Asset Reallocation under Cap-and-Trade: Evidence from the U.S. Power Sector

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Abstract

This paper examines how carbon pricing influences asset reallocation in the U.S. power sector. Carbon pricing alters the value of electricity generation assets, namely power plants, across both plants and firms. Using the staggered implementation of the Regional Greenhouse Gas Initiative and California's Cap-and-Trade Program from 2001 to 2019, I show that, in regulated states, traditional capacity sold increases by about 40.8%, while renewable capacity sold decreases by about 60.3%. This reallocation is concentrated among plants and firms with greater carbon exposure. Owners sell dirtier traditional plants, and firms with more carbon-intensive portfolios sell more traditional plants. By contrast, firms with stronger upgrading capability sell fewer plants and acquire traditional plants that subsequently exhibit lower CO_2 intensity. The effects also extend beyond regulated states. Exposed multi-state firms reduce traditional capacity, expand renewable capacity, and adjust self-generation in their broader portfolios. The results show that carbon pricing affects the real economy not only by changing current emissions, but also by reallocating ownership of long-lived productive assets.

Keywords: Cap-and-Trade, Power Sector, Asset Reallocation, Green Energy Transition, Policy Spillover, Carbon Emissions

1 Introduction

Carbon pricing is designed to change firms' incentives by making emissions costly. Cap-and-trade programs implement this idea by creating tradable emissions allowances and requiring regulated firms to surrender allowances for covered emissions. By converting emissions into an explicit compliance cost, these programs change the expected cash flows and risks of carbon-intensive assets and therefore alter the value of such assets.

In the model of Maksimovic and Phillips (2001), industry shocks that alter asset values can create incentives for ownership transfers toward more productive uses. More broadly, corporate asset markets facilitate the redeployment of assets when current owners and potential buyers differ in productivity, financial condition, redeployability, or complementarities (Shleifer and Vishny, 1992; Schlingemann et al., 2002; Warusawitharana, 2008). Carbon pricing can creates this type of valuation difference and therefore reshape the asset market.

This paper examines how asset markets in the power sector respond to cap-and-trade by exploiting two major U.S. programs, the Regional Greenhouse Gas Initiative implemented in 2009 and the California Cap-and-Trade Program implemented in 2013. The power sector provides a particularly suitable setting to study how carbon pricing affects asset reallocation. First, the sector is highly carbon-intensive, so the policy shock is economically meaningful. Electricity generation is one of the largest sources of emissions in the United States, accounting for roughly one quarter of total U.S. greenhouse gas emissions.[1] Second, the sector contains a large stock of heterogeneous assets that are traded in secondary markets. EIA reports that more than 107 GW of operating electric generating capacity was bought and sold in 2012, compared with about 1,168 GW of total installed capacity.[2] Recent evidence also documents substantial changes in the ownership and financing of electricity generation

[1] See EPA, "Sources of Greenhouse Gas Emissions," available at `https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions`.

[2] See U.S. Energy Information Administration, "Large mergers drive changes in ownership of electric generating capacity in 2012," *Today in Energy*, January 16, 2013, available at `https://www.eia.gov/todayinenergy/detail.php?id=9610`. Total installed capacity is from U.S. Energy Information Administration, *Electric Power Annual 2012*, Table 4.3, "Existing Capacity by Energy Source, 2012," available at `https://www.eia.gov/electricity/annual/archive/03482012.pdf`.

assets during the energy transition (Andonov and Rauh, 2024). Third, the power sector contains both carbon-intensive and low-carbon assets, which allows the analysis to compare how the same carbon-pricing shock affects different asset types.

This paper asks three related questions. First, does cap-and-trade alter ownership transfers of power plants, including both traditional and renewable plants? Second, do valuation differences across firms shape buying and selling decisions in the market for these assets? Third, does localized cap-and-trade affect how multi-state firms value plants outside regulated states?

The results show that cap-and-trade changes ownership transfers without producing an immediate contraction in total installed capacity, retirements, or new establishments. Traditional capacity sold rises by about 40.8%, while renewable capacity sold falls by about 60.3%. The plant-level evidence shows the same asymmetry. Traditional plants become more likely to be sold, renewable plants become less likely to be sold, and the increase in sale probability is strongest for coal- and oil-fired plants and for the dirtiest plants within a firm's own portfolio.

The cross-owner evidence further shows that asset reallocation depends on both carbon exposure and upgrading capability. Firms with higher pre-policy traditional capacity shares and higher pre-policy CO_2 intensity sell more traditional plants after regulation. At the same time, firms with more pre-policy green patents sell fewer traditional and renewable plants, suggesting that carbon exposure and upgrading capability change the value of these assets. Acquired traditional plants also exhibit lower post-sale CO_2 intensity, suggesting that ownership transfers are associated with changes in plant performance rather than only changes in ownership records.

The ownership response extends beyond regulated states. Multi-state firms with carbon-price exposure reduce traditional capacity and expand renewable capacity in states not covered by cap-and-trade. The outside-state response is stronger when firms enter the policy shock with more carbon-intensive portfolios, which suggests that firms revalue assets outside

regulated states based on anticipated carbon risk. The adjustment also appears in firms' electricity-supply choices. Among firms that supply electricity to customers, exposed firms with more carbon-intensive portfolios shift away from supplying customers with electricity generated from their own plants and toward wholesale market purchases, while firms with stronger upgrading capability increase self-generation.

The firm-level results indicate that these real adjustments are visible in investment and innovation, but not in all financial outcomes. Exposure to cap-and-trade is associated with more green patenting, higher total assets, and higher capital expenditure. I do not detect statistically significant average changes in ESG scores, profitability, leverage, or Tobin's Q. This pattern is consistent with the main interpretation of the paper. Cap-and-trade changes the ownership and composition of generating assets, while diversified firms can partly absorb these adjustments within broader portfolios.

The paper makes three contributions. First, it adds an ownership channel to the literature evaluating carbon markets in the electricity sector. The closest paper is Kumar and Purnanandam (2022), which shows that RGGI reduced emissions and electricity generation among regulated utilities and affected shareholder value. Related studies also document that cap-and-trade programs reduce emissions or traditional generation in electricity markets (Fowlie et al., 2012; Murray and Maniloff, 2015; Yan, 2021; Lessmann and Kramer, 2024; Bai and Ru, 2024). I complement this work by showing that carbon pricing changes the secondary market for productive assets. The response is not limited to dispatch or output. It also reallocates control rights over existing power plants. The paper is also related to Andonov and Rauh (2024), who document changes in the ownership and financing of electricity generation during the energy transition. My evidence identifies cap-and-trade as a policy shock that changes asset sales, retention, and portfolio choices across regulated and unregulated states.

Second, the paper connects the market for corporate assets to climate finance. The corporate asset-market literature studies how assets move across firms when buyers and sellers

have different valuations or operating ability (Maksimovic and Phillips, 2001; Warusawitharana, 2008; Maksimovic et al., 2011). The climate-finance literature shows that carbon risk is reflected in investor portfolios, the cost of capital, and asset prices (Heinkel et al., 2001; Krueger et al., 2020; Pastor et al., 2021; Bolton and Kacperczyk, 2021; Jung et al., 2018; Zhang, 2025). Recent work more directly studies the reallocation of polluting assets and asks whether divestitures reduce pollution or move dirty assets to different owners (Berg et al., 2023; Darmouni and Zhang, 2024; Duchin et al., 2025; Chen, 2025). I add to this literature by showing how a carbon-price shock changes both brown and green asset ownership in a regulated product market. Carbon exposure predicts real asset sales and capacity holdings, while upgrading capability predicts which firms are more willing to retain or acquire traditional plants. The post-sale evidence further shows that acquired traditional plants experience lower emissions intensity, consistent with ownership reallocation having operating consequences.

Third, the paper contributes to the literature on geographically incomplete environmental regulation and leakage. Prior work shows that regional regulation can shift production, emissions, or supply chains toward less regulated locations (Fowlie, 2009; Bartram et al., 2022; Benincasa et al., 2024; Zhou and Huang, 2021). The power sector provides a different margin because long-distance relocation of electricity generation is constrained by transmission limits and regional market structure. I show that regional carbon pricing spills over through firm-wide ownership and investment choices rather than through higher traditional output elsewhere. The evidence therefore highlights a portfolio channel through which localized carbon markets can reduce traditional plant exposure and expand renewable exposure outside the regulated region.

The remainder of the paper proceeds as follows. Section 2 describes the institutional background. Section 3 develops the hypotheses. Section 4 presents the data and research design. Section 5 reports the empirical results. Section 6 concludes.

2 Background

2.1 Cap-and-Trade Programs

Cap-and-trade programs are a central component of market-based climate regulation in the United States. These programs impose a declining cap on total greenhouse gas emissions and allow regulated entities to trade emissions allowances. The purpose of these programs is to provide firms with incentives to reduce emissions. In this paper, I focus on two major state-level cap-and-trade program initiatives that substantially impacted the power sector: the Regional Greenhouse Gas Initiative (RGGI) and California's Cap-and-Trade Program.

The Regional Greenhouse Gas Initiative is the first legally binding regional cap-and-trade program in the United States, specifically targeting carbon dioxide emissions from the power sector. In 2005, seven states in the Northeast and Mid-Atlantic regions–Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont–signed an agreement to create a cooperative emissions reduction program. RGGI covers traditional plants with a capacity of 25 megawatts or greater and sets a regional cap on total carbon dioxide emissions.

Allowances are distributed by participating states in proportion to their share of the regional cap and are sold through quarterly auctions. Unlike earlier emissions trading systems that allocated permits for free, RGGI's auction-based design imposes explicit compliance costs on power producers while generating revenue for participating states. The first auction was held in September 2008, and the initial compliance period began on January 1, 2009. The emissions cap declines over successive compliance periods, gradually tightening carbon constraints on regulated generators. Several additional states joined the program in subsequent years, including Massachusetts, Maryland, and Rhode Island.[3]

California's Cap-and-Trade Program was established following the passage of Assembly Bill 32 in 2006, which mandated a reduction in statewide greenhouse gas emissions to 1990 levels by 2020. To achieve this target, California adopted a comprehensive climate policy

[3]New Jersey withdrew from RGGI in 2012 and is therefore excluded from the analysis.

framework that includes renewable energy mandates, energy efficiency standards, a low-carbon fuel standard, and a statewide cap-and-trade system. The cap-and-trade program began operating in 2013.

The program initially covered electricity generators and large industrial facilities emitting more than 25,000 metric tons of carbon dioxide equivalent annually, with fuel suppliers included starting in 2015. By that year, approximately 450 entities were regulated, accounting for roughly 80 percent of California's total emissions. While some allowances were initially allocated for free—particularly to electricity generators and energy-intensive industries—the share of permits distributed through auctions increased over time. Allowances can be banked for future use, and firms may meet part of their compliance obligation using approved offsets. Permit prices stabilized around \$12–\$13 per ton of carbon dioxide in the early years of the program.

Although they differ in geographic scope and regulatory design, the two programs share several core features that are central to this study. Both are implemented at the state or regional level, directly regulate carbon dioxide emissions from traditional plants, and rely on allowance trading to impose explicit carbon costs. Importantly, neither program restricts firms' operations or asset ownership outside regulated jurisdictions. This institutional structure makes the power sector particularly well suited for examining how regional climate policies affect firms' asset reallocation decisions within and beyond regulated areas.

2.2 Importance of the U.S. Power Sector for Green Energy Transition

The electricity generation sector possesses several institutional and technological features that provide an ideal setting for studying how market-based climate policies shape firm-level investment and investment decisions across regions.

First, electricity generation is one of the largest sources of carbon dioxide emissions in the United States and plays a foundational role in the broader economy. According to the

U.S. Environmental Protection Agency, the power sector accounted for roughly one quarter of total U.S. greenhouse gas emissions in 2022, making it one of the most carbon-intensive sectors in aggregate.[4] At the same time, electricity is a critical input for virtually all other industrial and commercial activities. As a result, carbon pricing in electricity generation has the potential to affect not only emissions at the source but also production costs and investment decisions throughout downstream sectors.

Despite substantial growth in renewable energy, electricity generation remains heavily reliant on fossil fuels. As of 2022, approximately 60% of U.S. electricity was generated from fossil sources, including natural gas, coal, and petroleum, while renewables accounted for about 21% and nuclear energy for 18%.[5] The continued dependence on carbon-intensive generation implies that climate policies targeting the power sector directly affect a large and economically important stock of polluting assets.

Second, the power sector is characterized by a highly capital-intensive production structure. Electricity generation relies on large, durable physical assets, with power plants requiring substantial upfront investment and exhibiting long operational lifespans. Coal and nuclear facilities, in particular, often operate for 40 to 60 years, and many nuclear plants receive license extensions allowing operation for up to 80 years.[6] This slow rate of capital turnover implies that climate policies such as cap-and-trade can have persistent effects on firm valuations and strategic decisions.

Third, another defining feature of the electricity sector is the homogeneity of its output. One megawatt-hour of electricity is identical regardless of the generating technology or the firm that produces it. Unlike manufacturing firms, electricity producers cannot differentiate products in response to regulation, which shifts competitive dynamics toward cost efficiency

[4]Source: `https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions`

[5]As of 2022, approximately 60% of electricity was generated from fossil fuels, including natural gas (39%), coal (20%), and petroleum (1%). The remaining share came from renewable sources (21%), led by wind, solar, and hydroelectric power, and from nuclear energy (18%). Source: `https://www.eia.gov/electricity/annual/html/epa_03_01_a.html`

[6]`https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html`

and regulatory exposure.

Lastly, electricity generation exhibits limited geographic flexibility. Electricity cannot be transported over long distances without significant losses, and interregional trade depends on transmission infrastructure that is costly, capacity constrained, and subject to regulatory approval. New interstate transmission lines typically cost several million dollars per mile and require multi-year planning and permitting processes.[7] Moreover, the U.S. grid is segmented into largely independent regional interconnections, further constraining cross-region electricity flows. These frictions make it difficult for firms to respond to state-level climate policies by relocating production, in contrast to many manufacturing industries where output can be shifted across regions.

At the same time, such rigidity is partially offset by the geographic scope of generation portfolios. Many large electricity producers operate plants across multiple states. While short-run production relocation is limited, firms retain flexibility in how they allocate investment and ownership of generation assets in response to differences in state-level environmental policy.

Taken together, the sector's emissions intensity, reliance on long-lived capital, standardized output, and constrained production mobility imply that asset reallocation, rather than production shifting, could be a primary channel through which electricity producers respond to state-level carbon pricing.

3 Hypothesis Development

A central idea in corporate finance is that asset ownership matters because owners differ in their ability to control, finance, and redeploy productive assets. In incomplete-contracting models, ownership allocates residual control rights and affects the value created from an asset (Grossman and Hart, 1986; Hart and Moore, 1990). In models and evidence on corporate

[7] Interstate transmission lines typically cost $2–$4 million per mile and require extensive regulatory approvals. Source: `https://www.energy.gov/oe/articles/electricity-transmission-primer`

asset markets, firms buy and sell assets when the value of an asset differs across potential users, so asset sales can reallocate assets toward owners with higher valuations or superior operating ability (Maksimovic and Phillips, 2001; Warusawitharana, 2008). The value of an asset also depends on the depth of the market for potential buyers and on whether the asset can be redeployed to alternative users (Shleifer and Vishny, 1992; Schlingemann et al., 2002). Consistent with this view, industry shocks to technology, regulation, or input costs are associated with waves of takeovers and restructuring because firms adjust their boundaries when the relative value of assets changes (Mitchell and Mulherin, 1996; Harford, 2005).

Carbon pricing is a regulatory shock that can change these owner-specific asset values. A cap-and-trade program attaches a price to emissions, raising the expected operating cost of carbon-intensive production and increasing the salience of carbon-transition risk. Finance research shows that climate and carbon risks are reflected in investors' portfolio choices, firms' cost of capital, and asset prices (Heinkel et al., 2001; Krueger et al., 2020; Pastor et al., 2021; Bolton and Kacperczyk, 2021; Zhang, 2025; Jung et al., 2018). In the power sector, prior work shows that emissions trading systems and related carbon policies reduce emissions and alter generation decisions (Fowlie et al., 2012; Murray and Maniloff, 2015; Yan, 2021; Kumar and Purnanandam, 2022; Lessmann and Kramer, 2024; Bai and Ru, 2024). These operating responses are important, but they are only one margin of adjustment. Because power plants are long-lived assets, a change in expected compliance costs should also be capitalized into the asset values at which firms are willing to hold, sell, or acquire plants.

Consider a multi-state electricity producer that owns both traditional plants and renewable plants. A regional carbon price lowers the value of traditional plants in regulated states because these plants generate emissions-related compliance costs and increase the owner's exposure to carbon risk. At the same time, renewable plants are affected through a different channel: they are not directly burdened by emissions costs and may become more valuable as investors, regulators, and firms place greater weight on transition risk (Heinkel et al., 2001; Pastor et al., 2021; Hong et al., 2023). Carbon pricing should therefore change the relative

asset values of traditional and renewable plants. Because asset sales depend on how current owners and potential buyers value the same plant, the net effect on ownership transfers need not be identical across asset types. The central prediction is that cap-and-trade alters the secondary market for power plants in a way that differs between traditional and renewable plants.

Hypothesis 1. *Cap-and-trade alters ownership transfers in the market for power plants.*

The first hypothesis follows from asset-type differences in how carbon pricing changes asset values. The same mechanism also implies differences across owners. Corporate finance theories of asset sales emphasize that asset values are user-specific: the same asset may be worth more to one firm than to another because firms differ in productivity, financial condition, and asset complementarities (Maksimovic and Phillips, 2001; Warusawitharana, 2008; Shleifer and Vishny, 1992). Under carbon pricing, a traditional plant's value depends on the owner's existing exposure to emissions costs. A firm that already owns a large amount of carbon-intensive capacity bears greater compliance risk and has a stronger incentive to reduce the marginal contribution of an additional traditional plant to firm-level carbon exposure. This prediction is consistent with the broader climate-finance evidence that investors and lenders price carbon exposure and that firms with higher emissions face different financing and valuation consequences (Bolton and Kacperczyk, 2021; Jung et al., 2018; Zhang, 2025).

Carbon pricing should therefore create stronger divestment incentives for owners whose portfolios are more exposed to carbon costs. For these firms, holding traditional plants imposes a larger expected cost and a larger exposure to transition risk. A less exposed owner, by contrast, may face a lower marginal burden from the same plant. The asset-market response should thus be stronger among high-exposure owners, even if all firms face the same formal regulatory regime.

Hypothesis 2. *The effect of cap-and-trade on traditional plant divestment is stronger for owners with greater carbon exposure.*

Theories of takeovers and post-merger restructuring emphasize that transactions occur because buyers and sellers assign different values to the same asset, often because the buyer can operate, finance, or combine the asset more efficiently (Jovanovic and Braguinsky, 2004; Maksimovic et al., 2011). In the power sector, traditional plants may retain value because they provide reliability, flexibility, capacity-market revenues, or strategic value in regional electricity markets. Moreover, some owners may have cleaner surrounding portfolios, lower effective compliance costs, or stronger capability to improve plant performance. Prior power-plant studies link ownership changes to plant incentives and efficiency, suggesting that reallocation can have operating consequences rather than merely changing the identity of the owner (Bushnell and Wolfram, 2005; Demirer and Karaduman, 2024).

This reasoning implies that upgrading capability can create value differences across firms. Environmental regulation can induce innovation, technology adoption, and changes in energy efficiency (Popp, 2006; Calel, 2020; Casey, 2024). Firms with stronger technical or organizational capability may be better able to reduce emissions intensity, improve dispatch efficiency, integrate cleaner technologies, or combine traditional plants with cleaner generation portfolios. These capabilities raise the value that such owners can create from assets whose value falls for more exposed owners. If the resulting transfers are efficiency-enhancing rather than purely cosmetic, acquired traditional plants should exhibit improved post-transfer operating performance.

Hypothesis 3. *Owners with stronger upgrading capability are more willing to retain or acquire traditional power plants under cap-and-trade*

Finance theory and evidence on multi-asset firms show that firms allocate capital and redraw firm boundaries across divisions when fundamentals change (Maksimovic and Phillips, 2002, 2013). A regional carbon price may therefore affect a firm's entire generation portfolio, not only the plants physically located in regulated states. Once a multi-state producer becomes exposed to carbon pricing, the firm may update the shadow value of traditional and renewable assets throughout its organization. This updating can extend to assets outside

regulated states if firms anticipate future carbon pricing, regulatory diffusion, or stricter climate policy. Anticipated carbon pricing can affect current asset values and investment decisions even before future regulation is realized (Lemoine, 2017). Carbon pricing can also increase the value of low-carbon capabilities, making renewable expansion more attractive even in markets that are not directly regulated.

This broader portfolio response differs from the standard leakage prediction. In many settings, geographically incomplete environmental regulation can shift production or emissions toward less regulated locations (Bartram et al., 2022; Benincasa et al., 2024; Zhou and Huang, 2021; Fang, 2024). In electricity markets, however, long-distance relocation of generation is constrained by regional market segmentation and transmission limits, so the relevant adjustment may occur through ownership and investment rather than a simple relocation of output. Exposed firms may reduce traditional plant exposure, expand renewable exposure, and adjust self-generation choices across their broader operations. In this way, a localized carbon price can reshape firm-wide portfolios even outside regulated states.

Hypothesis 4. *Firms exposed to localized cap-and-trade reorganize their broader generation portfolios by reducing traditional plant exposure and expanding renewable exposure outside regulated states.*

Taken together, these hypotheses frame cap-and-trade as a shock to the value of owning different types of power plants. If carbon pricing changes both the cash flows generated by plants and the risks borne by their owners, firms should respond not only by changing how plants are operated, but also by changing which plants they choose to own. The strength and scope of this response should depend on firms' carbon exposure, their ability to preserve value from regulated assets, and the extent to which a localized policy shock changes the value of the broader generation portfolio.

4 Data and Sample

4.1 Data

The dataset covers all power plants operating in the continental United States from 2001 to 2019.[8] Plant-level data are constructed from the U.S. Energy Information Administration's (EIA) Forms 860, 861, and 923, which provide detailed information on plant location, unit status, initial operating year, fuel type, direct ownership, annual net generation, and nameplate capacity.

I classify plants into two broad categories: traditional generation (coal-, oil-, and natural gas–fired) and renewable generation (hydro, geothermal, solar, biomass, and wind).[9] This classification allows me to distinguish between carbon-intensive and low-carbon technologies in a manner consistent with the design of U.S. cap-and-trade programs.

Figure 1 illustrates the geographic distribution of U.S. power plants in the beginning and end years of the sample. Plant locations are widely dispersed across the country, with traditional plants historically concentrated in the Midwest and Southeast, reflecting the legacy of coal- and gas-based electricity generation. In contrast, renewable plants such as wind and solar are more prevalent in the western and central regions, where natural resource conditions are favorable. Comparing the two panels reveals a clear shift in the generation mix over time. The number and capacity of wind and solar plants expand substantially from 2001 to 2019, particularly across the Great Plains, Texas, and the western United States. At the same time, coal-fired plants become less prominent, reflecting the gradual decline of coal generation in the U.S. power sector. Overall, the figure highlights the rapid growth of renewable generation capacity alongside the relative contraction of traditional plants during the sample period.

Plant-level emissions data are obtained from the Environmental Protection Agency's

[8] The sample ends in 2019 to avoid structural disruptions associated with the COVID-19 pandemic.

[9] Nuclear plants are excluded because they are neither fossil-fuel-based nor renewable and operate under distinct regulatory and economic frameworks. There are 60 nuclear plants during the sample period, accounting for less than 0.6% of total plants.

Clean Air Markets Division (CAMD), which reports emissions for traditional generating units with capacity greater than 25 MW. To ensure comparability across programs, I restrict the baseline sample to traditional generating units with nameplate capacity above 25 MW. This threshold corresponds to the regulatory coverage rule under RGGI and captures the vast majority of utility-scale traditional generation. Because California's cap-and-trade program defines compliance based on an emissions threshold (25,000 tons of CO e), applying a uniform capacity cutoff avoids differential sample selection across regulated states and ensures a consistent definition of economically significant generating units.[10]

New Jersey is included in the sample but excluded from the regulated-state group because it joined RGGI in 2009 and withdrew in 2012. This classification ensures consistent policy exposure within regulated states over time.[11]

To identify ultimate ownership, I combine ownership information from S&P Global Market Intelligence (GMI; formerly SNL Financial) with subsidiary structures disclosed in SEC filings. While the EIA reports only the direct owner of each plant, GMI provides full ownership chains up to the ultimate parent firm. I cross-validate the two sources and manually reconcile discrepancies where necessary. A firm is recorded as the ultimate owner only if it holds more than 50% of the plant's equity, ensuring effective control.

Privately held firms that do not appear in Compustat are retained in the plant-level analysis but excluded from specifications requiring financial statement data. Financial information for publicly traded utilities, including leverage, profitability, and capital expenditures, is obtained from Compustat and merged to the plant-level data using the constructed ultimate parent identifier.

For green patents, we use the micro-level records of all utility patents filed with and granted by the United States Patent and Trademark Office (USPTO) between January 1976 and December 2019. The data are obtained from the PatentsView database (June 2022

[10]California's emissions threshold varies over time and includes voluntary reporters. The results are robust to restricting the sample to plants that also exceed the 25,000-ton emissions threshold.

[11]The results are robust to treating New Jersey as regulated during its participation period.

release). To identify environmentally related innovations, we follow Cohen et al. (2026) and use the Environment-Related Technologies (Env-Tech) classification developed jointly by the OECD and the European Patent Office. The Env-Tech taxonomy relies on structured retrieval procedures and classification protocols developed by experienced patent examiners in collaboration with external technical experts. These examiners identify relevant patents through prior-art searches and assign technology classes based on their relevance to environmental technologies. Under the Env-Tech classification, environmentally related patents are grouped into eight technology families spanning three broad domains: environmental management, water-related adaptation technologies, and climate change mitigation technologies. This classification system provides a standardized approach to identifying green innovations across patent data (see Haščič and Migotto (2015) for a detailed description of the methodology).

I further supplement the dataset with state-level controls from the National Centers for Environmental Information (NCEI) and the EIA's State Energy Data System (SEDS). These controls include annual average temperature, GDP, population, Heating Degree Days (HDD), and Cooling Degree Days (CDD), which capture demand-side variation in electricity consumption driven by weather conditions.

Table 1 reports summary statistics for the main variables at the state, plant, and firm levels.

4.2 Sample Statistics

Panel A of Table 1 summarizes the characteristics of the 10,295 U.S. power plants observed from 2001 to 2019. The distribution of generation and capacity is highly skewed. The average plant produces 541,000 MWh annually and has installed capacity of 166 MW, yet the median plant generates only 26,000 MWh with 19 MW of capacity. This dispersion reflects the coexistence of a small number of large utility-scale generators and a broad mass of smaller facilities, and motivates the use of log-transformed outcomes in the empirical

analysis.

The sample is nearly evenly split between traditional plants (46%) and renewable plants (54%), but this balance masks a sharp asymmetry in economic scale. The average traditional plant generates over 1 million MWh per year and operates with 303 MW of capacity, roughly six times the average renewable plant, and carries average annual CO2 emissions of 1.97 million short tons. Traditional plants are also somewhat older on average, reflecting the long-lived capital stock that underlies much of the existing generation fleet. Together, these differences underscore the asymmetric regulatory exposure of traditional and renewable plants to carbon pricing and motivate the plant-level reallocation patterns examined in Section 5.1 and Section 5.3.

Within the traditional category, gas-fired plants account for the largest share by plant count, followed by oil and coal. Coal plants, while fewer in number, are the largest by capacity and the most emissions-intensive. Among renewables, hydropower remains the dominant technology throughout the sample period, while wind and solar grow considerably after 2010 but represent a smaller share in aggregate. This within-category heterogeneity in size, vintage, and emissions intensity provides additional cross-sectional variation that the empirical strategy exploits.

Panel B reports state-level characteristics across the 48 continental states included in the analysis.[12] Electricity generation averages 82 million MWh per year per state, with traditional generation accounting for the majority of output. States produce an average of 46 million short tons of CO2 annually, with traditional plants responsible for most of this total. Renewable penetration, while smaller in aggregate, varies considerably across states, consistent with heterogeneity in resource endowments, regulatory environments, and renewable portfolio standards. This cross-state variation in generation mix, emissions intensity, and renewable capacity is central to the difference-in-differences identification strategy developed

[12]New Jersey is excluded from the regulated-state group because it joined RGGI in 2009 and withdrew in 2012, creating an ambiguous policy status. Results are robust to treating New Jersey as regulated during its participation period.

in Section 5.1 and Section 5.3.

Panel C summarizes the 510 publicly traded parent firms that own generation assets in the sample. Ownership is concentrated, such that although the average firm owns 5.9 plants, the median firm owns only one, and a small number of large multi-plant utilities account for a disproportionate share of total capacity. Firms control on average 1,371 MW of nameplate capacity, though the distribution is heavily right-skewed. Geographic diversification is also notable, as 29% of firms own plants in more than one state and the average firm operates across 1.69 states [13]. This multi-jurisdictional footprint is central to the analysis, as it allows firms to reallocate investment and capacity between RGGI and non-RGGI states in response to carbon pricing, which is the reallocation margin examined in Section 5.3. Taken together, the summary statistics reveal substantial heterogeneity across plants, states, and firms in size, technology mix, emissions intensity, and geographic scope. This variation provides the empirical leverage needed to separately identify the within-firm reallocation response from broader industry-wide trends in the transition toward cleaner generation.

5 Empirical Results

5.1 Ownership Transfers within Regulated States

The central prediction of Hypothesis 1 is that cap-and-trade changes ownership transfers in the market for power plants. Because power plants are long-lived assets, carbon pricing should affect not only how intensively plants are operated, but also the asset values at which firms are willing to sell or retain them.[14] I examine retirements and new construction to distinguish ownership transfers from changes in the physical stock of generating capacity. This comparison allows me to test whether cap-and-trade reallocates existing plants across

[13] Multi-state firms control more than 90% of total generating capacity on average.

[14] Appendix Table A.2 shows that cap-and-trade reduces traditional generation and CO_2 emissions in regulated states, consistent with the operating response documented by Kumar and Purnanandam (2022). Appendix Figure A.1 and Appendix Table A.3 report the dynamic and program-specific evidence.

owners, rather than simply removing old plants or inducing new investment.

At the state-year level, I estimate

$$Y_{st} = \beta \text{Regulated}_{st} + \Gamma' X_{st} + \mu_s + \lambda_t + \varepsilon_{st}, \tag{1}$$

where Regulated_{st} equals one beginning in the year a cap-and-trade program is implemented in state s, X_{st} includes state-level controls, and μ_s and λ_t are state and year fixed effects. The outcomes in Panel A of Table 2 distinguish total capacity, capacity sold, retired capacity, and newly established capacity. This aggregate specification shows whether any change in ownership transfers is accompanied by changes in the physical stock of power plants.

At the plant-year level, I estimate

$$\Pr(\text{Sold}_{i,s,t+1} = 1) = \beta \text{Regulated}_{st} + \Gamma' X_{st} + \Pi' Z_{ist} + \mu_i + \lambda_t + \varepsilon_{ist}, \tag{2}$$

where Z_{ist} includes plant capacity and age, and μ_i are plant fixed effects. The plant-year specification examines whether the same valuation force appears at the individual-plant level.

Table 2 shows that the regulated-state response is not primarily a decline in installed traditional capacity. Panel A shows little evidence that cap-and-trade immediately destroys traditional capacity. Total traditional capacity, retired capacity, and newly established capacity do not change significantly. Instead, the response appears in ownership transfers. Capacity sold for traditional plants rises by about 40.8% after cap-and-trade implementation. Renewable plants move in the opposite direction. Renewable capacity sold falls by about 60.3%, while total renewable capacity, retired capacity, and newly established capacity do not change significantly. The contrast is important because it shows that carbon pricing changes the market for existing assets even when the physical stock of capacity is relatively slow moving.

Panel B shows the same asymmetry at the plant level. Traditional plants become 1.8

percentage points more likely to be sold in the following year, which represents a 16.5% increase relative to the baseline annual sale probability of 10.9%. Renewable plants become 2.8 percentage points less likely to be sold, corresponding to a 22.5% decline relative to the baseline annual sale probability of 12.5%. The plant-level evidence therefore supports the central prediction in Hypothesis 1. Carbon pricing changes ownership transfers, and it does so differently for traditional and renewable plants.

The heterogeneity within traditional plants is especially informative. *Dirty Fuel* identifies coal- and oil-fired plants relative to natural-gas plants. The interaction between Regulated and *Dirty Fuel* implies an additional 4.2 percentage point increase in the sale probability for coal- and oil-fired plants after regulation. *Dirty Percentile* measures a traditional plant's relative dirtiness within its owner's state-year portfolio. The positive interaction between Regulated and *Dirty Percentile* indicates that firms are not simply selling traditional plants at random. They are more likely to divest the dirtiest plants within their own portfolios. This pattern suggests that cap-and-trade changes the relative value of assets even within the same owner, pushing firms to shed the traditional plants that contribute most to portfolio-level carbon exposure.

Taken together, the evidence in Table 2 points to asset reallocation rather than simple capacity contraction. Cap-and-trade does not primarily remove traditional plants from the generation fleet through retirement. Instead, it changes which plants owners are willing to sell, and this response differs sharply between traditional and renewable plants. The result extends prior work on environmental regulation and asset markets by showing that carbon pricing affects the secondary market for productive assets, not only emissions or output (Darmouni and Zhang, 2024; Berg et al., 2023; Duchin et al., 2025; Chen, 2025).[15]

[15]Appendix Table A.4 decomposes transactions by owner type. The table shows that the increase in traditional-plant sales is concentrated among independent power producers, while government-owned entities are less likely to buy regulated traditional plants.

5.2 Carbon Exposure, Upgrading Capability, and Post-Sale Performance

Building on Hypothesis 2 and Hypothesis 3, the analysis now shifts from differences across asset types to differences across owners. If carbon pricing changes asset values, then the same plant should become less attractive to owners with greater carbon exposure and more attractive to owners with stronger upgrading capability. A firm with greater carbon exposure internalizes a larger compliance-cost shock from holding traditional plants. By contrast, a firm with stronger upgrading capability may be able to operate, retrofit, or integrate the same plant more effectively. I examine these owner-level differences using firm-state-year specifications of the form

$$Y_{jst} = \beta \text{Regulated}_{st} + \theta \left(\text{Regulated}_{st} \times M_j^{pre} \right) + \Gamma' X_{st} + \Pi' W_{jt} + \mu_j + \mu_s + \lambda_t + \varepsilon_{jst}, \quad (3)$$

where Y_{jst} is either net sales or capacity holdings for producer j in state s and year t, M_j^{pre} is a pre-implementation measure of carbon exposure or upgrading capability, W_{jt} is a vector of firm controls, and X_{st} is a vector of state controls. The interacted variables in Table 3 are measured using the firm's average value over the three years before the relevant cap-and-trade program is implemented.

Table 3 shows that carbon exposure strengthens the incentive to reduce traditional plants. In Panel A, the interactions of Regulated with pre-policy traditional capacity share and CO_2 intensity are positive and significant for net sales of traditional plants. Positive net sales mean that exposed firms dispose of more traditional plants relative to acquisitions. In Panel B, the same exposure measures are negative and significant for traditional capacity holdings. The coefficient on Regulated $\times$ *CO_2 Intensity* in the traditional capacity regression is -0.546, implying that a one-unit increase in pre-policy carbon intensity is associated with about a 42.1% lower traditional capacity holding after regulation. These results are consistent with

Hypothesis 2 and with climate-finance evidence that carbon exposure is priced by investors and lenders (Bolton and Kacperczyk, 2021; Jung et al., 2018; Zhang, 2025).

The renewable columns help clarify the economic interpretation. Carbon exposure does not produce a comparable reduction in renewable capacity holdings. The response is therefore not a general downsizing by high-emission owners. It is concentrated in traditional plants, the assets whose operating cash flows and compliance costs are most directly affected by carbon pricing. This asymmetry is consistent with the idea that cap-and-trade changes the relative value of traditional and renewable plants rather than simply reducing the scale of regulated firms.

The upgrading-capability results point in the opposite direction and support Hypothesis 3. Firms with more pre-policy green patents sell fewer traditional plants and hold more traditional capacity after regulation. The same measure is also positively associated with renewable capacity holdings and negatively associated with renewable net sales. This pattern suggests that upgrading capability changes the value of both clean and carbon-intensive assets. Green patents are not direct evidence of lower renewable deployment costs, but they indicate low-carbon knowledge and organizational capability. Such capability can make renewable expansion more valuable while also allowing some firms to preserve value from traditional plants that would be less attractive to more carbon-exposed owners.

Table 4 provides a more direct test of whether transfers are associated with operating improvements. If asset reallocation merely moves plants between balance sheets, post-sale operating performance need not change. Instead, acquired traditional plants in regulated states experience a statistically significant decline in CO_2 intensity. The interaction between Regulated and *Acquired* is -0.059, implying about a 5.7% reduction in emissions intensity relative to non-acquired traditional plants. The corresponding interactions for total emissions and generation are not statistically significant. This pattern suggests that post-sale improvements occur through efficiency conditional on output, rather than simply through lower utilization.

The combination of Tables 3 and 4 helps distinguish two forces that operate at the same time. High-exposure owners have stronger incentives to reduce traditional plants, while firms with stronger upgrading capability appear better positioned to retain, acquire, or improve them. The evidence is consistent with corporate asset-market theories in which assets move toward owners with higher valuations or superior operating ability (Maksimovic and Phillips, 2001; Warusawitharana, 2008; Maksimovic et al., 2011). It also helps explain why traditional plants do not simply disappear after carbon pricing. Some owners value these assets less, but others may still be able to create value from them.

5.3 Cap-and-Trade and Firms' Broader Generation Portfolios

The prediction in Hypothesis 4 extends the asset value mechanism from regulated plants to firms' broader generation portfolios. If carbon pricing only affects plants physically located inside regulated states, the ownership response should stop at the policy border. The portfolio mechanism implies a broader response. Multi-state producers may anticipate future regulatory risk and update the value of assets outside regulated states once part of their portfolio becomes exposed to carbon pricing. The key firm-level variable is Exposed_{jt}, which equals one after cap-and-trade implementation for producers that owned at least one plant in a regulated state before the program was implemented. This definition is distinct from Regulated_{st}, the state-level policy indicator used above.

I estimate the following firm-state-year specification for states outside cap-and-trade regions.

$$Y_{jst} = \beta \text{Exposed}_{jt} + \Gamma' W_{jt} + \Pi' X_{st} + \mu_j + \mu_s + \lambda_t + \varepsilon_{jst}, \tag{4}$$

where Y_{jst} measures the number or capacity of traditional and renewable plants owned by producer j in unregulated state s and year t. In the stricter specifications, state-by-year fixed effects absorb time-varying local shocks.

Figure 2 shows why this broader portfolio margin is economically relevant. Exposed producers are not confined to neighboring states. The California panel shows exposed owners with plants in Texas and other non-California electricity markets, and the RGGI panel shows similarly dispersed portfolios outside the Northeast. The spillover margin is therefore not only a response in adjacent states. It is a firm-level portfolio response across electricity markets. Table 5 confirms this interpretation. Exposed firms reduce the number of traditional plants outside regulated states by about 0.4% and traditional capacity by about 3.9%. At the same time, they increase the number of renewable plants by about 1.8% and renewable capacity by about 6.1%. The estimates are nearly identical when state-by-year fixed effects are included, suggesting that the result is not driven by local shocks common to all firms in the same state and year.

To examine the timing of the portfolio response, I estimate an event-study version of the outside-state specification.

$$Y_{jst} = \sum_{\ell \neq -1} \delta_\ell D^\ell_{jt} + \Gamma' W_{jt} + \Pi' X_{st} + \mu_j + \mu_s + \lambda_t + \varepsilon_{jst}, \tag{5}$$

where D^ℓ_{jt} equals one if producer j is exposed to cap-and-trade and year t is ℓ years relative to the implementation year of the relevant program. Never-exposed producers have $D^\ell_{jt} = 0$ for all event years. The omitted category is the year immediately before implementation, $\ell = -1$. The coefficients δ_ℓ trace the difference in outside-state portfolio outcomes between exposed and unexposed producers relative to this omitted year.

Figure 3 plots these dynamic coefficients. The pre-exposure coefficients are close to zero, while the post-exposure path shows a gradual decline in traditional capacity and a corresponding expansion in renewable capacity outside regulated states. The timing is consistent with portfolio reorganization rather than an immediate mechanical response.

This evidence differs from the standard leakage prediction. In geographically incomplete environmental regulation, firms may shift production or emissions to unregulated locations

(Fowlie, 2009; Bartram et al., 2022; Benincasa et al., 2024; Zhou and Huang, 2021). In the power sector, however, long-distance output shifting is constrained by transmission limits and regional market structure. The results indicate that exposed producers reduce traditional ownership and expand renewable ownership outside regulated states rather than moving dirty production there.[16]

Table 6 helps explain why the outside-state response occurs. If exposed firms anticipate future carbon risk or revise the value of assets throughout their portfolios, the response outside regulated states should be stronger when firms enter the policy shock with higher carbon exposure. Consistent with this prediction, exposed firms with higher pre-policy traditional capacity shares and higher CO_2 intensity reduce traditional capacity more strongly outside regulated states. The interaction with CO_2 intensity is -0.145, corresponding to about a 13.5% lower traditional capacity holding for a one-unit increase in the pre-policy intensity measure. The result links Table 5 to the paper's mechanism. Outside-state reallocation is not merely a general expansion or contraction by exposed firms. It is strongest precisely where the firm has more carbon-intensive assets whose value is most exposed to transition risk.

This heterogeneity is central to the interpretation of spillovers. The outside-state plants are not directly covered by California or RGGI, so the Table 6 patterns are difficult to explain as a mechanical compliance response. Instead, they suggest that exposed firms revalue assets outside regulated states based on the carbon intensity of their broader portfolios. Firms with dirtier outside portfolios reduce traditional capacity more, while firms with higher CO_2 intensity expand renewable capacity more. This pattern is consistent with anticipatory adjustment to future carbon risk and with the idea that a local carbon price can change asset values beyond the regulated region.

The renewable capacity results show the other side of the same portfolio adjustment.

[16] Appendix Table A.5 directly examines operational outcomes in unregulated states. Exposed firms reduce traditional generation by about 7.5% and traditional CO_2 emissions by about 5.1%, while increasing renewable generation by about 18.2%. Appendix Table A.5 therefore provides no evidence that the outside-state portfolio response reflects carbon leakage through higher traditional output.

Exposed firms with higher pre-policy CO_2 intensity in unregulated states expand renewable capacity more strongly, and the interaction coefficient of 0.114 corresponds to about a 12.1% increase. The interaction with green patents is not positive for renewable capacity in Table 6, but green patents are positively associated with traditional capacity outside regulated states. This pattern suggests that upgrading capability changes how firms value outside assets under carbon pricing. High carbon exposure pushes firms away from traditional capacity, while upgrading capability may help them preserve value from some traditional plants.

Table 7 examines whether this broader portfolio adjustment also appears in firms' electricity-supply choices. The sample is restricted to firms that supply electricity to customers, and the dependent variable is the percentage of electricity supplied to customers that is generated by the firm's own power plants. This outcome captures a business-model margin that is distinct from plant ownership. A lower self-generation share means that a firm supplies a smaller share of customer electricity through its own generating assets, which is consistent with relying more on purchased power, contracts, or a different supply mix.

The results follow the same economic pattern as the portfolio tests. Exposed firms with higher CO_2 intensity or higher traditional capacity share reduce self-generation, consistent with a move away from internal carbon-intensive supply. By contrast, exposed firms with more green patents increase self-generation. This result is consistent with the idea that upgrading capability changes the value of internal generation under carbon pricing, although it does not by itself identify the cost of renewable deployment. Table 7 therefore extends the evidence from asset ownership to the way firms organize electricity supply to customers.

I next examine whether exposure to cap-and-trade is reflected in firms' broader financial outcomes. This test asks whether the real adjustments in ownership, capacity, and self-generation are large enough to appear in firm-level outcomes, or whether they are absorbed within diversified firms. I estimate

$$Y_{jt} = \beta \text{Exposed}_{jt} + \Gamma' W_{j,t-1} + \mu_j + \lambda_t + \varepsilon_{jt}, \tag{6}$$

where $W_{j,t-1}$ contains lagged firm controls. Exposure is associated with a 9.7% increase in green patents and a 2.5% increase in total assets, along with a positive coefficient on CAPEX. These estimates are consistent with the earlier portfolio results and with evidence that carbon pricing can stimulate low-carbon innovation (Calel, 2020). They suggest that exposed firms respond through investment and innovation margins, not only through the sale and purchase of plants.

However, I do not detect statistically significant changes in ESG scores, ROA, leverage, or Tobin's Q. This null evidence should be interpreted cautiously. It indicates that the firm-level average effects are not statistically distinguishable from zero in this sample, not that carbon pricing has no effect on firm value or profitability in all settings. The contrast with Kumar and Purnanandam (2022), who document profitability and valuation effects for RGGI utilities, suggests that the ability of multi-state firms to reallocate assets across regions may dampen the effect of carbon pricing on consolidated accounting and valuation outcomes. In this sense, the firm-level results are consistent with the paper's main interpretation. Cap-and-trade induces real asset reallocation, but diversified firms can partly absorb these adjustments without a detectable average change in profitability, leverage, or market valuation.

Overall, the empirical evidence supports the mechanism developed in the hypotheses. Cap-and-trade affects operations, but it also changes ownership transfers, capacity holdings, and portfolio choices. The response is strongest where carbon exposure is high, differs for firms with greater upgrading capability, and extends outside regulated states through the broader portfolios of exposed producers.

6 Conclusion

This paper studies whether carbon pricing reshapes the market for power plants. A cap-and-trade program changes the value of owning carbon-intensive assets, and corporate asset markets can transmit that change through ownership transfers. Exploiting the staggered

introduction of the Regional Greenhouse Gas Initiative and California's Cap-and-Trade Program, I show that carbon pricing affects not only how power plants are operated, but also who owns them and how multi-state firms organize their generation portfolios.

Within regulated states, cap-and-trade changes the allocation of existing generating assets. Traditional capacity sold rises by about 40.8%, while renewable capacity sold falls by about 60.3%. These changes are not accompanied by statistically significant changes in total capacity, retirements, or newly established capacity, which points to asset sales as an important margin of adjustment. At the plant level, traditional plants become more likely to be sold and renewable plants become less likely to be sold. The sale response is concentrated among coal- and oil-fired plants and among the dirtiest traditional plants in an owner's portfolio, indicating targeted divestment of the plants most exposed to carbon costs.

The ownership response also varies systematically across firms. Firms with higher pre-policy traditional capacity shares and higher pre-policy CO_2 intensity sell more traditional plants after regulation, while firms with stronger upgrading capability sell fewer traditional and renewable plants. Acquired traditional plants subsequently exhibit lower CO_2 intensity. These patterns are consistent with the view that carbon pricing creates valuation differences across owners. Some firms reduce exposure to traditional plants, while others with stronger upgrading capability can preserve or improve value from the same assets.

The effects extend beyond regulated states. Multi-state firms exposed to cap-and-trade reduce traditional capacity and expand renewable capacity in unregulated states, especially when their pre-policy portfolios are more carbon intensive. These firms also adjust how they supply customers. Among firms that sell electricity to customers, those with more carbon-intensive portfolios shift away from supplying customers with electricity generated from their own plants and toward wholesale market purchases, while firms with stronger upgrading capability increase self-generation. The outside-state evidence therefore suggests that localized carbon pricing affects firm-wide portfolio choices rather than simply shifting traditional generation to unregulated locations.

At the firm level, exposure to cap-and-trade is associated with more green patenting, higher total assets, and higher capital expenditure. I do not detect statistically significant average changes in ESG scores, profitability, leverage, or Tobin's Q. This contrast suggests that asset reallocation can be economically meaningful even when the average effect on consolidated financial outcomes is difficult to detect, especially for diversified firms with portfolios spanning multiple states.

Overall, the results highlight the market for productive assets as an important channel through which carbon pricing affects the real economy. Ownership matters because it determines who controls future dispatch, maintenance, retrofitting, retirement, financing, and investment decisions. Regional cap-and-trade programs can therefore shape the transition of the power sector not only by changing current emissions, but also by reallocating long-lived generating assets across firms and across locations. This asset-market perspective suggests that evaluations of climate policy should consider how regulation changes firm boundaries and portfolio composition, not only emissions within regulated jurisdictions.

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Figures and Tables

Figure 1: Geographic Distribution of U.S. Power Plants

This figure presents maps of all U.S. electric power plants in 2001 and 2019. Plant locations are shown as colored circles, where each color represents a fuel type (coal, gas, nuclear, hydro, wind, solar, biomass, geothermal, and others), and circle size is proportional to the plant's nameplate capacity.

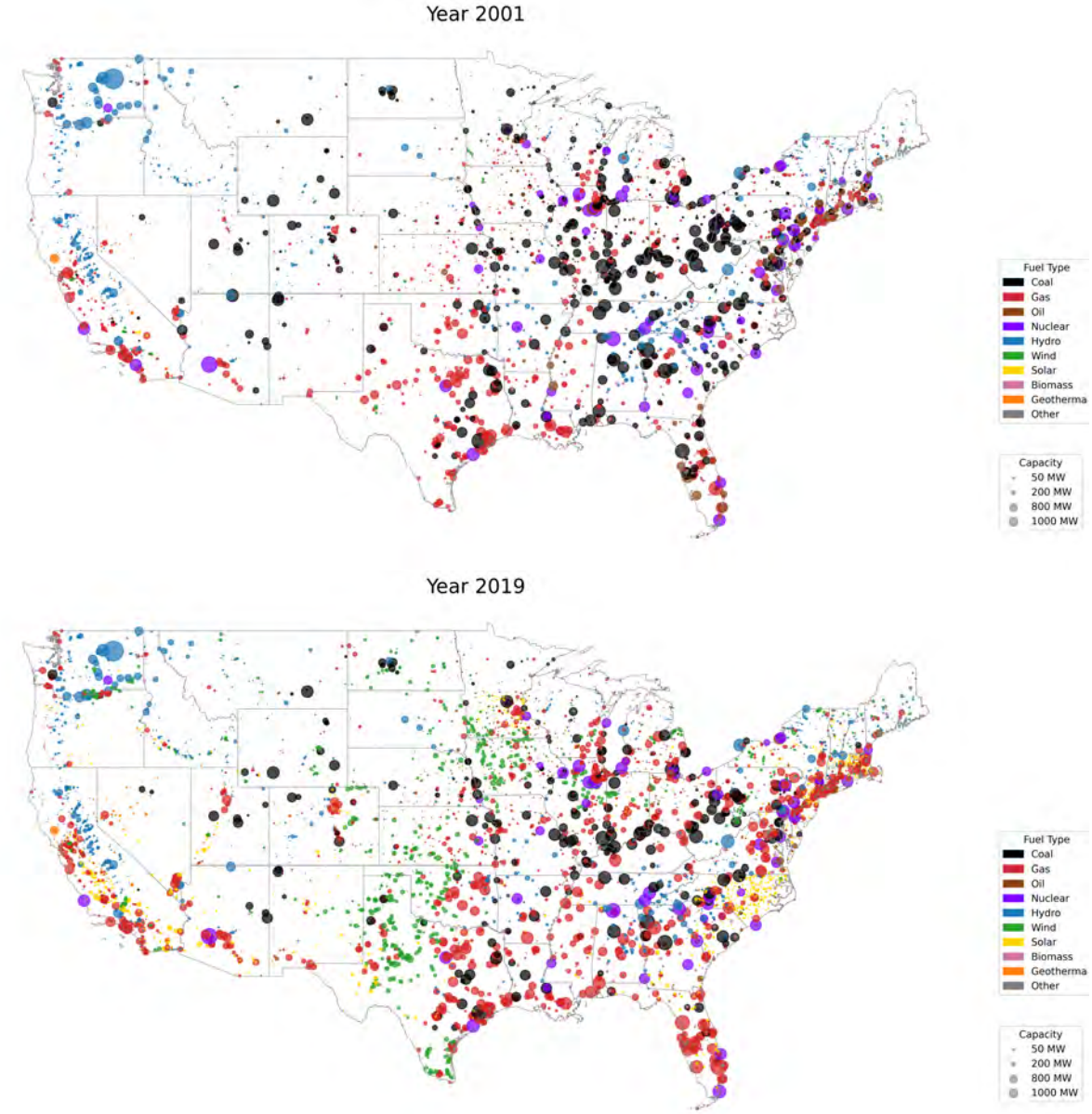


Figure 2: Cap-and-Trade Exposure and Power Plant Portfolios Outside Regulated States

This figure maps the geographic distribution of U.S. power plants owned by electricity producers that are either exposed or unexposed to the California Cap-and-Trade program and the Regional Greenhouse Gas Initiative (RGGI). The sample is restricted to power plants in states that are not directly regulated by the corresponding cap-and-trade program. Panel A focuses on exposure to the California Cap-and-Trade program, while Panel B focuses on exposure to RGGI. A producer is defined as *exposed* to a cap-and-trade program if it owned at least one plant in a cap-and-trade state before the program was implemented, and *unexposed* otherwise. Each point represents a power plant location. Circles denote plants owned by exposed producers, while triangles denote plants owned by unexposed producers. Color indicates plant type, distinguishing traditional plants (coal, oil, and natural gas) from renewable plants (wind, solar, hydro, geothermal, and biomass). Marker size is proportional to the plant's nameplate generating capacity. For each policy, the top map shows the pre-treatment distribution of plants before the implementation of the program, while the bottom map shows the post-treatment distribution afterward. The pre-treatment period corresponds to the years prior to the introduction of the cap-and-trade program (before 2013 for the California Cap-and-Trade program and before 2009 for RGGI), while the post-treatment period corresponds to the years after the programs became effective.

Panel A: Exposed by California Cap-and-Trade



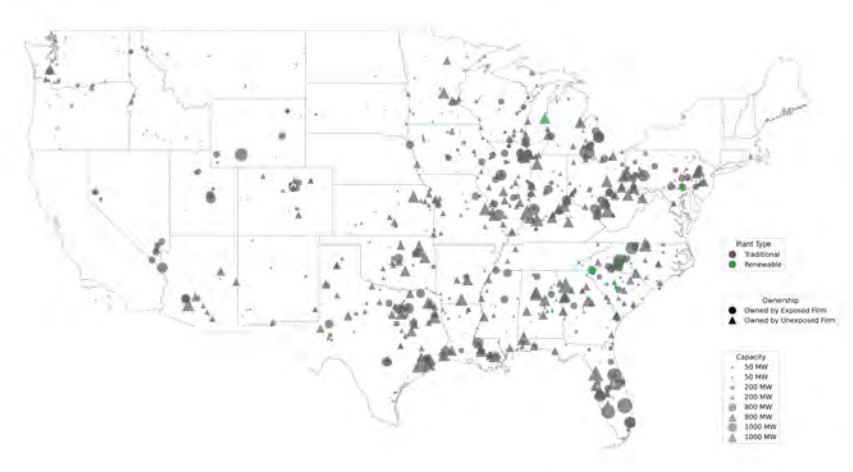
Pre-treatment



Post-treatment

Figure 2: (continued)

Panel B: Exposed by RGGI



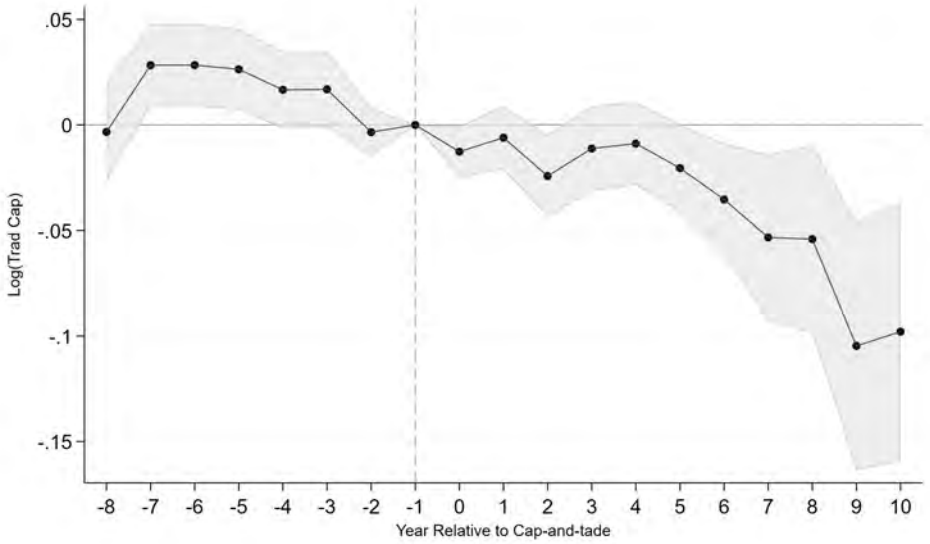
Pre-treatment



Post-treatment

Figure 3: Dynamic Effects of Cap-and-Trade Exposure on Portfolio Reallocation Outside Regulated States

This figure plots the dynamic differences-in-differences estimates of the spillover effects of cap-and-trade programs on electricity producers' power plant portfolios in unregulated states. The estimates are obtained from an event-study specification of a staggered difference-in-differences model exploiting the implementation of the California Cap-and-Trade program and the Regional Greenhouse Gas Initiative (RGGI). The sample includes firm–state–year observations in states that are not directly regulated by cap-and-trade programs over the period 2001–2019. The horizontal axis shows years relative to the implementation of cap-and-trade (year 0). Producers are defined as *exposed* if they owned at least one plant in a cap-and-trade state before the program was implemented. The top panel reports the estimated effects on the logarithm of producers' traditional generating capacity in unregulated states (*Log(Trad Cap)*), while the bottom panel reports the effects on the logarithm of producers' renewable generating capacity in unregulated states (*Log(Renew Cap)*). Points represent coefficient estimates for each relative year, and shaded areas denote 95% confidence intervals. The omitted category is the year immediately preceding the policy implementation (year −1). All specifications include producer, state, and year fixed effects, and standard errors are clustered at the state level.



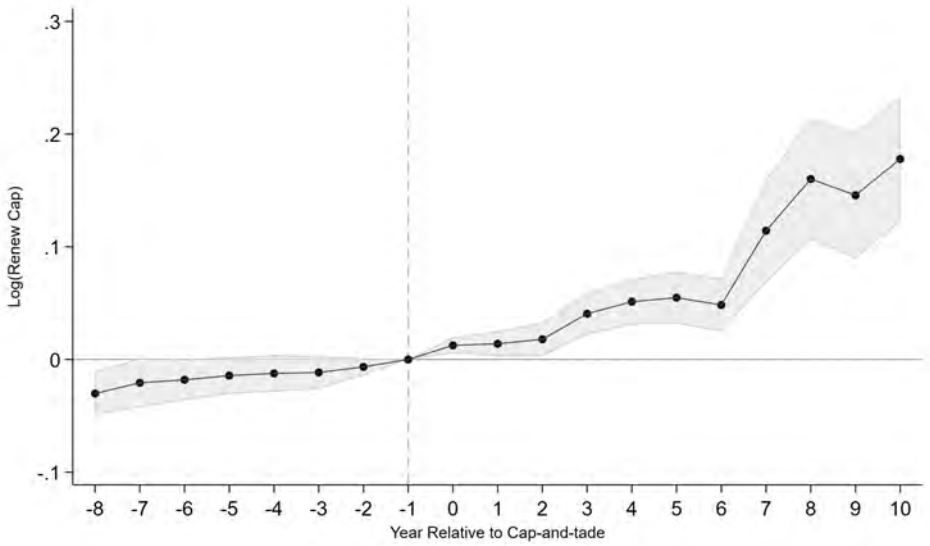


Table 1: Summary Statistics

This table reports summary statistics for the main variables used in the analysis. The sample includes U.S. electricity producers and their power plants observed between 2001 and 2019. Panel A reports summary statistics for power plant characteristics. The sample includes 10,295 unique power plants and 108,639 plant–year observations. *Net Generation* measures annual electricity generation in thousand megawatt-hours (MWh). *Capacity* measures the plant's nameplate generating capacity in megawatts (MW). *Plant Age* is the number of years since the plant's initial operation year. *Is Traditional* is an indicator equal to one for traditional plants (coal, oil, and natural gas). *Is Renewable* is an indicator equal to one for renewable plants (wind, solar, hydro, geothermal, and biomass). Additional indicator variables identify specific fuel types. For traditional plants, CO_2 *Emission* measures annual carbon emissions in million short tons and CO_2 *Emission Rate* measures emissions per unit of electricity generation in short tons per MWh. Panel B reports summary statistics for state-level characteristics. The sample includes 48 U.S. jurisdictions observed over the period 2001–2019. *Net Generation* measures total electricity generation within a state. *Capacity of Traditional Plants* and *Capacity of Renewable Plants* measure installed generating capacity by plant type. *RPS State* is an indicator equal to one if the state has a Renewable Portfolio Standard in a given year. *GDP* measures state gross domestic product in billions of U.S. dollars, and *Population* measures the state population. *Temperature* reports the annual average temperature in degrees Fahrenheit. *Heating Degree Days (HDD)* and *Cooling Degree Days (CDD)* measure heating and cooling demand conditions. Panel C reports summary statistics for firm characteristics. The sample includes 510 public traded electricity producers. *No. Total Plants Owned*, *No. Traditional Plants Owned*, and *No. Renewable Plants Owned* measure the number of power plants owned by a firm. *Total Capacity Owned*, *Traditional Capacity Owned*, and *Renewable Capacity Owned* measure generating capacity owned by the firm in MW. *Market Value* and *Total Assets* are measured in billions of U.S. dollars. *Tobin's Q* is the ratio of market value to book value of assets. *Leverage* is defined as total debt divided by total assets. *ROA* is return on assets. *Market-to-Book Ratio* is the ratio of market value to book value of equity. *CAPEX* measures capital expenditures scaled by total assets. *Sales* measures firm revenue in billions of U.S. dollars. *No. Operating States* measures the number of U.S. states in which the firm operates power plants, and *Whether Operates in Multiple States* is an indicator equal to one if the firm operates plants in more than one state.

Panel A: Power Plant Characteristics

	N	Mean	Std. Dev.	P25	Median	P75
Panel A: All Power Plants (No. Plants = 10,295)						
Net Generation (Thousand MWh)	108639	541.31	1781.15	3.42	26.15	213.63
Capacity (MW)	108639	166.11	395.53	4.10	19.00	107.85
Plant Age	108639	31.21	28.12	7.00	23.00	51.00
Is Traditional	108639	0.46	0.50	0.00	0.00	1.00
Is Oil	108639	0.12	0.32	0.00	0.00	0.00
Is Coal	108639	0.08	0.27	0.00	0.00	0.00
Is Gas	108639	0.25	0.44	0.00	0.00	1.00
Is Renewable	108639	0.54	0.50	0.00	1.00	1.00
Is Biomass	108639	0.09	0.28	0.00	0.00	0.00
Is Geothermal	108639	0.01	0.10	0.00	0.00	0.00
Is Hydro	108639	0.24	0.42	0.00	0.00	0.00
Is Solar	108639	0.11	0.32	0.00	0.00	0.00
Is Wind	108639	0.10	0.30	0.00	0.00	0.00
Panel B: Traditional Power Plants (No. Plants = 3,659)						
Net Generation (Thousand MWh)	49483	1011.62	2463.86	0.34	35.47	622.46
Capacity (MW)	49483	303.29	516.18	9.60	58.00	381.90
Plant Age	49483	32.22	21.63	13.00	29.00	50.00
CO2 Emission (Million Short Tons)	21142	1.97	3.44	0.06	0.52	2.10
CO2 Emission Rate (Short Tons/MWh)	21081	2.08	271.94	0.52	0.72	1.08
Panel C: Renewable Power Plants (No. Plants = 6,636)						
Net Generation (Thousand MWh)	59156	147.90	639.19	5.76	23.08	116.16
Capacity (MW)	59156	51.36	188.46	2.80	8.00	40.00
Plant Age	59156	30.37	32.55	4.00	17.00	52.00

Table 1 (continued): Summary Statistics

Panel B: State Characteristics

	N	Mean	Std. Dev.	P25	Median	P75
(No. States = 48)						
Net Generation (Million MWh)	912	82.33	75.58	34.20	57.92	113.12
CO2 Emission (Million Short Tons)	912	46.30	44.52	15.18	36.23	62.52
Net Generation of Traditional Plants (Million MWh)	912	56.06	58.36	19.28	40.47	78.21
Capacity of Traditional Plants (Thousand MW)	912	16.61	16.98	5.48	11.84	23.50
Net Generation of Renewable Plants (Million MWh)	912	9.92	16.58	1.98	4.46	9.28
Capacity of Renewable Plants (Thousand MW)	912	3.10	5.17	0.65	1.59	2.98
RPS State	912	0.49	0.50	0.00	0.00	1.00
Average Temperature (°F)	912	52.79	7.95	46.36	51.63	58.95
GDP (Billion USD)	912	307.40	396.66	79.01	184.92	353.67
Population (Billion)	912	6.16	6.97	1.82	4.22	6.64
Heating degree days (HDD)	912	5170.27	2109.04	3520.00	5360.00	6806.00
Cooling degree days (CDD)	912	1152.29	839.85	518.00	905.00	1651.00

Panel C: Firm Characteristics

	N	Mean	Std. Dev.	P25	Median	P75
(No. Firms = 510)						
No. Total Plants Owned	9690	5.90	19.22	0.00	1.00	3.00
No. Traditional Plants Owned	9690	2.48	6.60	0.00	0.00	2.00
No. Renewable Plants Owned	9690	3.22	15.07	0.00	0.00	1.00
Total Capacity Owned (MW)	9690	1370.58	5499.93	0.00	2.00	118.80
Traditional Capacity Owned (MW)	9690	1062.97	4332.54	0.00	0.00	45.48
Renewable Capacity Owned (MW)	9690	148.96	819.97	0.00	0.00	2.10
Market Value (Billion)	6122	26.16	59.03	1.50	5.63	23.03
Total Assets (Billion)	7285	56.89	179.94	2.52	9.99	35.51
Tobin's Q	6100	2.03	21.87	1.11	1.30	1.68
Leverage	7230	0.43	4.99	0.22	0.32	0.43
ROA	6586	-0.06	4.16	0.01	0.03	0.06
Market to Book Ratio	6100	9.37	575.04	1.30	1.87	2.94
Capex	6520	0.16	0.15	0.08	0.12	0.18
Sale (Billion)	6587	20.26	46.46	1.32	5.26	15.74
No. Operating States	9690	1.69	3.38	0.00	1.00	2.00
Whether Operates in Multiple States	9690	0.29	0.45	0.00	0.00	1.00

Table 2: Cap-and-Trade and the Reallocation of Power Plants

This table reports the effects of cap-and-trade programs on the asset reallocation of power plants within regulated states. The analysis is conducted in a staggered difference-in-differences framework exploiting the implementation of the California Cap-and-Trade program and the Regional Greenhouse Gas Initiative (RGGI). The sample period is 2001–2019. Panel A uses a state-year panel to examine generating capacity outcomes. Columns (1)–(4) report outcomes for traditional plants, and columns (5)–(8) report outcomes for renewable plants. *Log(Total Cap)* is the logarithm of total installed capacity, *Log(Cap Sold)* is the logarithm of capacity sold through ownership transactions, *Log(Cap Retired)* is the logarithm of retired capacity, and *Log(Cap Estab)* is the logarithm of newly established capacity. Panel B uses a plant-year panel and estimates linear probability models in which *Is Plant Sold* equals one if the plant is sold, or otherwise experiences an ownership change, in year $t + 1$. Columns (1)–(3) report estimates for traditional plants, while column (4) reports the corresponding estimate for renewable plants. *Regulated* is an indicator equal to one beginning in the year a cap-and-trade program is implemented in a state and in all subsequent years, and zero otherwise. *Dirty Fuel* is an indicator for coal- and oil-fired plants relative to natural-gas-fired plants. *Dirty Percentile* measures a traditional plant's relative dirtiness within its owner's portfolio in a given state-year. Plant-level controls include the logarithm of plant capacity (*Plant Cap*) and plant age (*Plant Age*). State-level controls include an indicator for whether the state has a Renewable Portfolio Standard (*RPS State*), the logarithm of state GDP (*GDP*), the logarithm of population (*Population*), average temperature (*Temperature*), heating degree days (*HDD*), and cooling degree days (*CDD*). All specifications include the fixed effects indicated in each column. Standard errors are clustered at the state level. t-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

Panel A: State-Year Outcomes

	Traditional Plants				Renewable Plants			
	Log(Total Cap)	Log(Cap Sold)	Log(Cap Retired)	Log(Cap Estab)	Log(Total Cap)	Log(Cap Sold)	Log(Cap Retired)	Log(Cap Estab)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Regulated	-0.005	0.342*	-0.608	0.291	-0.193	-0.924**	0.164	0.041
	(-0.11)	(1.72)	(-1.43)	(0.90)	(-0.59)	(-2.38)	(0.75)	(0.12)
RPS State	-0.153	0.160	0.260	0.341	0.411*	0.680*	0.027	0.861**
	(-1.22)	(1.17)	(0.82)	(1.00)	(1.84)	(1.75)	(0.19)	(2.59)
GDP	0.011	-0.140	-1.008	3.995***	0.851	2.137	0.001	0.359
	(0.05)	(-0.38)	(-0.76)	(3.03)	(1.05)	(1.05)	(0.00)	(0.26)
Population	-0.849	0.108	-5.127*	-2.627	-0.033	3.790	1.648	3.434
	(-0.41)	(0.08)	(-1.77)	(-0.87)	(-0.01)	(0.97)	(1.07)	(1.21)
Temperature	-1.024	1.826	-4.010	9.737**	0.530	-5.022	0.155	-6.512
	(-1.14)	(1.31)	(-0.69)	(2.30)	(0.75)	(-1.41)	(0.06)	(-1.37)
HDD	0.046	0.387**	-1.557	1.219	0.386	-0.506	-0.901	-2.070**
	(0.36)	(2.08)	(-1.09)	(1.05)	(1.66)	(-0.69)	(-1.13)	(-2.29)
CDD	-0.035	-0.087	0.482	-0.065	-0.045	0.062	-0.282	-0.346
	(-0.51)	(-1.14)	(0.78)	(-0.15)	(-0.50)	(0.17)	(-0.81)	(-0.74)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	912	912	912	912	912	912	912	912
Adj. R^2	0.94	0.91	0.31	0.52	0.93	0.71	0.33	0.51

Table 2 (continued)

Panel B: Plant-Year Outcomes

	Is Plant Sold			
	Traditional Plants			Renewable Plants
	(1)	(2)	(3)	(4)
Regulated	0.018*	0.008	0.052***	-0.028**
	(1.83)	(0.89)	(4.81)	(-2.47)
Dirty Fuel		0.039***		
		(3.09)		
Regulated × Dirty Fuel		0.042**		
		(2.14)		
Dirty Percentile			0.018	
			(0.69)	
Regulated × Dirty Percentile			0.046**	
			(2.08)	
Plant Cap	-0.040*	-0.038*	-0.044***	-0.012
	(-1.78)	(-1.74)	(-6.04)	(-0.78)
Plant Age	-0.003	-0.003	-0.005	0.014
	(-0.42)	(-0.43)	(-0.95)	(1.68)
RPS State	-0.003	-0.004	0.006	-0.023
	(-0.47)	(-0.59)	(0.97)	(-1.00)
GDP	-0.051	-0.051	-0.074	-0.127
	(-1.22)	(-1.20)	(-1.65)	(-1.66)
Population	-0.170**	-0.160**	0.067	-0.017
	(-2.38)	(-2.28)	(0.85)	(-0.13)
Temperature	-0.201	-0.196	-0.247*	-0.182
	(-1.65)	(-1.62)	(-1.86)	(-1.02)
HDD	-0.035	-0.039	-0.056	-0.005
	(-0.96)	(-1.10)	(-1.41)	(-0.15)
CDD	0.007	0.008	0.014	0.011
	(0.43)	(0.50)	(0.74)	(0.55)
Year FE	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes
Obs.	49,858	49,858	46,832	55,507
R^2	0.50	0.50	0.15	0.60

Table 3: Carbon Exposure, Upgrading Capability, and the Reallocation of Power Plants

This table examines whether firms' carbon exposure and upgrading capability shape their asset reallocation responses to cap-and-trade programs within regulated states. The analysis is conducted in a staggered difference-in-differences framework exploiting the implementation of the California Cap-and-Trade Program and the Regional Greenhouse Gas Initiative (RGGI). The sample period is 2001–2019. Panel A reports firm-state-year regressions of net sales of traditional and renewable power plants. Panel B reports firm-state-year regressions of capacity holdings, measured as the logarithm of traditional capacity and the logarithm of renewable capacity. In each panel, columns (1)–(3) report outcomes for traditional plants, and columns (4)–(6) report outcomes for renewable plants. *Regulated* is an indicator equal to one beginning in the year a cap-and-trade program is implemented in a state and in all subsequent years, and zero otherwise. The interacted variables are measured using firms' average values over the three years before the relevant cap-and-trade program is implemented. *%Trad Cap* is the firm's pre-implementation average traditional capacity share, *CO_2 Intensity* is the firm's pre-implementation average carbon intensity of generation, and *Log(Green Patents)* is the logarithm of the firm's pre-implementation average green patents and proxies for upgrading capability. Firm-level controls include market value, total assets, Tobin's Q, leverage, return on assets, market-to-book ratio, capital expenditures, and sales. State-level controls include an indicator for whether the state has a Renewable Portfolio Standard, the logarithm of state GDP, the logarithm of population, average temperature, heating degree days, and cooling degree days. All specifications include the fixed effects indicated in each column. Standard errors are clustered at the state level. *t*-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

Panel A: Net Asset Sales

	Trad Net Sale			Renew Net Sale		
	(1)	(2)	(3)	(4)	(5)	(6)
Regulated	-0.003	0.001	0.004**	0.004***	0.004***	0.005***
	(-1.01)	(0.56)	(2.28)	(2.81)	(2.90)	(3.66)
Regulated × %Trad Cap	0.071**			0.002		
	(2.33)			(0.49)		
Regulated × CO_2 Intensity		0.164**			0.015	
		(2.55)			(0.87)	
Regulated × Log (Green Patents)			-0.001***			-0.001***
			(-3.49)			(-4.38)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	183,424	183,424	183,424	183,424	183,424	183,424
Adj. R^2	0.02	0.02	0.02	0.01	0.01	0.01

Table 3 (continued)

Panel B: Capacity Holdings

	Log (Trad Cap)			Log (Renew Cap)		
	(1)	(2)	(3)	(4)	(5)	(6)
Regulated	0.028**	0.024**	0.009	0.021	0.022	0.015
	(2.50)	(2.20)	(0.86)	(1.38)	(1.54)	(1.02)
Regulated × %Trad Cap	-0.152***			-0.019		
	(-4.44)			(-0.72)		
Regulated × CO_2 Intensity		-0.546***			-0.166	
		(-3.78)			(-1.10)	
Regulated × Log (Green Patents)			0.006**			0.004***
			(2.46)			(2.85)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	183,424	183,424	183,424	183,424	183,424	183,424
Adj. R^2	0.11	0.11	0.11	0.12	0.12	0.12

Table 4: Cap-and-Trade and Post-Sale Operating Performance of Traditional Plants

This table examines whether traditional plants that are sold after cap-and-trade implementation experience differential post-sale operating outcomes. The analysis is conducted in a staggered difference-in-differences framework exploiting the implementation of the California Cap-and-Trade Program and the Regional Greenhouse Gas Initiative (RGGI). The sample consists of traditional plant-year observations over 2001–2019. *Log(CO_2)* measures the logarithm of plant-level carbon emissions, *Log(Gen)* measures the logarithm of plant-level electricity generation, and *Log(CO_2 Intensity)* measures the logarithm of carbon emissions per unit of electricity generation. *Regulated* is an indicator equal to one beginning in the year a cap-and-trade program is implemented in a state and in all subsequent years, and zero otherwise. *Acquired* is an indicator equal to one beginning in the year a plant is first sold to, or acquired by, another owner in the sample and in all subsequent years, and zero otherwise. The interaction *Regulated* × *Acquired* captures the differential post-sale outcomes of acquired traditional plants in regulated states relative to non-acquired traditional plants. Plant-level controls include the logarithm of plant capacity (*Plant Cap*) and plant age (*Plant Age*). State-level controls include an indicator for whether the state has a Renewable Portfolio Standard (*RPS State*), the logarithm of state GDP (*GDP*), the logarithm of population (*Population*), average temperature (*Temperature*), heating degree days (*HDD*), and cooling degree days (*CDD*). All specifications include plant and year fixed effects. Standard errors are clustered at the state level. *t*-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

	Log(CO_2)	Log(Gen)	Log(CO_2 Intensity)
	(1)	(2)	(3)
Regulated	-0.202	-0.285*	0.083**
	(-1.45)	(-1.87)	(2.56)
Acquired	0.010	-0.003	0.013
	(0.22)	(-0.07)	(1.29)
Regulated × Acquired	-0.101	-0.042	-0.059***
	(-0.72)	(-0.30)	(-3.06)
Plant Cap	1.171***	1.448***	-0.277***
	(12.87)	(15.47)	(-5.59)
Plant Age	0.504***	0.492***	0.012
	(9.03)	(8.94)	(1.12)
RPS State	0.001	0.011	-0.010
	(0.01)	(0.19)	(-0.70)
GDP	-0.286	-0.181	-0.106
	(-0.99)	(-0.58)	(-1.26)
Population	-0.703	-0.754	0.051
	(-1.26)	(-1.26)	(0.29)
Temperature	1.772***	1.888***	-0.117
	(4.11)	(3.69)	(-0.57)
HDD	0.112	0.105	0.007
	(0.97)	(0.93)	(0.13)
CDD	0.426***	0.425***	0.001
	(4.34)	(3.76)	(0.05)
Year FE	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes
Obs.	20,369	20,369	20,369
Adj. R^2	0.91	0.90	0.72

Table 5: Cap-and-Trade Exposure and Portfolio Reallocation Outside Regulated States

This table examines whether exposure to cap-and-trade programs changes electricity producers' generation portfolios in states that are not directly regulated by carbon markets. The analysis is conducted in a staggered difference-in-differences framework exploiting the implementation of the California Cap-and-Trade Program and the Regional Greenhouse Gas Initiative (RGGI). The sample consists of firm-state-year observations in unregulated states over 2001–2019. Columns (1)–(2) use *Log(No. Trad Plants)*, the logarithm of the number of traditional plants owned by a producer in a state-year, as the dependent variable. Columns (3)–(4) use *Log(Trad Cap)*, the logarithm of total installed traditional capacity. Columns (5)–(6) use *Log(No. Renew Plants)*, the logarithm of the number of renewable plants owned by a producer in a state-year. Columns (7)–(8) use *Log(Renew Cap)*, the logarithm of total installed renewable capacity. Traditional plants include coal-, oil-, and natural-gas-fired plants. Renewable plants include wind, solar, hydro, geothermal, and biomass plants. *Exposed* equals one after cap-and-trade implementation for producers that owned at least one plant in a cap-and-trade state before the program was implemented, and zero otherwise. Firm-level controls include market value, total assets, Tobin's Q, leverage, return on assets (ROA), market-to-book ratio, capital expenditures (CAPEX), and sales. State-level controls include an indicator for whether the state has a Renewable Portfolio Standard (*RPS State*), the logarithm of state GDP (*GDP*), the logarithm of population (*Population*), average temperature (*Temperature*), heating degree days (*HDD*), and cooling degree days (*CDD*). All specifications include firm fixed effects. Odd-numbered columns include state and year fixed effects and state-level controls, while even-numbered columns include state-by-year fixed effects. *t*-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

	Log(No.Trad Plants)		Log (Trad Cap)		Log(No.Renew Plants)		Log (Renew Cap)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposed	-0.004**	-0.004**	-0.040***	-0.040***	0.018***	0.018***	0.059***	0.059***
	(-2.67)	(-2.67)	(-3.89)	(-3.89)	(5.28)	(5.28)	(4.85)	(4.86)
Market Value	-0.000	-0.000	-0.005**	-0.005**	-0.000	-0.000	-0.001	-0.001
	(-0.90)	(-0.90)	(-2.05)	(-2.05)	(-0.38)	(-0.38)	(-0.65)	(-0.65)
Total Asset	0.005***	0.005***	0.029***	0.029***	0.006***	0.006***	0.026***	0.026***
	(4.10)	(4.10)	(4.95)	(4.95)	(5.32)	(5.32)	(6.42)	(6.42)
Tobin's *Q*	0.000	0.000	0.001**	0.001**	0.000	0.000	0.001***	0.001***
	(1.22)	(1.22)	(2.45)	(2.45)	(1.14)	(1.14)	(3.00)	(3.00)
Leverage	-0.002***	-0.002***	-0.008***	-0.008***	-0.004***	-0.004***	-0.015***	-0.015***
	(-4.04)	(-4.04)	(-5.11)	(-5.11)	(-6.43)	(-6.43)	(-5.90)	(-5.90)
ROA	-0.004***	-0.004***	-0.020***	-0.020***	-0.008***	-0.008***	-0.030***	-0.030***
	(-4.22)	(-4.22)	(-5.18)	(-5.18)	(-5.70)	(-5.70)	(-5.20)	(-5.20)
Market To Book	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(4.18)	(4.18)	(4.69)	(4.69)	(4.55)	(4.55)	(3.27)	(3.27)
CAPEX	0.001	0.001	0.011*	0.011*	0.005***	0.005***	0.019***	0.019***
	(1.35)	(1.35)	(1.94)	(1.94)	(3.53)	(3.53)	(4.06)	(4.06)
Sale	0.000*	0.000*	0.000***	0.000***	0.000	0.000	0.000*	0.000*
	(1.94)	(1.94)	(3.13)	(3.13)	(1.44)	(1.44)	(1.98)	(1.98)
RPS State	0.001		0.009		0.007**		0.025**	
	(0.87)		(0.91)		(2.22)		(2.04)	
GDP	0.001		0.009		-0.003		0.023	
	(0.18)		(0.22)		(-0.20)		(0.49)	
Population	0.008		0.048		0.086**		0.217	
	(0.46)		(0.44)		(2.44)		(1.64)	
Temperature	0.001		0.005		-0.014		-0.003	
	(0.09)		(0.10)		(-0.67)		(-0.05)	
HDD	-0.002		-0.016		-0.005		0.006	
	(-0.58)		(-0.82)		(-0.85)		(0.24)	
CDD	-0.002**		-0.009**		0.001		-0.001	
	(-2.42)		(-2.49)		(0.68)		(-0.12)	
State×Year FE	No	Yes	No	Yes	No	Yes	No	Yes
State FE	Yes	No	Yes	No	Yes	No	Yes	No
Year FE	Yes	No	Yes	No	Yes	No	Yes	No
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	236,837	236,837	236,837	236,837	236,793	236,793	236,837	236,837
Adj. R^2	0.07	0.07	0.09	0.09	0.08	0.08	0.09	0.09

Table 6: Carbon Exposure, Upgrading Capability, and Portfolio Reallocation Outside Regulated States

This table examines whether firms' carbon exposure and upgrading capability shape portfolio reallocation in states that are not directly regulated by cap-and-trade programs. The analysis is conducted in a staggered difference-in-differences framework exploiting the implementation of the California Cap-and-Trade Program and the Regional Greenhouse Gas Initiative (RGGI). The sample consists of firm-state-year observations in unregulated states over 2001–2019. Columns (1)–(3) use *Log(Trad Cap)*, the logarithm of traditional capacity owned by a producer in an unregulated state-year, as the dependent variable. Columns (4)–(6) use *Log(Renew Cap)*, the logarithm of renewable capacity owned by a producer in an unregulated state-year. *Exposed* equals one after cap-and-trade implementation for producers that owned at least one plant in a cap-and-trade state before the program was implemented, and zero otherwise. The interacted variables are measured using firms' average values over the three years before the relevant cap-and-trade program is implemented. $\%Trad\ Cap_{unreg}$ is the firm's pre-implementation average traditional capacity share in unregulated states, $CO_2\ Intensity_{unreg}$ is the firm's pre-implementation average carbon intensity of generation in unregulated states, and *Log(Green Patents)* is the logarithm of the firm's pre-implementation average green patents and proxies for upgrading capability. Firm-level controls include market value, total assets, Tobin's Q, leverage, return on assets, market-to-book ratio, capital expenditures, and sales. State-level controls include an indicator for whether the state has a Renewable Portfolio Standard, the logarithm of state GDP, the logarithm of population, average temperature, heating degree days, and cooling degree days. All specifications include the fixed effects indicated in each column. Standard errors are clustered at the state level. *t*-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

	Log (Trad Cap)			Log (Renew Cap)		
	(1)	(2)	(3)	(4)	(5)	(6)
Exposed	0.001	-0.009	-0.054***	0.055***	0.036***	0.061***
	(0.18)	(-1.31)	(-3.40)	(4.03)	(3.51)	(4.77)
Exposed × %Trad Cap_{unreg}	-0.089***			0.009		
	(-3.33)			(0.56)		
Exposed × CO_2 Intensity_{unreg}		-0.145***			0.114***	
		(-3.24)			(3.59)	
Exposed × Log (Green Patents)			0.005**			-0.000
			(2.03)			(-1.57)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	201,724	201,724	201,724	201,724	201,724	201,724
Adj. R^2	0.09	0.09	0.09	0.13	0.13	0.13

Table 7: Carbon Exposure, Upgrading Capability, and Self-Generation

This table examines whether firms' carbon exposure and upgrading capability shape their self-generation responses to cap-and-trade programs. The sample includes firms that supply electricity to customers during the sample period, 2001–2019. The dependent variable, *%Self-Gen*, measures the percentage of electricity supplied to customers that is generated by the firm's own power plants. *Exposed* equals one after cap-and-trade implementation for producers that owned at least one plant in a cap-and-trade state before the program was implemented, and zero otherwise. The interacted variables are measured using firms' average values over the three years before the relevant cap-and-trade program is implemented. *CO_2 Intensity* is the firm's pre-implementation average carbon intensity of generation, *%Trad Cap* is the firm's pre-implementation average traditional capacity share, and *Log(Green Patents)* is the logarithm of the firm's pre-implementation average green patents and proxies for upgrading capability. Firm-level and state-level controls are included. All specifications include firm, state, and year fixed effects. Standard errors are clustered at the state level. *t*-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

	%Self-Gen		
	(1)	(2)	(3)
Exposed	0.003	0.006	-0.017
	(0.41)	(0.90)	(-1.55)
Exposed × CO_2 Intensity	-0.099**		
	(-2.21)		
Exposed × %Trad Cap		-0.034*	
		(-1.68)	
Exposed × Log (Green Patents)			0.005**
			(2.17)
Firm Controls	Yes	Yes	Yes
State Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
State FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Obs.	8,116	8,116	8,116
Adj. R^2	0.75	0.74	0.74

Table 8: Cap-and-Trade Exposure and Firm-Level Outcomes

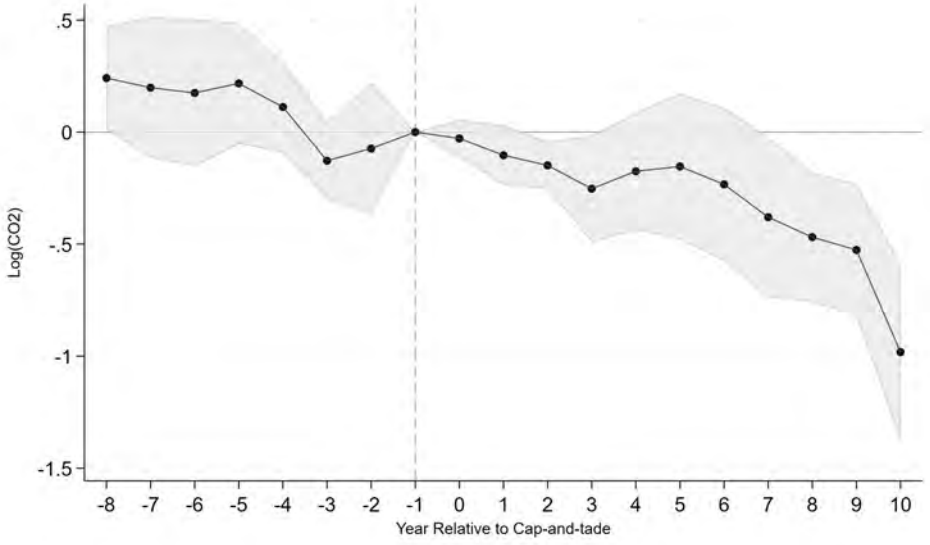
This table reports the effects of cap-and-trade exposure on firm-level innovation, investment, ESG, profitability, leverage, and valuation outcomes. The analysis is conducted in a staggered difference-in-differences framework exploiting the implementation of the California Cap-and-Trade Program and the Regional Greenhouse Gas Initiative (RGGI). The sample consists of firm-year observations over 2001–2019. *Exposed* equals one after cap-and-trade implementation for producers that owned at least one plant in a cap-and-trade state before the program was implemented, and zero otherwise. *Green Patents* measures the logarithm of the number of green patents filed by the firm. *Total Assets* measures firm size as the logarithm of total assets. *CAPEX* measures capital expenditures scaled by total assets. *ESG Score* measures the firm's environmental, social, and governance rating. *ROA* measures return on assets. *Leverage* measures the ratio of total debt to total assets. *Tobin's Q* measures the market value of assets relative to their book value. Control variables are included with one-year lags. All specifications include firm and year fixed effects. Standard errors are clustered at the state level. t-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

	Green Patents	Total Assets	CAPEX	ESG Score	ROA	Leverage	Tobin's Q
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Exposed	0.093**	0.025*	0.018*	-0.167	0.014	-0.007	-0.021
	(2.20)	(1.89)	(1.94)	(-0.53)	(0.12)	(-0.07)	(-0.05)
Total Asset$_{t-1}$	-0.006	0.761***	-0.031***	-0.162	2.338	-2.103	-9.615
	(-0.16)	(30.96)	(-2.70)	(-0.60)	(1.37)	(-1.38)	(-1.44)
Tobin's Q_{t-1}	-0.071**	0.048***	0.013***	0.092	2.271	-2.061	-8.003
	(-2.49)	(3.45)	(2.77)	(1.34)	(1.28)	(-1.28)	(-1.23)
Leverage$_{t-1}$	0.019	-0.163***	0.009	0.051	-6.593**	6.451***	23.065**
	(0.53)	(-4.14)	(0.50)	(0.06)	(-2.45)	(2.63)	(2.42)
ROA$_{t-1}$	-0.260**	-0.072	0.099***	-0.570	2.779	-2.540	-9.715
	(-2.57)	(-0.97)	(3.68)	(-0.91)	(0.90)	(-0.91)	(-0.87)
Market To Book$_{t-1}$	0.000**	-0.000	-0.000	0.006*	0.000*	-0.000*	-0.000*
	(2.11)	(-0.90)	(-0.13)	(1.84)	(1.76)	(-1.85)	(-1.83)
Market Value$_{t-1}$	0.063**	0.066***	0.015**	0.041	-1.301	1.174	5.768
	(2.05)	(4.32)	(2.36)	(0.22)	(-1.38)	(1.39)	(1.41)
CAPEX$_{t-1}$	-0.041	0.087**	0.186***	1.006	-0.737	0.878	2.337
	(-0.75)	(1.97)	(3.93)	(1.16)	(-0.67)	(0.74)	(0.59)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	4,747	4,664	4,378	3,163	4,391	4,657	4,378
Adj. R^2	0.86	0.99	0.44	0.52	0.60	0.67	0.57

Appendix A. Appendix Figures and Tables

Figure A.1: Dynamic Effects of Cap-and-Trade on Traditional Plant Operations

This figure plots the dynamic differences-in-differences estimates of the effects of cap-and-trade programs on power plant operations. The estimates are obtained from an event-study specification of the staggered difference-in-differences model that exploits the implementation of the California Cap-and-Trade program and the Regional Greenhouse Gas Initiative (RGGI). The horizontal axis shows years relative to the implementation of cap-and-trade, where year 0 denotes the first year the program becomes effective. The top panel reports the estimated effects on the logarithm of plant-level CO_2 emissions (*Log(*CO_2*)*), and the bottom panel reports the estimated effects on the logarithm of plant-level electricity generation (*Log(Gen)*). The sample includes traditional plants observed from 2001 to 2019. Points represent coefficient estimates for each relative year, and shaded areas denote 95% confidence intervals. The omitted category is the year immediately preceding the policy implementation (year −1). All specifications include plant and year fixed effects, and standard errors are clustered at the state level.



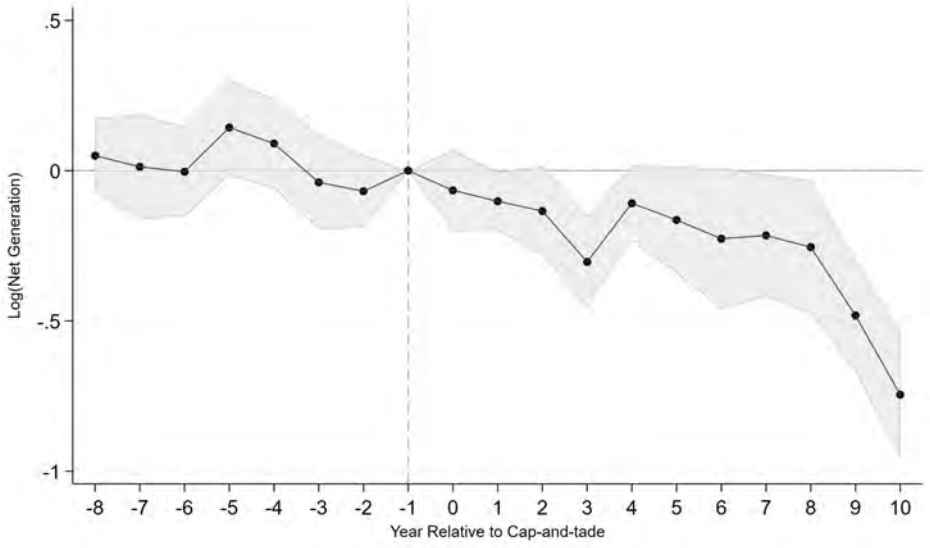


Table A.1: Institutional Features of RGGI and California Cap-and-Trade Programs

	RGGI	**California Cap-and-Trade**
Launch year	2009	2013
Jurisdictions	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey (withdrew in 2012), New York, Rhode Island, Vermont, Pennsylvania (2022), Virginia (2021)	California
Industry coverage	Power sector only	Power, industrial facilities, transport, buildings, mining and agriculture
Inclusion threshold	Traditional plants with capacity $\geq$ 25 MW	Units emitting $\geq$ 25,000 metric tons CO_2e annually
Allowance allocation	Mostly auctioned (>90%); limited free allocation	Auction; free allocation to emissions-intensive trade-exposed industries; utilities receive allowances on behalf of ratepayers
Auction price	Around \$4 per short ton of CO_2 during sample period	Around \$15 per metric ton of CO_2e during sample period
Offset credits	Up to 3.3% of compliance obligation	Initially 8%; reduced to 4% (2021–2025) and 6% thereafter

Table A.2: Cap-and-Trade and Power Plant Operations

This table reports the estimated effects of cap-and-trade programs on power plant operations. The analysis is conducted in a staggered difference-in-differences framework exploiting the implementation of the California Cap-and-Trade program and the Regional Greenhouse Gas Initiative (RGGI). The sample period spans from year 2001 to 2019. Panel A presents state-year regressions examining the impact of cap-and-trade implementation on aggregate electricity sector outcomes. *Log(Total CO_2)* measures the logarithm of total CO_2 emissions from electricity generation within a state. *Log(Total Gen)* denotes the logarithm of total electricity generation. *Log(Trad Gen)* measures the logarithm of electricity generation from traditional plants, including coal-, oil-, and natural-gas-fired plants. *Log(Renew Gen)* measures the logarithm of electricity generation from renewable plants, including wind, solar, hydro, geothermal, and biomass plants. Panel B reports plant-year regressions for traditional plants, examining how cap-and-trade affects plant-level operations. *Log(CO_2)* is the logarithm of plant-level CO_2 emissions, *Log(Gen)* is the logarithm of plant-level electricity generation, and *Log(CO_2 Intensity)* measures emissions intensity, defined as the logarithm of CO_2 emissions per unit of electricity generation. *Regulated* is an indicator equal to one beginning in the year a cap-and-trade program is implemented in a state and in all subsequent years, and zero otherwise. *Dirty Fuel* is an indicator for coal- and oil-fired plants relative to natural-gas-fired plants. Plant-level control variables include the logarithm of plant capacity (*Plant Cap*) and plant age (*Plant Age*). State-level control variables include an indicator for whether the state has a Renewable Portfolio Standard (*RPS State*), the logarithm of state GDP (*GDP*), the logarithm of population (*Population*), average temperature (*Temperature*), heating degree days (*HDD*), and cooling degree days (*CDD*). All specifications include the fixed effects indicated in each column. Standard errors are clustered at the state level. *t*-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

Panel A: State Level Outcomes

	Log(Total CO2)	Log(Total Gen)	Log(Trad Gen)	Log(Renew Gen)
	(1)	(2)	(3)	(4)
Regulated	-0.247***	-0.150**	-0.267**	0.350
	(-3.12)	(-2.37)	(-2.17)	(0.40)
RPS State	-0.041	0.001	-0.034	0.900*
	(-0.95)	(0.03)	(-0.50)	(1.94)
GDP	0.089	0.150	-0.149	-0.615
	(0.53)	(1.24)	(-0.78)	(-0.27)
Population	0.233	0.679*	0.822	8.077
	(0.44)	(1.88)	(1.12)	(1.17)
Temperature	-0.252	0.035	0.593	2.290
	(-0.56)	(0.07)	(1.02)	(1.44)
HDD	-0.142	-0.065	-0.222*	1.305**
	(-1.29)	(-1.02)	(-1.75)	(2.41)
CDD	0.045	0.004	0.011	0.028
	(1.06)	(0.13)	(0.20)	(0.16)
Year FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Obs.	912	912	912	912
Adj. R^2	0.99	0.99	0.98	0.84

Panel B: Traditional Power Plant Level Outcomes

	Log(CO2)		Log(Gen)		Log(CO2 Intensity)	
	(1)	(2)	(3)	(4)	(5)	(6)
Regulated	-0.278***	-0.139*	-0.200***	-0.109*	0.035	0.043
	(-3.48)	(-1.78)	(-3.00)	(-1.79)	(1.54)	(1.29)
Dirty Fuel		0.530***		-0.268***		0.425***
		(4.47)		(-2.83)		(9.01)
Regulated × Dirty Fuel		-0.786***		-0.393***		-0.015
		(-6.69)		(-3.52)		(-0.29)
Plant Cap	1.181***	1.194***	1.567***	1.551***	-0.278***	-0.252***
	(13.31)	(13.63)	(11.89)	(11.35)	(-5.62)	(-5.59)
Plant Age	0.514***	0.457***	0.391***	0.391***	0.013	-0.018*
	(8.79)	(8.01)	(6.71)	(6.40)	(1.25)	(-1.75)
RPS State	-0.003	-0.005	-0.087	-0.084	-0.009	-0.013
	(-0.05)	(-0.09)	(-1.22)	(-1.20)	(-0.66)	(-0.95)
GDP	-0.318	-0.443	-0.491	-0.519	-0.107	-0.153*
	(-1.02)	(-1.39)	(-1.22)	(-1.29)	(-1.27)	(-1.87)
Population	-0.564	-0.420	0.691	0.666	0.054	0.109
	(-0.91)	(-0.67)	(0.75)	(0.73)	(0.30)	(0.65)
Temperature	2.123***	2.267***	1.285**	1.276**	-0.109	0.020
	(3.72)	(3.94)	(2.15)	(2.19)	(-0.53)	(0.10)
HDD	0.133	0.185*	0.148	0.191	0.006	0.014
	(1.18)	(1.89)	(0.98)	(1.45)	(0.12)	(0.27)
CDD	0.416***	0.401***	0.433***	0.425***	0.000	-0.006
	(4.15)	(4.01)	(5.26)	(5.22)	(0.01)	(-0.26)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	20,507	20,507	44,377	44,377	20,369	20,369
Adj. R^2	0.90	0.90	0.94	0.95	0.72	0.73

Table A.3: Program-Specific Effects on Traditional Plant Operations

This table reports the estimated effects of each cap-and-trade program on power plant operations. The analysis employs a staggered difference-in-differences framework that exploits the implementation of the California Cap-and-Trade program or the Regional Greenhouse Gas Initiative (RGGI). The sample period spans 2001–2019. Columns (1)–(2) examine the impact of California's cap-and-trade program, while Columns (3)–(4) analyze the effects of RGGI. *Regulated_CA* equals one for plants located in California in years after the implementation of the cap-and-trade program in 2013. *Regulated_RGGI* equals one for plants located in RGGI states in years after the program began in 2009. *Over_Threshold_CA* is an indicator equal to one if a plant's baseline emissions exceed the regulatory threshold of 25,000 metric tons of CO_2e in the year prior to the implementation of California's cap-and-trade program. Plant-level control variables include the logarithm of plant capacity (*Plant Cap*) and plant age (*Plant Age*). State-level control variables include an indicator for whether the state has a Renewable Portfolio Standard (*RPS State*), the logarithm of state GDP (*GDP*), the logarithm of population (*Population*), average temperature (*Temperature*), heating degree days (*HDD*), and cooling degree days (*CDD*). All specifications include plant and year fixed effects. Standard errors are clustered at the state level. *t*-statistics are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	California		RGGI	
	Log(CO2)	Log(Gen)	Log(CO2)	Log(Gen)
	(1)	(2)	(3)	(4)
Regulated_CA	-0.188**	-0.170**		
	(-2.60)	(-2.30)		
Regulated_RGGI			-0.356***	-0.424***
			(-3.85)	(-4.61)
Regulated_CA × Over_Threshold_CA	-0.075***	-0.120***		
	(-3.23)	(-5.29)		
Plant Cap	1.174***	1.413***	1.198***	1.452***
	(11.60)	(13.84)	(12.68)	(15.27)
Plant Age	0.537***	0.511***	0.552***	0.522***
	(8.35)	(8.41)	(9.46)	(8.99)
RPS State	-0.039	-0.018	-0.006	0.003
	(-0.63)	(-0.33)	(-0.10)	(0.06)
GDP	-0.232	-0.069	-0.185	-0.015
	(-0.74)	(-0.21)	(-0.60)	(-0.05)
Population	-0.880	-1.041	-0.707	-0.919
	(-1.27)	(-1.53)	(-1.13)	(-1.53)
Temperature	1.920***	1.653***	2.046***	1.804***
	(3.01)	(3.01)	(3.48)	(3.27)
HDD	0.180	0.163	0.183*	0.185**
	(1.41)	(1.31)	(1.95)	(2.13)
CDD	0.499***	0.514***	0.325***	0.326***
	(4.70)	(4.16)	(3.96)	(3.53)
Year FE	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes
Obs.	17,372	17,294	19,347	19,379
Adj. R^2	0.91	0.89	0.90	0.90

Table A.4: Cap-and-Trade and Power Plant Transactions Across Owner Types

This table examines how cap-and-trade programs affect transactions of power plants across different owner types within regulated states. The analysis is conducted in a staggered difference-in-differences framework exploiting the implementation of the California Cap-and-Trade program and the Regional Greenhouse Gas Initiative (RGGI). The sample period spans from year 2001 to 2019. Panel A reports results for traditional plants, while Panel B reports results for renewable plants. Each column corresponds to a different seller-buyer ownership pair, including investor-owned utilities (IOUs), government-owned utilities, and independent power producers (IPPs). The dependent variables are indicators equal to one if the buyer (seller) belongs to the corresponding ownership type and zero otherwise. *Regulated* is an indicator equal to one beginning in the year a cap-and-trade program is implemented and in all subsequent years, and zero otherwise. Plant-level control variables include the logarithm of plant capacity and plant age. State-level control variables include an indicator for *RPS State*, the logarithm of GDP, population, temperature, heating degree days (HDD), and cooling degree days (CDD). All specifications include the fixed effects indicated in each column. t-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

Panel A: Transactions of Traditional Power Plants

	Seller Is IOU	Seller Is Gov	Seller Is IPP	Buyer Is IOU	Buyer Is Gov	Buyer Is IPP
	(1)	(2)	(3)	(4)	(5)	(6)
Regulated	-0.062	-0.004	0.190**	-0.042	-0.010**	0.106
	(-0.76)	(-0.61)	(2.07)	(-0.57)	(-2.07)	(0.87)
Plant Cap	0.023	-0.001	-0.030**	0.032*	-0.001	-0.027*
	(1.42)	(-0.59)	(-2.16)	(1.82)	(-1.07)	(-1.92)
Plant Age	0.089***	-0.002	-0.035*	0.050**	0.003	-0.015
	(4.98)	(-1.55)	(-1.69)	(2.57)	(1.16)	(-0.64)
RPS State	0.146	-0.004	-0.145	0.057	-0.014*	-0.046
	(1.02)	(-0.59)	(-1.10)	(0.37)	(-1.79)	(-0.27)
GDP	-0.351	-0.091	0.958	-0.082	-0.101	0.789
	(-0.46)	(-1.06)	(1.06)	(-0.11)	(-0.99)	(0.88)
Population	1.562	-0.019	-1.460	1.401	0.062	-1.803
	(1.05)	(-0.14)	(-0.97)	(0.91)	(0.44)	(-1.33)
Temperature	-4.160	-0.226	5.422**	-1.310	-0.431	1.829
	(-1.36)	(-0.60)	(2.12)	(-0.65)	(-0.96)	(0.94)
HDD	-0.727	-0.224**	0.872**	-0.522	-0.194*	0.848**
	(-1.59)	(-2.25)	(2.32)	(-1.58)	(-1.88)	(2.69)
CDD	0.142	0.018	-0.492**	-0.122	-0.023	0.156
	(0.70)	(0.64)	(-2.32)	(-0.62)	(-0.45)	(0.71)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	820	820	820	820	820	820
Adj. R^2	0.38	0.10	0.35	0.39	0.07	0.32

Panel B: Transactions of Renewable Power Plants

	Seller Is IOU	Seller Is Gov	Seller Is IPP	Buyer Is IOU	Buyer Is Gov	Buyer Is IPP
	(1)	(2)	(3)	(4)	(5)	(6)
Regulated	-0.034	-0.070**	-0.034	0.030	-0.070**	0.060
	(-0.49)	(-2.62)	(-0.25)	(0.33)	(-2.62)	(0.38)
Plant Cap	-0.008	0.001	-0.011	-0.007	0.001	-0.002
	(-0.89)	(0.48)	(-0.59)	(-0.81)	(0.48)	(-0.13)
Plant Age	0.044**	0.005	-0.020	0.046**	0.005	-0.023
	(2.43)	(1.49)	(-1.06)	(2.45)	(1.49)	(-0.95)
RPS State	0.001	-0.023	-0.020	0.033	-0.023	-0.225**
	(0.01)	(-1.10)	(-0.17)	(0.48)	(-1.10)	(-2.49)
GDP	-0.103	0.244*	-0.591	-0.200	0.244*	-0.946
	(-0.26)	(1.81)	(-0.83)	(-0.54)	(1.81)	(-1.26)
Population	0.309	-0.350*	2.808***	0.189	-0.350*	3.292***
	(0.42)	(-1.76)	(2.88)	(0.25)	(-1.76)	(2.73)
Temperature	-2.586	1.418	5.490**	-3.442**	1.418	5.148**
	(-1.47)	(1.59)	(2.03)	(-2.03)	(1.59)	(2.46)
HDD	-0.394	0.309	1.001**	-0.582*	0.309	1.036**
	(-1.37)	(1.54)	(2.41)	(-1.85)	(1.54)	(2.67)
CDD	0.216	-0.051	-0.028	0.162	-0.051	-0.319
	(1.35)	(-0.83)	(-0.09)	(0.93)	(-0.83)	(-1.08)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	830	830	830	830	830	830
Adj. R^2	0.33	0.12	0.21	0.50	0.12	0.34

Table A.5: Cap-and-Trade Exposure and Power Plant Operations Outside Regulated States

This table reports the spillover effects of cap-and-trade programs on electricity producers' operational outcomes in states that are not directly regulated by carbon markets. The analysis is conducted in a staggered difference-in-differences framework exploiting the implementation of the California Cap-and-Trade program and the Regional Greenhouse Gas Initiative (RGGI). The sample includes only firm–state–year observations in unregulated states. The sample period spans from year 2001 to 2019. *Log(Trad Gen)* measures the logarithm of electricity generation from traditional power plants owned by the producer, *Log(Trad CO_2)* measures the logarithm of carbon emissions from those traditional plants, and *Log(Renew Gen)* measures the logarithm of electricity generation from renewable plants. *Exposed* equals one after cap-and-trade implementation for producers that owned at least one plant in a cap-and-trade state before the program was implemented, and zero otherwise. Firm-level control variables include market value, total assets, Tobin's Q, leverage, return on assets (ROA), market-to-book ratio, capital expenditures (CAPEX), and sales. State-level control variables include an indicator for whether the state has a Renewable Portfolio Standard (*RPS State*), the logarithm of state GDP (*GDP*), the logarithm of population (*Population*), average temperature (*Temperature*), heating degree days (*HDD*), and cooling degree days (*CDD*). All specifications include the fixed effects indicated in each column. *t*-statistics are reported in parentheses. Statistical significance is denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

	Log (Trad Gen)		Log (Trad CO2)		Log (Renew Gen)	
	(1)	(2)	(3)	(4)	(5)	(6)
Exposed	-0.078***	-0.078***	-0.052***	-0.052***	0.167***	0.167***
	(-3.48)	(-3.48)	(-2.92)	(-2.92)	(5.22)	(5.23)
Market Value	-0.008	-0.008	-0.015**	-0.015**	-0.004	-0.004
	(-1.32)	(-1.32)	(-2.66)	(-2.66)	(-0.70)	(-0.70)
Total Asset	0.062***	0.062***	0.045***	0.045***	0.074***	0.074***
	(4.49)	(4.49)	(4.86)	(4.86)	(6.68)	(6.68)
Tobin's Q	0.001**	0.001**	0.001**	0.001**	0.002**	0.002**
	(2.03)	(2.03)	(2.60)	(2.60)	(2.56)	(2.56)
Leverage	-0.017***	-0.017***	-0.016***	-0.016***	-0.042***	-0.042***
	(-3.79)	(-3.79)	(-5.88)	(-5.88)	(-6.02)	(-6.02)
ROA	-0.040***	-0.040***	-0.035***	-0.035***	-0.085***	-0.085***
	(-4.06)	(-4.06)	(-5.27)	(-5.27)	(-5.26)	(-5.26)
Market To Book	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(4.36)	(4.36)	(3.65)	(3.65)	(3.65)	(3.65)
CAPEX	0.020	0.020	0.021**	0.021**	0.052***	0.052***
	(1.38)	(1.38)	(2.37)	(2.37)	(3.47)	(3.47)
Sale	0.000***	0.000***	0.000	0.000	0.000*	0.000*
	(3.25)	(3.25)	(1.66)	(1.66)	(1.92)	(1.92)
RPS State	0.017		0.021		0.073**	
	(0.88)		(1.15)		(2.33)	
GDP	0.030		-0.014		0.001	
	(0.36)		(-0.21)		(0.01)	
Population	0.056		0.054		0.780**	
	(0.25)		(0.37)		(2.32)	
Temperature	0.115		0.004		-0.000	
	(1.32)		(0.04)		(-0.00)	
HDD	-0.018		-0.026		-0.001	
	(-0.52)		(-0.74)		(-0.02)	
CDD	-0.019**		-0.004		0.007	
	(-2.29)		(-0.74)		(0.46)	
State×Year FE	No	Yes	No	Yes	No	Yes
State FE	Yes	No	Yes	No	Yes	No
Year FE	Yes	No	Yes	No	Yes	No
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	223,695	223,695	223,739	223,739	223,670	223,670
Adj. R^2	0.08	0.08	0.09	0.09	0.14	0.14