matched with three non-violating plants based on the closest propensity scores. Panel A of Table 9 shows that the main findings on emission and electricity generation reductions remain consistent after applying PSM to address potential endogeneity.

Instrumental Variable Analysis

We use instrumental variable analysis to strengthen our results and address endogeneity concerns. A valid instrument must correlate with the likelihood of violation and enforcement (demonstrating relevance) without directly affecting plant-specific outcomes (satisfying the exclusion restriction). We measure plant exposure to environmental regulations by analyzing the frequency of air-related violations within each county. We consider many emission sources, including manufacturing, oil and gas, refineries, and chemical, metal, and mineral production facilities, rather than focusing solely on the power sector. This county-level metric gauges exposure to environmental regulations. Our test limits the control group to power plants within a 100-kilometer radius but located in counties different from the violators. The frequency of violations and subsequent enforcement actions within each county serves as a proxy for a plant's exposure to regulations and the likelihood of being targeted by the EPA. For plant i in county j at time t, we count the number of enforcement actions targeting other emission sources in the same county-year ($\#Enforcement_{-i,j,t}$). We adjust this count with two weighting factors: the number of plants in each county and their relative sizes. One weighting factor is the proportion of a plant's nameplate capacity relative to the county's total nameplate capacity. The instrument for power plant i at time t in county j is computed as follows:

$$EnforceExposure_{1,i,j,t}\ (Size - Weighted) = \frac{NamePlate_{i,j,t}}{Nameplate_{j,t}} * \#Enforcement_{-i,j,t}.$$

For the second instrument, we assign equal weight to all plants within each county and calculate it as follows.

$$EnforceExposure_{2,i,j,t}\ (Equally - Weighted) = \frac{1}{\#Plants_{j,t}} * \#Enforcement_{-i,j,t}.$$

Our identifying assumption is that a higher frequency of enforcement actions in a specific geographic area increases the likelihood of power plants being targeted by the EPA. However, it is unlikely that enforcement actions directed at other emission sources within a county, particularly those in different industries, would affect power plants' emissions and operational decisions, except through their exposure to environmental enforcement.

Before running the 2SLS regressions, we assess our instruments' relevance to the likelihood of a plant receiving enforcement actions. In columns (1) and (2) of Table A4, we examine the relationship between ($Enforcement$ (a dummy variable equal to 1 if a plant is targeted within a year) and our instruments across all U.S. power plants with available emission data. A one-standard-deviation increase in $EnforceExposure_1$ and $EnforceExposure_2$ raises the likelihood of enforcement by 2.5% and 2.7%, respectively. Columns (3) and (4) repeat the analysis in our primary sample, where violating plants are matched with control plants within a 100-kilometer radius. Here, the instruments increase the likelihood of enforcement by 1.4% and 2%, respectively. These results confirm a strong correlation between our instruments and the possibility of enforcement.

Using the two instruments, we formally run the following 2SLS regressions:

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

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

Eq. 4 shows the first-stage regression, where $EnforceExposure_{i,j,t_0}$ is used as an instrument for the endogenous treatment variable of plant i in county j at the time of violation t_0.

Eq. 5 presents the second-stage regression, where we regress plant i's outcomes on the fitted values from the first stage. Panels B and C report the 2SLS results. Column (1) in both panels shows the first-stage estimates, with Cragg-Donald F-statistics of 62.208 and 131.459, strongly rejecting weak instruments. Columns (2)-(4) demonstrate that reductions in CO2, SO2, and NOx emissions from the baseline analysis are not driven by endogeneity bias. However, no significant impact on electricity generation is found. The instrumental variable analysis also shows that emission reductions are even more pronounced than initially observed, further supporting the causal interpretation of our findings.

Control Group Selection Method

Previously, we demonstrated the robustness of our baseline stacked DiD analysis using control groups based on propensity score matching. In Table **10**, we extend this by exploring alternative matching methods. In Panel A, we construct control groups by matching each violating plant with three controls of similar size, based on nameplate capacity. Panel B uses fuel mix similarity, measured by the cosine similarity of fuel inputs, to match control plants. Panel C matches violating plants with non-violating ones of similar age, and Panel D matches based on generation technology (e.g., coal- or oil-based steam generators), which tend to be more polluting and have a higher propensity for violations. The results across Panels A-D are consistent with our main findings, confirming the robustness of our methodology regardless of the control group selection method.

Conclusion

The U.S. electricity sector has long been a major contributor to environmental pollution, largely due to its heavy reliance on fossil fuels like coal and natural gas. Despite stricter regulations and a gradual shift toward cleaner energy, gaps remain in understanding how utilities respond to environmental violations, the financial costs of compliance, and the impact on consumers. Our research reveals that when power plants violate environmental regulations, they reduce pollution by cutting electricity generation, upgrading equipment, installing advanced control technologies, and transitioning away from coal—often supported by economies of scale and government subsidies. These violating utilities experience increases in assets, capital expenditures, long-term debt, and operating revenue, while production costs rise. However, operating income remains steady, with the financial burden of compliance ultimately passed on to consumers through higher electricity prices, raising serious social welfare concerns.

Our findings highlight the urgent need for policies that enforce environmental protection while promoting economic and social equity. Although regulations play a crucial role in reducing pollution and advancing cleaner energy, consumers—especially the most vulnerable—should not bear the brunt of these costs. Policymakers must ensure fairness and transparency to prevent companies from shifting compliance costs onto the public. A balanced approach is essential, one that fosters sustainability while protecting consumers. Strong oversight and accountability are key to ensuring utilities share the costs of transitioning to cleaner energy. At the same time, targeted incentives, such as subsidies, can support utilities in achieving environmental goals without making electricity unaffordable. The success of these policies depends on balancing environmental objectives with affordability and access, ensuring a cleaner future that benefits everyone without disproportionately burdening those least able to afford it.

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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.

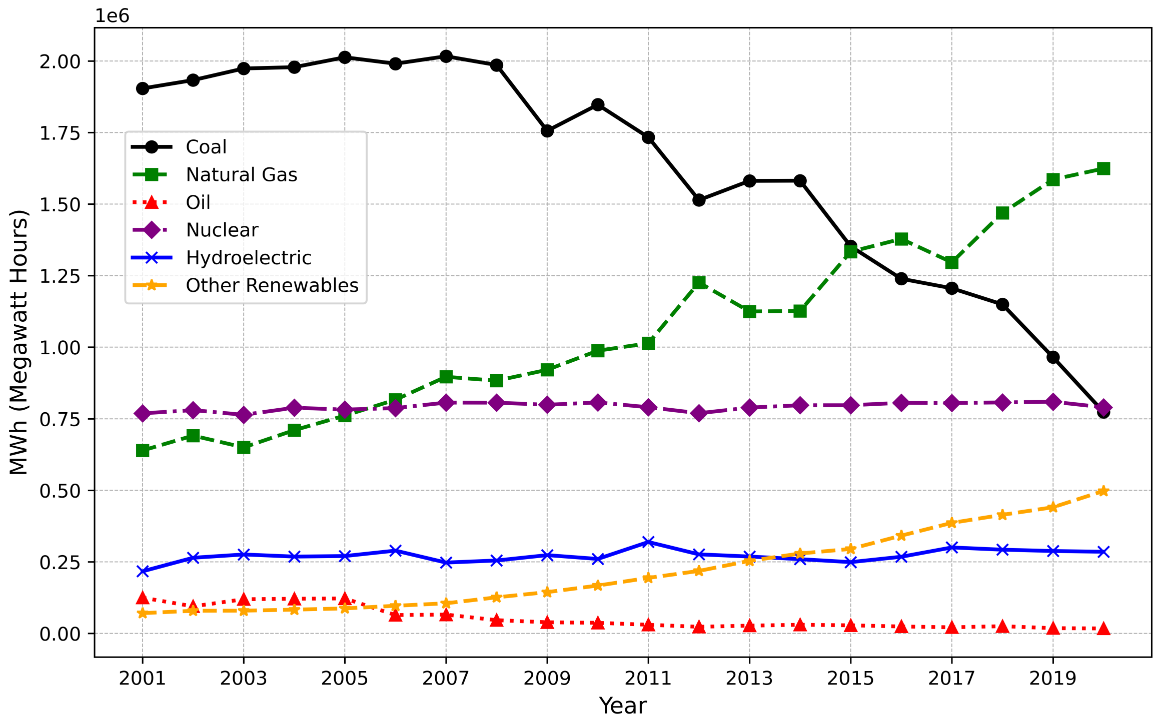


Figure 2
The Geographical Dispersion of U.S. Power Plants in 2020

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

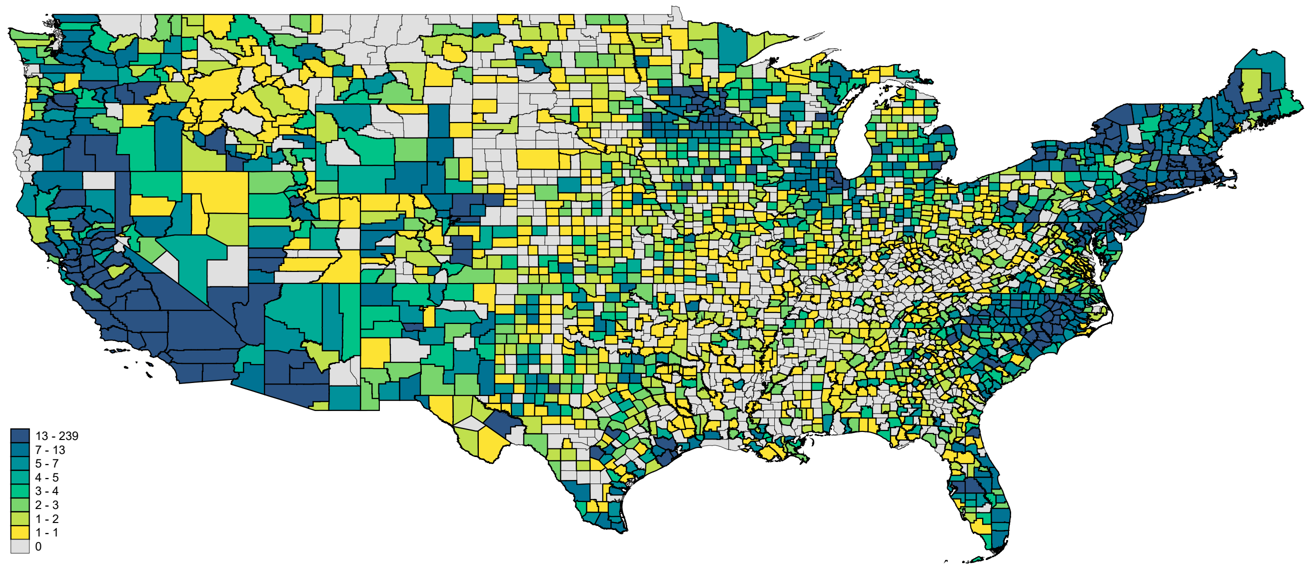
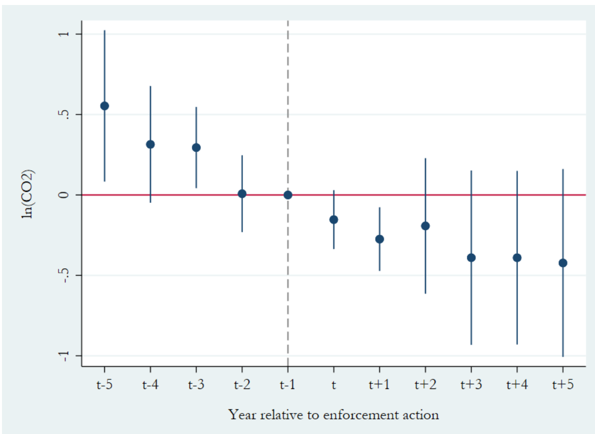
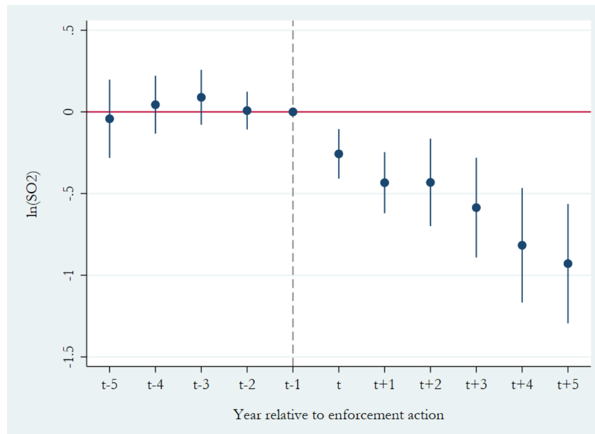


Figure 3
Dynamic Effects of Environmental Violations on Air Pollution

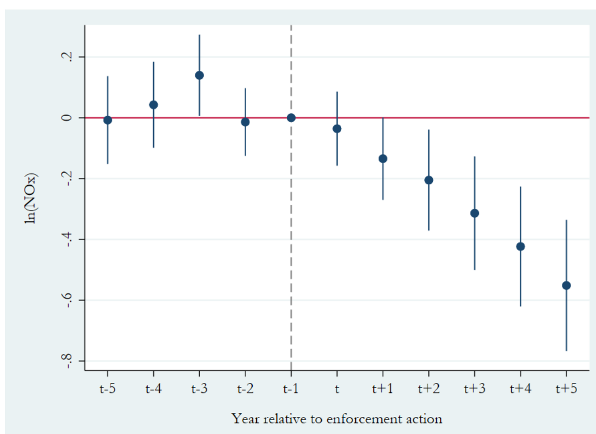
The figure illustrates the dynamic impacts of environmental violations on power plants' emissions and electricity generation. Specifically, Figures (a)-(c) depict the changes in CO_2, SO_2, and NO_x emissions, respectively. Each subfigure presents estimated coefficients and their 95% confidence intervals, 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. The appendix details the definition of all the variables. 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)	12820	10.443	5.19	9.639	12.305	13.936
ln(SO2)	12820	2.607	3.31	0.148	1.142	3.037
ln(NOx)	12820	4.819	2.15	3.391	4.682	6.084
ln(CO2/GWh)	12820	5.355	2.55	6.060	6.397	6.700
ln(SO2/GWh)	12820	0.338	0.71	0.002	0.003	0.107
ln(NOx/GWh)	12820	0.445	0.50	0.086	0.286	0.660
Corporate Responses						
ln(GWh)	12820	5.989	2.02	4.717	6.093	7.617
ln(Sulfur)	12820	2.514	3.77	0.000	0.000	4.672
ln(Sulfur Intensity)	12820	0.166	0.33	0.000	0.000	0.146
Coal Share	12793	0.213	0.40	0.000	0.000	0.000
Gas Share	12793	0.705	0.43	0.037	0.999	1.000
ln(Scrubbers)	8060	0.175	0.42	0.000	0.000	0.000
ln($Abatement)	5322	0.373	1.04	0.000	0.000	0.000
ln(New Generators)	12820	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
ln(Electricity Price)	1868	4.184	0.37	3.967	4.228	4.449

Table 2
Power Plant Emissions Post-Environmental Violations

This table reports the emission level and intensity of violating power plants post-violation using stacked DiD regressions. Panel A and B show post-violation impacts, respectively, on different types of emissions and emissions intensity. Treated dummy equals one if the plant is in an environmental violation and zero otherwise. The control group consists of plants within a 100-kilometer radius from the treated plants; the control plants have neither received any enforcement action themselves nor experienced any in one of their siblings. Post dummy equals one after the first enforcement offense. Each cohort consists of one treated plant and is associated control plants surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. 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.

	Panel A: Emission Level		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.481**	-0.595***	-0.335***
	(-2.39)	(-4.30)	(-4.29)
Observations	12820	12820	12820
Adjusted R^2	0.854	0.902	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	-0.132	-0.163***	-0.057**
	(-1.27)	(-4.19)	(-2.19)
Observations	12820	12820	12820
Adjusted R^2	0.824	0.852	0.840
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

Table 3
Enforcement Agency for Environmental Violations

This table presents the differential impact of environmental violations based on the enforcing agency. Odd-numbered columns represent enforcement actions handled federally by the EPA and reported in ICIS-FE&C, while even-numbered columns include cases managed by state agencies and reported in ICIS-Air. Treated dummy is set to one if a plant receives an enforcement action and zero otherwise. The control group consists of plants within a 100-kilometer radius of the treated ones that have neither received enforcement actions themselves nor experienced any in their sibling plants. Post dummy is set to one after the first enforcement action. Each cohort includes one treated plant and its surrounding control plants. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. t-statistics are reported in parentheses. Standard errors are clustered at the plant-cohort level. Superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	ln(CO2)		ln(SO2)		ln(NOx)	
	State	Federal	State	Federal	State	Federal
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Treated	-0.355	-1.060*	-0.359**	-1.678***	-0.173**	-1.076***
	(-1.64)	(-1.95)	(-2.56)	(-4.27)	(-2.24)	(-4.96)
Difference (Federal - State)	-0.705		-1.319***		-0.903***	
Observations	11182	1638	11182	1638	11182	1638
Adjusted R^2	0.853	0.862	0.898	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
Corporate Responses to Environmental Violations

This table reports the results from stacked DiD regressions that examine post-environmental violation corporate responses in operational practices. Column (1) shows the impact of violation on the level of electricity generation. Columns (2) and (3) present the post-enforcement impact on the sulfur content and intensity while Columns (4) and (5) show that on the share of different types of fuels employed. Columns (6)-(8) report the post-violation effect on a plant's installation of scrubbers, dollar amount spent on pollution abatement, and purchase of new generators. Treated dummy equals one if the plant is in an environmental violation and zero otherwise. The control group consists of plants within a 100-kilometer radius from the treated plants; the control plants have neither received any enforcement action themselves nor experienced any in one of their siblings. Post dummy equals one after the first enforcement offense. Each cohort consists of one treated plant and is associated control plants surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. 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.

	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	-0.256***	-0.356***	-0.018*	-0.027**	0.034***	0.051**	0.181*	0.031***
	(-3.19)	(-3.54)	(-1.80)	(-2.55)	(2.93)	(2.26)	(1.81)	(2.70)
Observations	12820	12820	12820	12791	12791	7905	5037	12820
Adjusted R^2	0.906	0.959	0.959	0.983	0.968	0.867	0.540	0.076
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 Firms with Violating Plants

This table shows the results of how the organizational structure of firms with violating plants influences their responses following the plants' environmental breaches. Panel A presents the subsample results for single-plant and multi-plant operators. Panel B and C report the results for the subsample of multi-plant utility firms, which are further grouped into those with an above-median (High) and below-median (Low) coal share in their sibling plants. Treated dummy equals one if the plant is in an environmental violation and zero otherwise. The control group consists of plants within a 100-kilometer radius from the treated plants; the control plants have neither received any enforcement action themselves nor experienced any in one of their siblings. Post dummy equals one after the first enforcement offense. Each cohort consists of one treated plant and is associated control plants surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. 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.

	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	-0.268	-0.628**	0.065	-1.052***	0.111	-0.644***
	(-0.82)	(-2.48)	(0.35)	(-5.63)	(1.24)	(-6.00)
Difference (Multi - Single)	-0.359		-1.117***		-0.755***	
Observations	5339	7481	5339	7481	5339	7481
Adjusted R^2	0.838	0.866	0.879	0.915	0.914	0.920
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	-0.846**	-0.503	-0.598***	-1.311***	-0.256	-0.864***
	(-2.30)	(-1.47)	(-2.72)	(-4.90)	(-1.48)	(-6.62)
Difference (High - Low)	0.343		-0.713**		-0.608***	
Observations	3764	3717	3764	3717	3764	3717
Adjusted R^2	0.847	0.894	0.897	0.912	0.905	0.925
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 5 - Continued
Organizational Structure of Firms with Violating Plants

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	-0.108	-0.677***	-0.105	-0.865***	-0.017	-0.048**	-0.032**	-0.065**
	(-0.78)	(-4.37)	(-0.59)	(-4.02)	(-0.76)	(-2.20)	(-1.99)	(-2.57)
Difference (High - Low)	-0.568***		-0.760***		-0.032		-0.034	
Observations	3764	3717	3764	3717	3764	3717	3758	3709
Adjusted R^2	0.919	0.883	0.913	0.971	0.938	0.946	0.983	0.977
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	0.048**	0.065***	0.050*	0.043	0.138	0.275	0.078***	0.043***
	(1.97)	(2.65)	(1.70)	(0.87)	(0.57)	(1.44)	(3.03)	(3.31)
Difference (High - Low)	0.016		-0.007		0.137		-0.036	
Observations	3758	3709	2213	2108	1278	1624	3764	3717
Adjusted R^2	0.959	0.964	0.922	0.818	0.302	0.525	0.077	0.006
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 6
Access to Government Subsidies

This table reports how availability of government subsidies impacts utility firms response to environmental violations. We divide the sample into two groups based on the level of local subsidies allocated to utility firms in each state. Odd columns include treated plants with below-median levels of state subsidies while even columns include above-median ones. Panel A studies the impact of subsidies on emissions while Panel B investigates the impact on corporate responses. Treated dummy equals one if the plant receives an enforcement action and zero otherwise. The control group consists of plants within 100 kilometers radius around the treated ones; the plants have neither received any enforcement action themselves nor experienced any in one of their siblings. Post dummy equals one after the first enforcement action. Each cohort consists of one treated plant and the control plants surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. t-statistics are reported in parentheses. Standard errors are clustered at the plant-cohort level. Superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Subsidy and Emissions					
	ln(CO2)		ln(SO2)		ln(NOx)	
	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Treated	0.209	-1.342***	-0.324**	-0.934***	-0.118	-0.606***
	(0.71)	(-5.97)	(-1.97)	(-4.13)	(-1.27)	(-4.89)
Difference (High - Low)	-1.550***		-0.610**		-0.489***	
Observations	7233	5587	7233	5587	7233	5587
Adjusted R^2	0.860	0.847	0.907	0.896	0.917	0.918
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 6 - Continued
Access to Government Subsidies

Panel B: Subsidy 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	-0.094	-0.459***	-0.011	-0.787***	-0.001	-0.040**	0.002	-0.063***
	(-1.11)	(-3.20)	(-0.15)	(-4.04)	(-0.08)	(-2.29)	(0.37)	(-2.90)
Difference (High - Low)	-0.365**		-0.776***		-0.039*		-0.065***	
Observations	7233	5587	7233	5587	7233	5587	7214	5577
Adjusted R^2	0.911	0.901	0.966	0.949	0.966	0.951	0.991	0.973
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	0.062**	0.332**	0.023	0.051***	0.007
	(0.87)	(2.88)	(1.32)	(1.98)	(2.16)	(0.19)	(2.93)	(0.48)
Difference (High - Low)	0.061**		0.020		-0.309		-0.044**	
Observations	7214	5577	4528	3377	2946	2091	7233	5587
Adjusted R^2	0.975	0.959	0.838	0.900	0.532	0.551	0.101	0.030
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 focuses on the impact of EPA enforcement actions on financial outcomes of parent utility firms for which we have financial data. Treated dummy equals one if the utility firm receives an enforcement action in one of its plants and zero otherwise. The control group consists of three utility firms located closest to targeted plants but have received no enforcement action in any of their plants. Post dummy equals one after the first enforcement action received by each utility firm. Each cohort consists of one treated utility and the control utilities operating surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. The t-statistics are reported in parentheses. Standard errors are clustered at the firm-cohort level. The superscripts ***, **, and * indicate statistical 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	ln(Electricity Price)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post × Treated	0.060**	0.019***	0.026***	0.045**	0.039**	0.002	0.047**
	(2.00)	(2.67)	(3.69)	(2.32)	(2.45)	(1.02)	(2.24)
Observations	1850	1842	1850	1850	1850	1850	1849
Adjusted R^2	0.977	0.273	0.781	0.727	0.748	0.667	0.904
Cohort × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort × Utility FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 8
Electricity Prices and Environmental Violations

This table shows the impact of EPA enforcement actions on utility-level electricity prices. While Column (1) shows the baseline impact, the rest of columns study how the impact varies across subsamples with different levels of access to local subsidies and electricity market competition. Column (2) and (3) divide utility firms into two subsample based on the level of state-level subsidies granted to utility firms. Column (4) and (5) divide sample into two groups based on regulatory status of targeted utility firms. Columns (6) and (7) use the state-level concentration of electricity generation as a measure of competition in the electricity market. Column (8) and (9) use the ratio of electricity generated by independent power producers (IPP) within each state as a proxy for electricity market competition. Treated dummy equals one if the utility firm receives an enforcement action in one of its plants and zero otherwise. The control group consists of three utility firms located closest to targeted plants but have received no enforcement action in any of their plants. Post dummy equals one after the first enforcement action received by each utility firm. Each cohort consists of one treated utility and the control utilities operating surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. The t-statistics are reported in parentheses. Standard errors are clustered at the firm-cohort level. The superscripts ***, **, and * indicate statistical 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 × Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 9
Propensity Score Matching and Instrumental Variable Analysis

This table reports the results based on propensity score matching (Panel A) and instrumental variable approach (Panels B and C). The two instrumental variables are equal- and size-weighted *Enforce-Exposure*. Treated dummy equals one if the utility firm receives an enforcement action in one of its plants and zero otherwise. The control group consists of three utility firms located closest to targeted plants but have received no enforcement action in any of their plants. Post dummy equals one after the first enforcement action received by each utility firm. Each cohort consists of one treated utility and the control utilities operating surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. The t-statistics are reported in parentheses. Standard errors are clustered at the firm-cohort level. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Propensity Score Matching		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.151	-0.321***	-0.223***
	(-0.91)	(-2.63)	(-3.30)
Observations	8688	8688	8688
Adjusted R^2	0.868	0.928	0.941
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

Table 9 - Continued
Propensity Score Matching and Instrumental Variable Analysis

	Panel B: EnforceExposure (Equally Weighted)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)
$\widehat{Post \times Treated}$		-8.547***	-3.044**	-1.256**
		(-2.72)	(-2.32)	(-2.20)
Post × EnforceExposure (Equally-Weighted)	0.155***			
	(3.56)			
Observations	11715	11715	11715	11715
Adjusted R^2		-0.896	-0.417	-0.269
Cohort × Year FE	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes

	Panel C: EnforceExposure (Size Weighted)			
	1st Stage	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)	(4)
$\widehat{Post \times Treated}$		-16.884**	-4.319**	-2.220**
		(-2.39)	(-2.07)	(-1.96)
Post × EnforceExposure (Size-Weighted)	0.055***			
	(2.62)			
Observations	11715	11715	11715	11715
Adjusted R^2		-3.104	-0.732	-0.573
Cohort × Year FE	Yes	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes	Yes

Table 10
Robustness Tests: The Choice of Control Group

This table reports the robustness of baseline finding to different control group choices. Panels A-D present results using control groups of power plants in the same state as the violating plants with the closest nameplate capacity, fuel mix similarity, age, and a coal/oil-fired steam generation. Treated dummy equals 1 if the plant receives an enforcement action and 0 otherwise. The Post dummy equals 1 after the first enforcement action. Each cohort consists of one treated plant and the control plants matched to it. All continuous variables are winsorized at the 1st and 99th percentiles. Table A1 definition of all the variables. t-statistics are reported in parentheses. Standard errors are clustered at the plant-cohort level. Superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: Control Group Based on Nameplate Capacity		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.468***	-0.513***	-0.382***
	(-2.69)	(-4.41)	(-5.54)
Observations	8251	8251	8251
Adjusted R^2	0.871	0.929	0.920
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

	Panel B: Control Group Based on Fuel Mix Similarity		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.349*	-0.482***	-0.366***
	(-1.93)	(-3.63)	(-5.35)
Observations	8190	8190	8190
Adjusted R^2	0.876	0.917	0.931
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

Table 10 - Continued
Robustness Tests: The Choice of Control Group

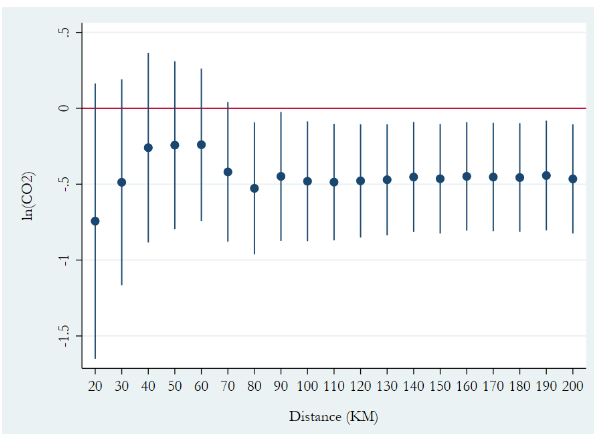
	Panel C: Control Group Based on Age		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.205	-0.343***	-0.315***
	(-1.34)	(-3.29)	(-5.11)
Observations	8260	8260	8260
Adjusted R^2	0.910	0.938	0.936
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes
	Panel D: Control Group Based on Coal-/Oil-fired Steam Generation		
	ln(CO2)	ln(SO2)	ln(NOx)
	(1)	(2)	(3)
Post × Treated	-0.437**	-0.306**	-0.153**
	(-2.16)	(-2.14)	(-2.01)
Observations	18866	18866	18866
Adjusted R^2	0.878	0.906	0.940
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

Appendix

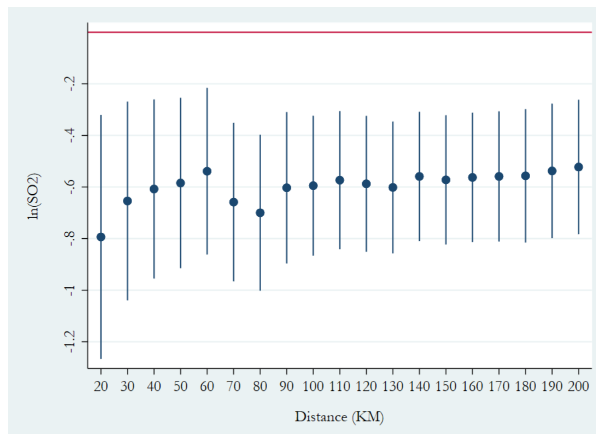
Figure A1

Robustness of Baseline Results to Geographical Distance of Control Group

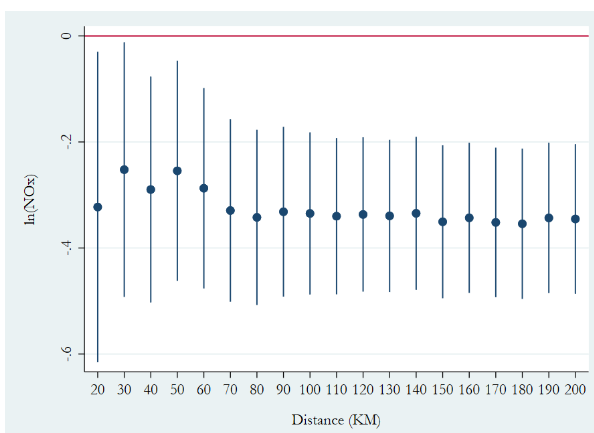
This figure depicts the robustness of baseline results to the choice of the geographical distance that is used to select the control group. Subfigures (a)-(c) show the robustness of results for CO2, SO2, NOx emissions, respectively. Each subfigure plots estimated coefficients and their 95% confidence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



(a) CO2 emissions



(b) SO2 emissions



(c) NOx emissions

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).
Federal Cases	Cases undertaken by EPA and reported in ICIS-FE&C database.
State Cases	Cases undertaken by state-level agencies and reported in ICIS-Air.
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 is only available for plants with steam-electric capacity of 10MW or more and this data is 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 is only available for plants with steam-electric capacity of 10MW or more and this data is 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).
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).
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).
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).
Regulated	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 (Equally-Weighted)	For each power plant, it is calculated as the number of air enforcement actions that other emission sources receive divided by the total number of operating power plants in each county-year.
EnforceExposure (Size-Weighted)	For each power plant, it is calculated as the number of air enforcement actions that all emission sources receive in the same county-year multiplied the share of plant's from county's generation capacity.

Table A2
Plant Share, Capacity Factor, and Environmental Violations

This table reports the effect of EPA enforcement on Plant Share and Capacity Factor of targeted power plants. Plant Share is defined as plant's electricity generation divided by the parent utility firm's generation. CapFactor is equal to the ratio of the electricity that is generated throughout the year to the maximum amount of the electricity that could be generated using 100% of capacity. The Treated dummy equals 1 if the plant receives an enforcement action and 0 otherwise. The control group consists of plants within 100 kilometers radius around the treated ones, but neither received any enforcement action themselves nor experienced any in one of their siblings. The Post dummy equal 1 after the first enforcement action. 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-cohort level. Superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Plant Share	CapFactor
	(1)	(2)
Post × Treated	-0.014	-0.043***
	(-0.95)	(-3.56)
Observations	12820	12820
Adjusted R^2	0.873	0.848
Cohort × Year FE	Yes	Yes
Cohort × Plant FE	Yes	Yes

Table A3
Response to Environmental Violations in Sibling Plants

This table reports the results of EPA enforcement actions on non-violating power plants that belong to the same parent as the violating ones. This test excludes plants that directly violated environmental regulations. Panel A shows the impact on pollution emissions. In Panel B, Column (1) shows the impact of violation on the level of electricity generation. Columns (2) and (3) present the post-enforcement impact on the sulfur content and intensity while Columns (4) and (5) show that on the share of different types of fuels employed. Columns (6)-(8) report the post-violation effect on a plant's installation of scrubbers, dollar amount spent on pollution abatement, and purchase of new generators. The Treated dummy equals one if one of plant siblings violate environmental regulation and zero otherwise. The control group consists of plants within 100 kilometers radius around the treated ones; the plants have neither received any enforcement action themselves nor experienced any in one of their siblings. The Post dummy equals one after a sibling receives its first EPA enforcement action. Each cohort consists of one treated plant and the control plants surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. The t-statistics are reported in parentheses. Standard errors are clustered at the plant-cohort level. The superscripts ***, **, and * indicate 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 A4
Validity of Instrumental Variables

This table tests the validity of two instruments, i.e., $EnforceExposure$ $(Equally - Weighted)$ and $EnforceExposure$ $(Size - Weighted)$, employed in the 2-stage least square (2SLS) regressions. For each power plant, $EnforceExposure$ $(Equally - Weighted)$ is defined as the number of air enforcement actions that other emission sources receive divided by the total number of operating power plants in each county-year. For each power plant, $EnforceExposure$ $(Size - Weighted)$ is the number of air enforcement actions that other emission sources receive in the same county-year multiplied the share of the plant's from total county capacity. In this table, we regress a binary indicator, *Enforcement*, which equals one if the plant receives an enforcement action in that year and zero 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 100KM radius around targeted ones. The control group consists of plants outside of the county but within 100 kilometers 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. The appendix details the definition of all the variables. t-statistics are reported in parentheses. Standard errors are clustered at the plant-cohort level. Superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)
EnforceExposure (Size-Weighted)	0.025***		0.014**	
	(4.85)		(2.15)	
EnforceExposure (Equally-Weighted)		0.027***		0.020**
		(4.01)		(2.22)
Observations	18955	18955	11715	11715
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 A5
Robustness to Violations' Penalty Size

This table reports the robustness of baseline finding to inclusion of enforcement actions with different penalty sizes. In Panel A and B, we include all enforcement actions with a total penalty greater than $0 and $10,000, respectively. The Treated dummy equals 1 if the plant receives an enforcement action and 0 otherwise. The control group consists of plants within 100 kilometers radius around the treated ones, but neither received any enforcement action themselves nor experienced any in one of their siblings. The Post dummy equal 1 after the first enforcement action. Each cohort consists of one treated plant and the control plants surrounding it. All continuous variables are winsorized at the 1st and 99th percentiles. The appendix details the definition of all the variables. t-statistics are reported in parentheses. Standard errors are clustered at the plant-cohort level. Superscripts ***, **, and * indicate 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	-0.334*	-0.467***	-0.224***
	(-1.86)	(-3.72)	(-3.27)
Observations	13953	13953	13953
Adjusted R^2	0.842	0.897	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	-0.418*	-0.610***	-0.395***
	(-1.87)	(-3.85)	(-4.61)
Observations	11664	11664	11664
Adjusted R^2	0.846	0.912	0.917
Cohort × Year FE	Yes	Yes	Yes
Cohort × Plant FE	Yes	Yes	Yes

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