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

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Abstract

This paper examines how cap-and-trade programs influence asset reallocation in the United States power sector. Using the staggered implementation of the Regional Greenhouse Gas Initiative and California's Cap-and-Trade Program, I show that electricity producers undertake substantial reallocation of generating assets in response to carbon pricing. Within regulated states, producers with greater exposure to carbon costs divest fossil-fuel plants and expand their holdings of renewable plants. Interestingly, asset allocation decisions are not confined to regulated areas only. Once subject to cap-and-trade, producers significantly reshape their portfolios in unregulated states by shifting toward cleaner assets. Two mechanisms appear to drive this spillover effect. First, producers anticipate policy diffusion to nearby states. Second, carbon pricing spurs innovation that facilitates broader deployment. Overall, the findings demonstrate that regional climate policies can induce widespread asset reallocation that extends well beyond the boundaries of regulated areas.

Keywords: Cap-and-trade; Electricity producers; Asset reallocation; Policy spillover; Carbon emissions

1 Introduction

Climate change has emerged as one of the most significant global economic and environmental challenges of the twenty-first century. Because greenhouse gas emissions are the primary drivers of global warming, policymakers have increasingly relied on market based mechanisms such as cap and trade to reduce emissions. By imposing an aggregate emissions cap and allowing firms to trade allowances, cap and trade programs create financial incentives for firms to reduce carbon output in a cost effective manner.

A growing body of research examines how firms respond to carbon pricing. Much of this work focuses on adjustments in operating behavior. For example, Bartram et al. (2022) document evidence of leakage, which occurs when firms shift production or emissions toward regions with weaker regulation. These findings show that firms can modify their production choices while continuing to rely on their existing asset base. However, there is limited evidence on whether carbon pricing affects the dirty and green assets that firms choose to own, or sell.

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 an especially compelling setting for analyzing how carbon pricing affects real asset reallocation. First, it is one of the dirtiest sectors in the United States. According to the EPA,[1] electricity generation produces roughly one quarter of total U.S. greenhouse gas emissions, which is more than any other major end-use sector including transportation, industry, and commercial or residential buildings. This heavy contribution stems from the sector's continued reliance on fossil fuel combustion. In 2022, roughly sixty percent of U.S. electricity still came from coal, oil, and natural gas.

Second, the power sector also operates with long-lived and capital-intensive assets whose

[1]See EPA (2024) "Sources of Greenhouse Gas Emissions" https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

output is completely uniform and perfectly substitutable. One megawatt hour of electricity is identical regardless of the plant or firm that produces it. This stands in contrast to manufacturing sectors where firms can differentiate products or vary quality in ways that obscure the effect of policy. This universality of output ensures that differences in firm behavior cannot be attributed to changes in product characteristics, allowing a cleaner identification of how carbon pricing influences asset decisions.

Finally, leakage is also far less feasible in electricity than in most industrial activities, which makes the sector an ideal laboratory for identifying real behavioral responses to carbon pricing. Electricity cannot be transported over long distances without substantial transmission losses. In addition, moving power across regions requires high-voltage transmission lines and interconnection infrastructure that are costly to build, limited in capacity, and heavily regulated. Evidence from the U.S. Energy Information Administration and the Edison Electric Institute indicates that new interstate transmission lines often cost between two and four million dollars per mile, and many regions of the United States remain only weakly interconnected.[2] Industrial firms such as cement, steel, or chemicals can more easily relocate production to underregulated areas, but utilities cannot shift generation in this way without massive and multi-year infrastructure investments. These constraints greatly limit the scope for leakage and strengthen the relevance of asset reallocation as the primary response to carbon costs.

In this paper, I find that electricity producers respond to carbon costs through substantial reallocation of generating assets. Traditional plants become 3% more likely to be divested by electricity producers, whereas renewable plants become 6% less likely to be divested. This pattern suggests that the trading market for power plants is strongly supply-driven. Traditional assets become less desirable and therefore more frequently offered for sale, while renewable assets become more attractive and are retained by current electricity producers. Cap-and-trade programs may affect these electricity producers differently because they have

[2]https://www.energy.gov/oe/articles/electricity-transmission-primer

different market roles and ownership objectives. Independent Power Producers (IPPs) operate in competitive wholesale markets and cannot pass carbon costs to ratepayers; for them, allowance prices directly raise marginal production costs and strengthen the incentive to shed high-emitting assets. Investor-Owned Utilities (IOUs), in contrast, often recover compliance costs through regulated rate adjustments, reducing their incentive to divest. Public utilities, which operate as non-profit entities and are guided primarily by service obligations and thus have weaker financial motives to reallocate assets. The results shows that IPPs are 19% more likely to sell traditional plants after cap-and-trade, compared with IOUs and public utilities. In addition, producers adjust their portfolios differently depending on their pre-existing generation mix, revealing a clear rebalancing pattern. Firms that were heavily fossil-intensive prior to regulation shift away from traditional generation and toward renewables, whereas firms that were initially more renewable-intensive move in the opposite direction by expanding their holdings of traditional capacity.

Electricity producers do not operate solely within the boundaries of a single cap-and-trade program. In our sample, about 29% of electricity producers have power plants in multiple states. When part of their portfolio becomes subject to cap-and-trade, the entire firm will adjust its nationwide asset strategy. Once exposed to cap-and-trade, electricity producers significantly reallocate their generating assets in other unregulated regions, reducing their ownership of fossil-fuel plants and increasing holdings of renewable plants in states without cap-and-trade. These patterns indicate that cap-and-trade shapes investment decisions across a firm's full portfolio, amplifying the policy's impact beyond the regulated states.

The evidence points to two channels behind this spillover effect. First, firms appear to adjust their behavior in anticipation of broader policy diffusion. Prior research shows that state level climate and renewable energy policies often diffuse geographically, with nearby states more likely to adopt similar regulations. Matisoff (2008) documents that the adoption of climate change policies and renewable portfolio standards exhibits clear regional clustering, indicating that states respond to policy actions taken by their neighbors. Consistent with this pattern, electricity producers exposed to cap and trade increase their renewable investment more strongly in states that are geographically close to existing programs, suggesting that firms expect these states to implement similar regulation in the future.

Second, carbon pricing encourages technological change that lowers the cost of clean production. The literature emphasizes that well designed carbon market programs should not only reduce emissions but also stimulate innovation that reduces the long run cost of abatement. Jaffe et al. (2003) and Stavins (2007) argue that technological progress plays a central role in reducing future marginal production costs for low carbon technologies. In our setting, we observe that firms regulated by cap and trade programs increase their low carbon innovation, which in turn makes renewable generation more cost effective and facilitates expansion of clean assets outside regulated states.

Finally, we find that producers expand their total assets and capital expenditures following cap-and-trade program, while profitability, leverage, valuation, and ESG performance remain largely unchanged.

This paper makes three primary contributions to the literature. First, it contributes to our understanding of the asset market for polluting assets. Prior work by Duchin et al. (2025) documents an active market for pollutive industrial plants, showing that firms facing stronger environmental scrutiny tend to divest dirty assets to buyers operating under weaker regulatory constraints. In a related context, Lin et al. (2023) shows that climate-related uncertainty about future electricity demand increases investment in flexible fossil fuel technologies while discouraging investment in inflexible renewable capacity. To the best of our knowledge, this paper is the first to examine how electricity producers adjust their asset holdings in response to climate policy. We find that firms not only rebalance their portfolios between dirty and green assets within regulated regions but also reduce their holdings of dirty assets and increase holdings of green assets in unregulated areas.

Second, the paper contributes to the literature on the external effects of regional policy.

Regional interventions often lead to unintended consequences that affect neighboring regions and sectors. Prior studies have documented such effects in the contexts of place-based development zones (Hanson and Rohlin, 2013), housing programs (Rossi-Hansberg et al., 2010), infrastructure investments (Chandra and Thompson, 2000), international trade (Curtis, 2014), and education policy (Ma et al., 2023). Within the context of climate regulation, a common criticism is the risk of leakage. For example, Bartram et al. (2022) shows that financially constrained industrial firms shift production and emissions to unregulated states. However, this paper shows that leakage is not inevitable and depends on the institutional and technological characteristics of the sector. In the power sector, electricity producers do not relocate emissions or expand fossil fuel generation outside regulated areas. Instead, cap and trade programs lead to additional renewable investment and reduced fossil capacity even in unregulated states.

Third, the paper adds to the understanding of cap and trade effectiveness in the electricity sector. While many studies examine the effects of carbon markets in industrial settings (see Betz and Sato 2010; Ellerman et al. 2010; Laing et al. 2013; Bartram et al. 2022; Ben-David et al. 2021), evidence on electricity producers remains limited. Two recent papers offer initial insights. Bai and Ru (2024) documents national reductions in emissions following the adoption of emissions trading systems. Kumar and Purnanandam (2022) finds that the Regional Greenhouse Gas Initiative reduced carbon emissions and influenced firm-level financial outcomes. Our study confirms the effectiveness of cap and trade in the power sector and provides new evidence on how firms reallocate their physical capital in response to carbon pricing.

2 Background

2.1 Cap and Trade Programs

Cap and trade programs have become a central component of market based climate regulation in the United States. These programs establish a declining cap on total greenhouse gas emissions and allow firms to trade emissions permits. This mechanism provides financial incentives to reduce emissions where it is most cost effective. This paper focuses on two major initiatives implemented in the United States, namely the California Cap and Trade Program and the Regional Greenhouse Gas Initiative, also known as RGGI.

California's cap and trade program was created following the passage of Assembly Bill 32 in 2006. This law mandated that greenhouse gas emissions be reduced to 1990 levels by the year 2020. To meet this target, California adopted a comprehensive approach including energy efficiency standards, renewable energy mandates, a low carbon fuel standard, and a statewide cap and trade program. The cap and trade program began in 2013. The initial emissions cap was set two percent below 2012 levels and declined by two percent in 2014. It then decreased by three percent each year through 2020. The program covers carbon dioxide and several other greenhouse gases. It includes all electricity producers and large industrial sources that emit more than 25000 metric tons of carbon dioxide equivalent annually. Fuel suppliers were included in the program starting in 2015. By 2015 approximately 450 entities were covered, representing 80 percent of the state's total emissions. Large industrial emitters initially received free allowances based on historical emissions and energy efficiency metrics. Over time a larger share of permits has been allocated through public auctions. Electricity generators received free allowances on the condition that any financial gains benefit utility customers. Permits can be banked for future use and firms may meet part of their compliance obligation by purchasing approved emissions offsets. Permit prices initially fluctuated but eventually stabilized around 12 to 13 dollars per ton of carbon dioxide in 2014.

The Regional Greenhouse Gas Initiative is the first legally binding regional program in the United States to target carbon dioxide emissions from the power sector. In 2005 seven states in the Northeast and Mid Atlantic regions signed an agreement to create a collaborative emissions reduction program. These states were Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont. The program sets a regional cap on total carbon dioxide emissions from power plants with capacity of 25 megawatts or greater. Each state distributes allowances proportional to its share of the regional cap. Unlike earlier emissions trading programs that granted allowances at no cost, RGGI conducts quarterly auctions and sells the allowances directly to power producers. This design both imposes actual financial costs and generates revenue for participating states. Additional states including Massachusetts, Maryland, and Rhode Island joined the program in 2007. New Jersey later withdrew in 2012 and is excluded from our analysis. The first auction was held in September 2008 and the initial compliance period began on January 1 of 2009. The emissions cap is designed to decline with each compliance period, thereby reducing total emissions over time.

Although the California and RGGI programs differ in their regulatory design and geographic scope, they share a core structural feature central to this study. Both programs directly regulate carbon dioxide emissions from fossil-fuel power plants and implement market-based allowance trading mechanisms to price carbon.

2.2 Institutional Background on the U.S. Power Sector

Electricity generation in the United States relies on a mix of fossil fuels, nuclear energy, and renewables. 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%).[3] While fossil fuels still dominate the generation mix, the share of renewables has steadily increased over time. For example, renewable sources accounted for only 10% of U.S. electricity generation in 2010 but rose to 21% by 2022, driven largely by growth in

[3] https://www.eia.gov/electricity/annual/html/epa_03_01_a.html

wind and solar capacity.

The capital structure of the power sector is highly intensive, with power plants representing large, long-lived investments. Coal and nuclear facilities, in particular, have historically operated for 40 to 60 years. For instance, the average coal unit retired in recent years was over 50 years old, and many nuclear plants receive license extensions allowing operations for up to 80 years.[4] This slow capital turnover implies that climate policies such as cap-and-trade can materially affect the valuation and strategic management of long-term assets.

Generation assets in the U.S. power sector are owned by a mix of investor-owned utilities (IOUs), public power utilities, electric cooperatives, and independent power producers (IPPs). IOUs are private, for-profit companies that serve the majority of customers and generation, operating under state regulation with cost recovery and return guarantees. Public utilities are government-owned, nonprofit entities focused on providing low-cost electricity to local communities. Cooperatives are member-owned nonprofits that primarily serve rural areas with limited grid access. IPPs are competitive, for-profit generators that sell electricity into wholesale markets without owning distribution networks. These structural differences shape each entity's regulatory exposure, investment flexibility, and responsiveness to carbon pricing. IOUs dominate the sector, accounting for more than 70% of total generation and the majority of retail electricity sales. IPPs, which primarily operate in competitive wholesale markets, have expanded significantly over the past two decades, particularly in renewable generation.[5]

Another defining feature of the power sector is the uniformity of its output. One megawatt-hour of electricity is identical regardless of the fuel source or the firm that generates it. This homogeneity limits the ability of firms to differentiate products and shifts competitive dynamics toward cost efficiency and regulatory exposure. Unlike industrial firms that can adjust product characteristics or relocate production facilities, electricity producers

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

[5] https://www.eia.gov/todayinenergy/detail.php?id=40913

face high switching costs and constrained geographic flexibility. Electricity cannot be transported over long distances without substantial transmission losses, and regional transmission requires high-voltage infrastructure that is costly, capacity-limited, and tightly regulated. According to estimates from the U.S. Energy Information Administration and the Edison Electric Institute, new interstate transmission lines typically cost between two and four million dollars per mile. [6] Additionally, the national grid is segmented into largely independent Eastern, Western, and ERCOT interconnections that allow for only limited electricity flows across regions.[7] These constraints significantly reduce the feasibility of shifting production in response to regional regulations. While industrial sectors such as cement, steel, or chemicals may respond to carbon costs by relocating to underregulated areas, utilities cannot easily move generation without large-scale, multi-year investments. As a result, asset reallocation becomes the primary channel through which power firms respond to climate policies.

This rigidity is partially offset by the geographic scope of generation portfolios. Many large electricity producers operate plants across multiple states, allowing for some reallocation of new investment in response to differences in state-level policy. For example, holding companies such as Duke Energy, American Electric Power, and NextEra Energy own and operate generation assets in both regulated and deregulated markets across state lines. These multi-state portfolios give firms strategic flexibility when navigating carbon pricing programs, even though production cannot be seamlessly shifted across regions in the short run.

Taken together, the sector's reliance on carbon-intensive assets, standardized output, and limited cross-region production flexibility make it an informative setting for studying how market-based climate policies shape firm-level investment and divestment decisions across regions.

[6] `https://www.energy.gov/oe/articles/electricity-transmission-primer`

[7] `https://www.epa.gov/green-power-markets/us-grid-regions`

3 Data and Sample

3.1 Data

The dataset covers all power plants operating in the continental United States from 2001 to 2019, constructed using the U.S. Energy Information Administration's (EIA) EIA-860, EIA-861, and EIA-923 files. These data provide detailed information on each plant's location, unit status, initial operating year, fuel type, direct owner, annual net generation, and nameplate capacity. I classify plants into traditional (coal, oil, and natural gas based) and renewable (hydro, geothermal, solar, biomass, and wind based). [8] Emissions data are sourced from the Environmental Protection Agency's Clean Air Markets Division (CAMD), which covers fossil-fuel generating units with capacity greater than 25 MW.

To identify the ultimate owner of each plant, I use both ownership information from S&P Global Market Intelligence (GMI; formerly SNL Financial) and public listed firms' subsidiary data obtained from SEC filings. While the EIA reports the direct owner, the GMI data provide ownership chains up to the ultimate parent firm. To confirm the accuracy GMI ownership, I further use subsidiary structures from SEC filings to match EIA direct owners to ultimate parents. A firm is recorded as the ultimate owner only when it holds more than 50% equity in the plant, ensuring that the firm exercises effective control.

I supplement these data with state-level controls, including average temperature, GDP, population, Heating Degree Days (HDD), and Cooling Degree Days (CDD), obtained from the National Centers for Environmental Information (NCEI) and the EIA's State Energy Data System (SEDS). Financial statement information for publicly traded utilities is drawn from Compustat.

[8] Nuclear plants are excluded from the analysis because they are neither fossil-fuel-based nor renewable and are typically regulated under different policy and operational frameworks.

3.2 Sample Statistics

Panel A of Table 1 reports summary statistics for the full sample of 10,295 U.S. power plants observed from 2001 to 2019. On average, a plant generates 541,000 MWh of electricity per year and has an installed capacity of 166 MW. The median plant age is 23 years, indicating that many facilities are relatively mature.

Across all plant-year observations, 46% correspond to traditional fossil-fuel plants (coal, gas, or oil), while 54% correspond to renewable plants (biomass, geothermal, hydro, solar, or wind). Among traditional plants, gas-fired units represent the largest share (25%), followed by oil (12%) and coal (8%). Within the renewable category, hydro plants are the most common (24%), followed by solar (11%), wind (10%), and biomass (9%), while geothermal plants account for just 1%.

Traditional plants (3,659 plants) exhibit substantially higher levels of production, generating on average 1,012,000 MWh per year and operating with a mean capacity of 303 MW. These units also tend to be older, with an average age of 32 years. Their average CO2 emissions total 1.97 million short tons, and their mean emissions rate is 2.08 short tons per MWh.

The renewable subsample includes 6,636 plants, which are generally smaller and younger. Their average annual generation is 148,000 MWh, and their average installed capacity is 51 MW, both considerably lower than their traditional counterparts. Renewable plants have a mean age of 30 years.

Panel B of Table **??** presents summary statistics for the 48 continental U.S. states included in our sample. New Jersey is excluded because it joined the RGGI program in 2009 but withdrew in 2012, and we omit it to maintain consistent policy exposure across states. [9]

Across the 912 state-year observations, states generate an average of 82.3 million MWh of electricity per year, with average annual CO2 emissions of 46.3 million short tons. Traditional plants account for the bulk of electricity production, generating on average 56.1 million MWh

[9] Our results are robust to the inclusion of New Jersey in the sample.

with an installed capacity of 16.6 thousand MW. In contrast, renewable plants produce 9.9 million MWh annually and operate with an average capacity of 3.1 thousand MW.

Panel C of Table 1 reports summary statistics for the 510 parent firms of the power plant (electricity producers) in our sample. On average, an electricity producer owns 5.9 power plants with 2.8 traditional plants and 3.2 renewable plants. In terms of scale, the average electricity producer controls 1,371 MW of total generation capacity, of which 1,063 MW is from traditional plants and 149 MW from renewable plants. It is common for electricity producers to operate in multiple states. On average, an electricity producer owns power plants in 1.69 states, and roughly 29% of producers have generation assets in more than one state.

4 Empirical evidence

4.1 Cap-and-Trade and Carbon Emission

To examine the direct effects of cap-and-trade programs on carbon emissions, I begin by estimating their impact at the state-year level, exploiting the staggered adoption of carbon trading policies across states. The baseline specification relates cap-and-trade implementation to a range of state-level outcomes:

$$Y_{st} = \beta \, \text{treated}_{st} + Controls_{st} + \mu_s + \lambda_t + \varepsilon_{st}, \tag{1}$$

where Y_{st} denotes the annual outcome of state s in year t. I examine overall CO_2 emissions, total net generation, and the generation and capacity of both traditional and renewable plants. The treatment indicator, treated_{st}, equals one in the year a state implements cap-and-trade and remains one thereafter. The controls includes states' key economic and climatic fundamentals, such as GDP, population, temperature, heating degree days (HDD), and cooling degree days (CDD). All regressions include state and year fixed effects.

Table 2 Panel A summarizes the state-level findings. Across all specifications, cap-and-trade implementation leads to large and statistically significant reductions in CO_2 emissions. Columns (3) and (4) show that the coefficient on treated_{st} is negative and significant at the 1% level. Column (4) implies that cap-and-trade reduces state-level CO_2 emissions by approximately 26%, an economically meaningful effect. This result is consistent with the broader literature. For example, Bai and Ru (2024) document that countries adopting emissions trading systems reduce their aggregate emissions by about 18.1%.

Cap-and-trade can lower emissions through several channels. Emissions may fall because electricity producers reduce overall generation, particularly from high-emitting units. Alternatively, producers may shut down or retire fossil-fuel plants altogether. A third possibility is that plants upgrade abatement technologies, thereby lowering emissions per MWh.

To distinguish between these mechanisms, I examine how cap-and-trade affects total state-level generation and the generation and capacity of traditional and renewable plants. The results indicate that emission reductions arise primarily from changes in operational behavior rather than changes in the capital stock. Following the introduction of cap-and-trade, total electricity generation declines by roughly 15%, as shown in Column (2) of Table 2 Panel A. Traditional plants exhibit even larger reductions, with net generation falling by about 26%. By contrast, the overall capacity of traditional plants does not significantly change, indicating that cap-and-trade does not trigger widespread retirements or shutdowns within the sample period. As expected, renewable generation and capacity remain largely unaffected, consistent with the fact that the regulation targets only fossil-fuel plants.

To further understand how emissions decline following cap-and-trade, I also estimate a plant-level difference-in-differences specification:

$$Y_{ist} = \beta \, \text{treated}_{st} + Controls_{st} + \mu_i + \lambda_t + \varepsilon_{ist}, \tag{2}$$

where Y_{ist} is the annual outcome of plant i in state s and year t. The outcomes include CO_2 emissions, net generation, and carbon intensity. The plant-level controls include generating capacity and plant age, and the regression includes plant and year fixed effects as well as the state-level economic controls included in equation (1).

Table 2 Panel B shows that traditional plants significantly reduce emissions following cap-and-trade. Column (2) indicates that plant-level emissions decline by about 28%, closely mirroring the state-level estimates. By exploring the effect of RGGI in (Kumar and Purnanandam, 2022), they find that carbon emission recuded 49.61%.

Since coal- and oil-fired plants emit substantially more carbon than natural gas plants, they are expected to experience stronger responses to carbon pricing. This pattern is confirmed in Column (3). The interaction between treatment status and an indicator for dirty-fuel plants is negative and statistically significant, implying that coal- and oil-fired plants reduce emissions by roughly 79% more than natural gas plants.

Plant-level generation results show similar patterns. Column (5) indicates that traditional plants reduce net generation by roughly 20%, and dirty-fuel plants reduce generation by an additional margin. These findings reinforce the conclusion that cap-and-trade reduces emissions largely through reductions in utilization, not through changes in generation capacity or technological upgrades.

Finally, I examine whether plants lower emissions through improvements in efficiency. The results do not show statistically significant changes in carbon intensity, suggesting that cap-and-trade does not induce measurable upgrades in abatement technologies during this period.

Taken together, the evidence demonstrates that cap-and-trade programs significantly reduce power-sector emissions. The decline is driven predominantly by reductions in electricity generation from fossil-fuel plants, especially heavily polluting coal- and oil-fired units. There is little evidence of widespread plant retirements or substantial improvements in emissions intensity. Overall, cap-and-trade programs effectively reduce power-sector emissions by curbing electricity generation from polluting plants.

4.2 Cap-and-Trade and Asset Reallocation

4.2.1 Asset Reallocation within Regulated Regions

Due to the increase in the operating cost of traditional plants under cap-and-trade, we next examine whether electricity producers reallocate generating assets within cap-and-trade regions.

We begin by analyzing whether the probability of ownership transfer differs for both traditional and renewable plants. In Table 3, we re-estimate model (2) using an outcome variable that equals one if the plant's ultimate parent changes in the following year. The results show that, after the introduction of cap-and-trade, traditional plants become 3% more likely to be divested, whereas renewable plants become 6% less likely to be sold. This pattern suggests that the trading market for power plants is strongly supply-driven. Traditional assets become less desirable and therefore more frequently offered for sale, while renewable assets become more attractive and are retained by current owners.

We then examine which types of firms are driving these transactions. In our sample, electricity producers fall into three categories: Investor-Owned Utilities (IOUs), Independent Power Producers (IPPs), and public utilities such as cooperatives and municipal systems. Cap-and-trade programs may affect these entities differently because they have different market roles and ownership objectives. IPPs operate in competitive wholesale markets and cannot pass carbon costs to ratepayers; for them, allowance prices directly raise marginal production costs and strengthen the incentive to shed high-emitting assets. IOUs, in contrast, often recover compliance costs through regulated rate adjustments, reducing their incentive to divest. Public utilities, which operate as non-profit entities and are guided primarily by service obligations and thus have weaker financial motives to reallocate assets.

The results in Table 4 are consistent with these distinctions. IPPs are 19 percentage points more likely to sell traditional plants after cap-and-trade, compared with IOUs and public utilities. On the buyer side, the patterns are less pronounced. Column (4) suggests that public utilities become 1 percentage point less likely to acquire traditional plants following cap-and-trade, implying a marginally higher likelihood that IOUs and IPPs serve as buyers. However, the magnitude of this effect is small.

Electricity producers may respond to cap-and-trade regulation differently depending on the composition of their pre-existing generation portfolios. Table 5 tests whether post-policy changes in traditional and renewable capacity systematically vary with firms' initial mixes of fossil and renewable assets. For the California Cap-and-Trade Program, the benchmark portfolio is measured as each firm's average capacity during the three years prior to implementation (2010–2012).

Column (1) shows that the interaction between *post* and $pre_{t}raditional_{c}apacity$ is significantly negative. The coefficient of –0.27 indicates that for every additional 1 MW of traditional capacity a firm held before the policy, it reduces its traditional capacity by 0.27 MW in the post–cap-and-trade period. In contrast, the interaction between *post* and $pre_{r}enewable_{c}apacity$ is significantly positive: firms with larger pre-existing renewable portfolios expand their traditional capacity instead. Specifically, each additional 1 MW of renewable capacity in the benchmark period is associated with a 0.37 MW increase in traditional capacity after regulation.

Column (2) reports the corresponding adjustments on the renewable side. Firms with larger traditional portfolios prior to regulation expand their renewable capacity more strongly. The coefficient of 0.05 implies that each additional 1 MW of initial fossil capacity leads to an 0.05 MW increase in renewable capacity. Conversely, firms that were already more renewable-intensive expand less after cap-and-trade. The coefficient of –0.18 suggests that for each additional 1 MW of pre-policy renewable capacity, these firms reduce 0.18 MW renewable capacity in the post period.

Overall, the evidence indicates that electricity producers respond to carbon costs through meaningful reallocation of generating assets. Traditional plants become significantly more likely to be divested, while renewable plants become less likely to be sold. These responses also vary across firm types in ways consistent with their regulatory and market environments: independent power producers (IPPs), which face the full marginal cost of carbon pricing, exhibit the strongest tendency to dispose of high-emitting plants. In addition, producers adjust their portfolios differently depending on their pre-existing generation mix, revealing a clear rebalancing pattern. Firms that were heavily fossil-intensive prior to regulation shift away from traditional generation and toward renewables, whereas firms that were initially more renewable-intensive move in the opposite direction by expanding their holdings of traditional capacity.

4.2.2 Spillover Effects: Asset Reallocation in unregulated Regions

We next examine whether electricity producers reallocate their asset portfolios in regions outside the cap-and-trade states once they become exposed to carbon pricing. Using the sample of publicly traded electricity producers, we estimate the following difference-in-differences specification:

$$Y_{jst} = \beta \, \text{Exposed}_{jt} + Firm\_Controls_{jt} + State\_Controls_{st} + \mu_j + \mu_s + \lambda_t + \varepsilon_{jst}, \qquad (3)$$

where Y_{jst} measures the generating portfolio of producer j in state s and year t. The outcome variables include the number and capacity of traditional and renewable plants owned in each state outside of cap-and-trade regions. The variable Exposed_j identifies electricity producers that owned at least one plant in a cap-and-trade state prior to the policy's implementation. The regression includes firm characteristics and state-level economic controls, as well as firm, year, and state fixed effects.

Table 6 presents the results. Electricity producers that experienced cap-and-trade meaningfully adjust their generating portfolios in other regions. Exposed firms hold approximately 0.4% fewer traditional plants in non-regulated states and 3.6% less traditional capacity. Meanwhile, exposed firms expand their renewable holdings elsewhere, owning 1.9% more renewable plants and 6.0% more renewable capacity in other states. These results indicate that firms shift away from carbon-intensive assets and increase their renewable footprint outside the regulated region once they have faced carbon pricing locally.

Two channels may explain this cross-regional reallocation. First, firms may adjust their behavior in anticipation of broader policy diffusion. Prior research shows that state level climate and renewable energy policies often diffuse geographically, with nearby states more likely to adopt similar regulations. Matisoff (2008) documents that the adoption of climate change policies and renewable portfolio standards exhibits clear regional clustering, indicating that states respond to policy actions taken by their neighbors. To explore this mechanism, we exploit the fact that states geographically close to existing cap-and-trade programs are more likely to adopt similar policies. Table 6 provides supportive evidence. In columns (5) to (8), the interaction between exposure and geographic proximity is positive and statistically significant. For example, exposed firms increase renewable capacity in geographically close states by roughly 12% more than in states farther away, suggesting forward-looking adjustment in anticipation of regulatory spillovers.

The second channel is capability learning. After operating under carbon regulation, exposed producers may develop expertise in integrating and managing low-carbon technologies, thereby reducing the marginal cost of deploying these technologies elsewhere. The literature emphasizes that well designed carbon market programs should not only reduce emissions but also stimulate innovation that reduces the long run cost of abatement. Jaffe et al. (2003) and Stavins (2007) argue that technological progress plays a central role in reducing future marginal production costs for low carbon technologies. To evaluate this mechanism, we examine whether exposed producers increase their innovation in low-carbon technologies. Consistent with this hypothesis, we find that green patenting activity rises by approximately 9% relative to non-exposed firms, indicating enhanced technological capability that facilitates renewable expansion beyond the regulated region.

Overall, these findings suggest that cap-and-trade not only affects firms within cap-and-trade regions but also induces broader reallocation elsewhere, accelerating the transition away from carbon-intensive assets and supporting the expansion of renewable generation in unregulated areas.

4.3 Firm outcomes

We next examine whether cap-and-trade has real effects on electricity producers' financial performance. To do so, we estimate the following model:

$$Y_{jt} = \beta\,\text{Exposed}_{jt} + Firm\_Controls_{j,t-1} + \mu_j + \lambda_t + \varepsilon_{jt}, \tag{4}$$

where Y_{jt} denotes the financial outcome of producer j in year t. The firm controls includes lagged financial characteristics to account for pre-existing firm trends. All regressions include firm fixed effects and year fixed effects.

The results are presented in Table 7. Apart from the increased green patents, We find weaker evidence that firms expand their total assets and capital expenditures following exposure to cap-and-trade, potentially reflecting strategic investment associated with asset reallocation. However, measures of profitability, leverage, valuation, and ESG performance remain largely unchanged. Understanding why financial outcomes appear relatively unaffected despite substantial operational adjustments remains an open question.

5 Conclusion

This paper studies how cap-and-trade programs reshape asset ownership and investment decisions in the U.S. power sector. Exploiting the staggered introduction of the Regional Greenhouse Gas Initiative and California's Cap-and-Trade Program, I show that carbon pricing affects firms not only through operating behavior but also through the market for physical generating assets. Electricity producers respond to carbon costs by actively reallocating ownership away from fossil-fuel plants and toward renewable generation.

Within regulated states, traditional power plants become significantly more likely to be divested, while renewable plants are retained. These patterns are consistent with a supply-driven asset market in which carbon pricing reduces the desirability of high-emission assets and increases the value of clean assets. The response varies systematically across ownership types and initial portfolio composition. Independent Power Producers, which face direct exposure to allowance costs, exhibit the strongest divestment of fossil assets, while regulated utilities respond more moderately. At the same time, firms rebalance their portfolios based on their pre-regulation energy mix, highlighting the role of asset reoptimization rather than uniform downsizing or expansion.

Importantly, the effects of cap-and-trade extend beyond regulated regions. Firms with multi-state operations adjust their nationwide portfolios once any part of their asset base becomes subject to carbon pricing. Exposure to cap-and-trade leads producers to reduce fossil-fuel ownership and expand renewable holdings even in unregulated states. This spillover effect operates through two complementary channels. First, firms appear to anticipate policy diffusion, increasing clean investment more strongly in states that are geographically closer to existing carbon markets. Second, carbon pricing stimulates low-carbon innovation, lowering the cost of renewable generation and facilitating expansion outside regulated areas. Together, these mechanisms amplify the reach of regional climate policy.

From a broader perspective, the findings underscore the importance of asset markets as a central mechanism through which climate policy affects the real economy. In contrast to concerns about leakage documented in other sectors, the power sector exhibits positive externalities: regional carbon pricing accelerates clean investment rather than displacing emissions to unregulated areas. Moreover, these adjustments occur without adverse effects on firm profitability, leverage, valuation, or ESG performance, while firms expand total assets and capital expenditures.

Overall, the results suggest that cap-and-trade programs can play a powerful role in steering capital toward cleaner technologies by reshaping asset ownership, not just production decisions. By influencing firms' long-lived capital portfolios and generating spillovers across regions, carbon markets may deliver broader and more persistent effects than implied by analyses focused solely on regulated emissions. These insights have direct implications for the design of climate policy, highlighting the potential for regional programs to induce economy-wide transitions toward cleaner capital even in the absence of full national coverage.

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Figures and Tables

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

This figure presents maps all U.S. electric power plants in both 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.

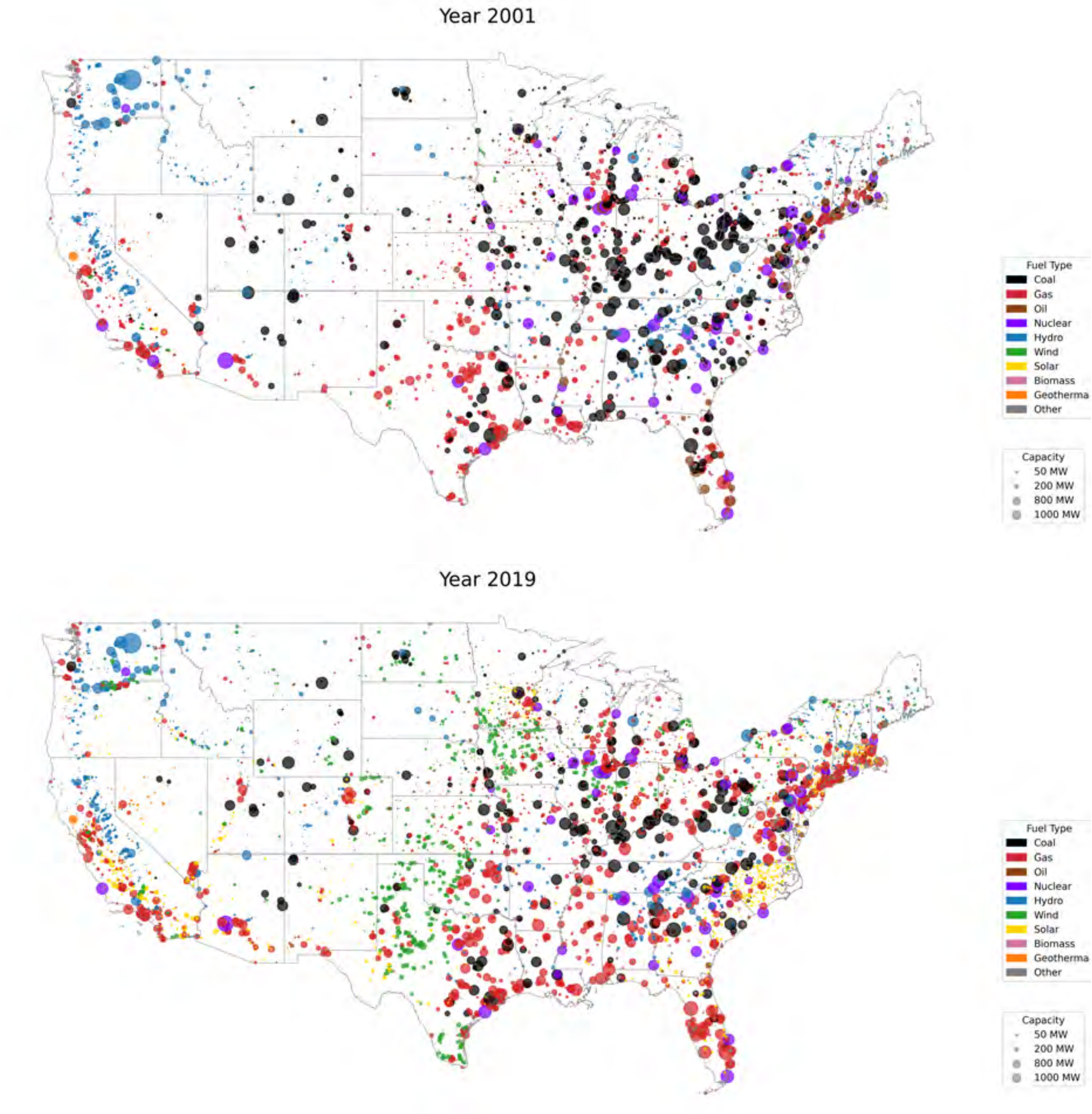


Figure 2: Dynamic Effect of Cap-and-Trade on Power Plants

This figure plots the dynamic differences-in-differences estimates of the effects of cap-and-trade programs on power plant outcomes. The horizontal axis shows years relative to the implementation of cap-and-trade (year 0). The top panel reports the estimated effects on log CO2 emissions, and the bottom panel reports the effects on log electricity generation. Points represent coefficient estimates, and shaded areas denote 95% confidence intervals. All specifications include plant and year fixed effects, and standard errors are clustered at the state level.

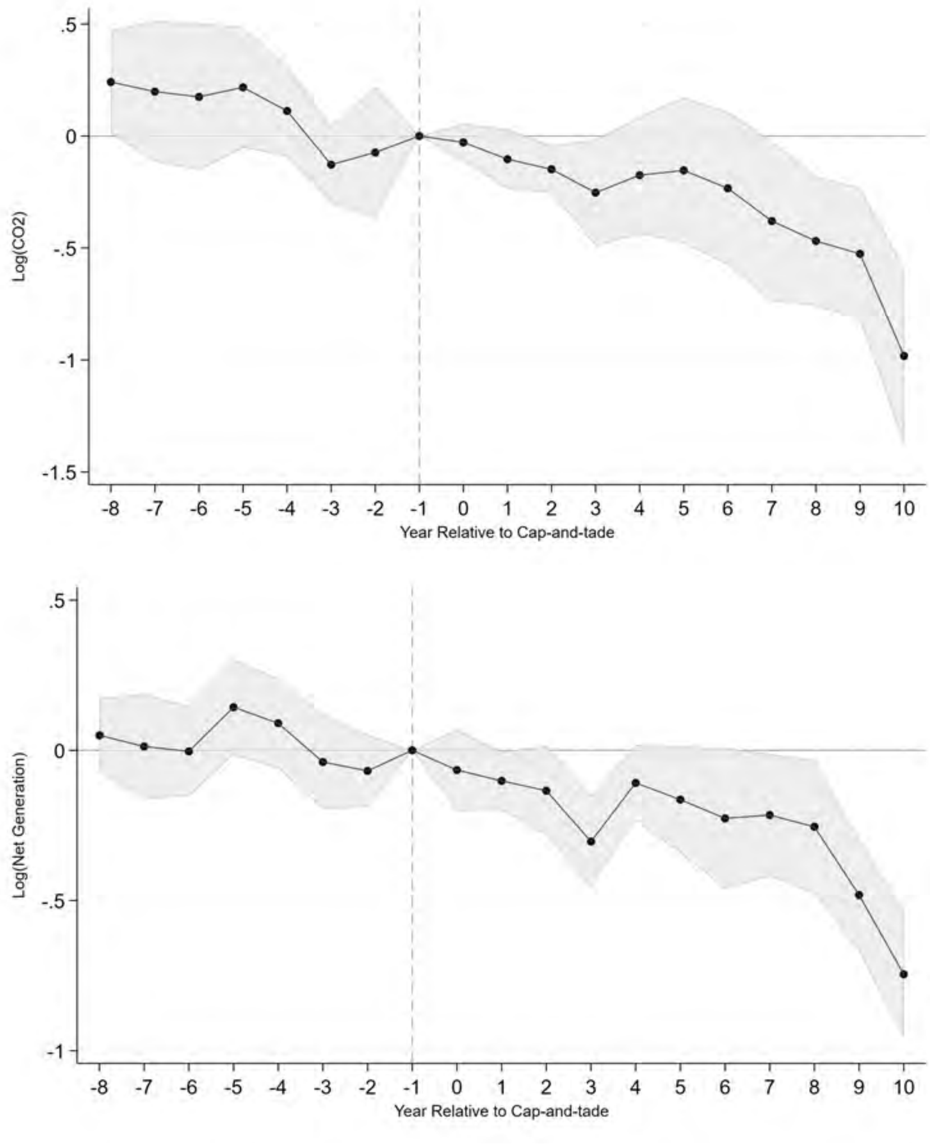


Figure 3: Power Plant Locations and Cap-and-Trade Spillover Effects

This figure maps U.S. power plants owned by electricity producers either exposed or unexposed to California cap-and-trade and RGGI. Traditional and renewable plants are differentiated by symbol type, and marker size indicates nameplate capacity. The pre-treatment map (top) shows the spatial distribution of plants owned by electricity producers either exposed or unexposed before the programs took effect, while the post-treatment map (bottom) illustrates the distribution afterward.

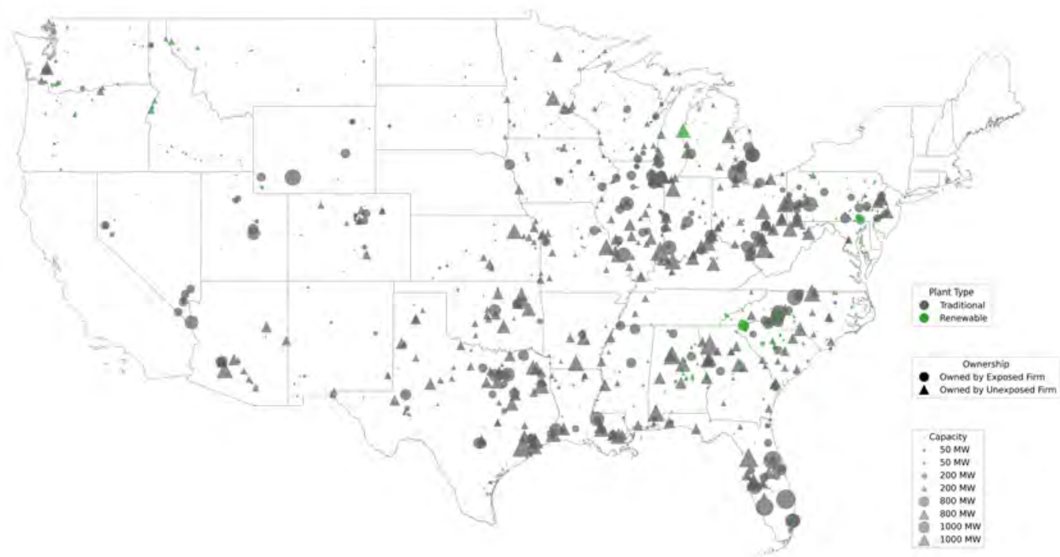
Panel A: Exposed by California Cap-and-Trade

Pre-treatment

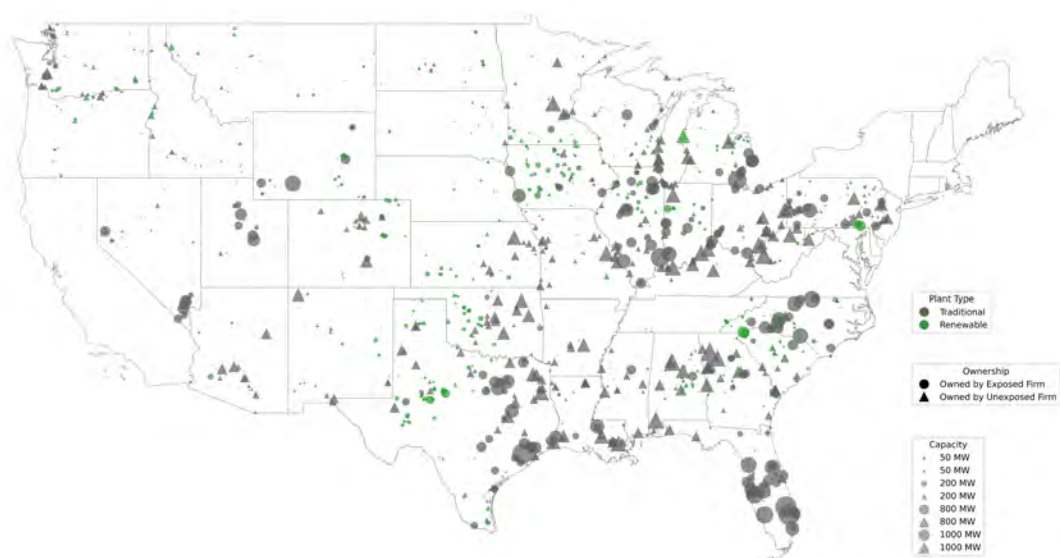
Post-treatment

Figure 3: (continued)

Panel B: Exposed by RGGI



Pre-treatment



Post-treatment

Table 1: Summary Statistics

This table presents a comprehensive summary of the variables employed in this study. Panel A displays the summary statistics for plant characteristics. Panel B provides the summary statistics for state characteristics. Panel B shows the summary statistics for firm characteristics.

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 = 47)						
Net Generation (Million MWh)	893	82.33	75.58	34.20	57.92	113.12
CO2 Emission (Million Short Tons)	893	46.30	44.52	15.18	36.23	62.52
Net Generation of Traditional Plants (Million MWh)	893	56.06	58.36	19.28	40.47	78.21
Capacity of Traditional Plants (Thousand MW)	893	16.61	16.98	5.48	11.84	23.50
Net Generation of Renewable Plants (Million MWh)	893	9.92	16.58	1.98	4.46	9.28
Capacity of Renewable Plants (Thousand MW)	893	3.10	5.17	0.65	1.59	2.98
RPS	893	0.49	0.50	0.00	0.00	1.00
Average Temperature (ºF)	874	52.79	7.95	46.36	51.63	58.95
GDP (Billion USD)	893	307.40	396.66	79.01	184.92	353.67
Population (Billion)	893	6.16	6.97	1.82	4.22	6.64
Heating degree days (HDD)	893	5170.27	2109.04	3520.00	5360.00	6806.00
Cooling degree days (CDD)	893	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: The Impact of Cap-and-Trade on the Power Sector

This table reports the estimated effects of cap-and-trade programs at both the state and power plant levels. Panel A presents state-level responses in CO_2 emissions, total electricity generation, fossil generation and capacity, and renewable generation and capacity. Panel B reports plant-level estimates for traditional facilities, including CO_2 emissions, electricity generation, and emissions intensity. *Treated* is an indicator equal to one in the year of an cap-and-trade implementation and all subsequent years, and zero otherwise. Fixed effects are used and indicated in each column. *t*-values are reported in parentheses. Statistical significance is denoted by *, **, and *** for the 10%, 5%, and 1% levels, respectively.

Panel A: State Level Outcomes

	Log(Total Gen)	Log(Total CO2)	Log((Trad Gen)	LogRenew Gen)	Log(Trad Cap)	Log(Renew Cap)
	(1)	(2)	(3)	(4)	(5)	(6)
Treated	-0.153**	-0.255***	-0.264**	0.283	-0.014	-0.227
	(-2.40)	(-3.19)	(-2.16)	(0.31)	(-0.40)	(-0.68)
RPS State	0.003	-0.033	-0.016	0.747	-0.028	0.391
	(0.09)	(-0.78)	(-0.23)	(1.61)	(-1.13)	(1.68)
Log(GDP)	0.165	0.080	-0.176	-0.170	-0.152	0.991
	(1.35)	(0.47)	(-0.92)	(-0.07)	(-1.45)	(1.21)
Log(Pop)	0.728*	0.453	1.285**	4.142	1.235***	-0.917
	(1.96)	(0.86)	(2.12)	(0.68)	(4.38)	(-0.40)
Log(Temp)	-0.119	-0.269	0.512	1.180	-0.156	0.388
	(-0.25)	(-0.58)	(0.85)	(1.11)	(-0.83)	(0.56)
Log(HDD)	-0.069	-0.125	-0.197	1.006**	0.068	0.301
	(-1.05)	(-1.14)	(-1.59)	(2.17)	(1.29)	(1.31)
Log(CDD)	0.022	0.067*	0.040	-0.082	0.016	-0.058
	(1.06)	(1.97)	(0.89)	(-0.71)	(0.84)	(-0.67)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	874	874	874	874	874	874
Adj. R^2	0.98	0.99	0.99	0.79	1.00	0.91

Panel B: Traditional Power Plant Level Outcomes

	Log(CO2)		Log(Gen)		Log(CO2 Intensity)	
	(1)	(2)	(3)	(4)	(5)	(6)
Treated	-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)
Treated × Dirty Fuel		-0.786***		-0.393***		-0.015
		(-6.69)		(-3.52)		(-0.29)
Log(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)
Log(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)
Log(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)
Log(Pop)	-0.564	-0.420	0.691	0.666	0.054	0.109
	(-0.91)	(-0.67)	(0.75)	(0.73)	(0.30)	(0.65)
Log(Temp)	2.123***	2.267***	1.285**	1.276**	-0.109	0.020
	(3.72)	(3.94)	(2.15)	(2.19)	(-0.53)	(0.10)
Log(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)
Log(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 3: Likelihood of Power Plant Ownership Change

This table presents regression estimates examining whether exposure to cap-and-trade regulation affects the probability that a power plant changes ownership in year $t+1$ within regulated states. *Treated* is an indicator equal to one in the year a cap-and-trade program is implemented and in all subsequent years, and zero otherwise. *Dirty Fuel* refers to coal- and oil-fired plants. *VHR* denotes renewable plants using solar, wind, or hydro technologies. Fixed effects are included as indicated in each column. t-values are reported in parentheses. Statistical significance is denoted by *, **, and *** for the 10%, 5%, and 1% levels, respectively.

	Ownership Changed in $t+1$			
	Trad Plant		Renew Plant	
	(1)	(2)	(3)	(4)
Treated	0.019*	0.009	-0.023*	-0.116***
	(1.81)	(0.90)	(-1.75)	(-4.72)
Dirty Fuel		0.037***		
		(2.84)		
Treated × Dirty Fuel		0.042**		
		(2.07)		
VHR				0.065
				(1.17)
Treated × VHR				0.113***
				(3.96)
Log(Cap)	-0.040*	-0.038	-0.008	-0.003
	(-1.69)	(-1.64)	(-0.50)	(-0.21)
Log(Age)	-0.003	-0.003	0.014	0.017*
	(-0.45)	(-0.45)	(1.58)	(1.93)
RPS State	-0.003	-0.003	-0.020	-0.021
	(-0.40)	(-0.50)	(-0.86)	(-0.86)
Log(GDP)	-0.055	-0.055	-0.122	-0.130
	(-1.31)	(-1.28)	(-1.56)	(-1.64)
Log(Pop)	-0.187**	-0.177**	0.065	0.088
	(-2.66)	(-2.60)	(0.68)	(0.88)
Log(Temp)	-0.203	-0.199	-0.171	-0.184
	(-1.58)	(-1.56)	(-0.93)	(-0.97)
Log(HDD)	-0.041	-0.044	-0.005	-0.011
	(-1.09)	(-1.24)	(-0.13)	(-0.28)
Log(CDD)	0.008	0.009	0.010	0.011
	(0.43)	(0.49)	(0.48)	(0.49)
Year FE	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes
Obs.	48,666	48,666	54,790	54,790
Adj. R^2	0.45	0.46	0.56	0.56

Table 4: Transactions of Power Plants Across Owner Types

This table presents regression estimates examining how cap-and-trade exposure affects transactions of power plants across different owner types within regulated states. Panel A reports results for traditional plants, while Panel B reports results for renewable plants. Each column represents a different seller–buyer ownership pair, including investor-owned utilities (IOUs), government-owned utilities, and independent power producers (IPPs). *Treated* is an indicator equal to one in the year of an cap-and-trade implementation and all subsequent years, and zero otherwise. Fixed effects are used and indicated in each column. *t*-values are reported in parentheses. Statistical significance is denoted by *, **, and *** for 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)
Treated	-0.062	-0.004	0.190**	-0.042	-0.010**	0.106
	(-0.76)	(-0.61)	(2.07)	(-0.57)	(-2.07)	(0.87)
Log(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)
Log(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)
Log(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)
Log(Pop)	1.562	-0.019	-1.460	1.401	0.062	-1.803
	(1.05)	(-0.14)	(-0.97)	(0.91)	(0.44)	(-1.33)
Log(Temp)	-4.160	-0.226	5.422**	-1.310	-0.431	1.829
	(-1.36)	(-0.60)	(2.12)	(-0.65)	(-0.96)	(0.94)
Log(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)
Log(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)
Treated	-0.034	-0.070**	-0.034	0.030	-0.070**	0.060
	(-0.49)	(-2.62)	(-0.25)	(0.33)	(-2.62)	(0.38)
Log(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)
Log(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)
Log(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)
Log(Pop)	0.309	-0.350*	2.808***	0.189	-0.350*	3.292***
	(0.42)	(-1.76)	(2.88)	(0.25)	(-1.76)	(2.73)
Log(Temp)	-2.586	1.418	5.490**	-3.442**	1.418	5.148**
	(-1.47)	(1.59)	(2.03)	(-2.03)	(1.59)	(2.46)
Log(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)
Log(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 5: The Effect of Cap-and-Trade on Power Producer Portfolio

This table reports how cap-and-trade implementation influences the composition of producers' generation portfolios within Caplifornia. The dependent variables are traditional capacity (column 1) and renewable capacity (column 2). *Post* is an indicator equal to one in the year of an cap-and-trade implementation and all subsequent years, and zero otherwise. The variables *Pre Avg Trad Cap* and *Pre Avg Renew Cap* represent producers' average portfolio shares before regulation. The interaction terms capture how producers with different initial portfolios rebalance capacity in the post-regulation period. Fixed effects are used and indicated in each column. t-values are reported in parentheses. Statistical significance is denoted by *, **, and *** for the 10%, 5%, and 1% levels, respectively.

	Trad Cap	Renew Cap
	(1)	(2)
Post × Pre Avg Trad Cap	-0.271***	0.048***
	(-3.35)	(3.10)
Post × Pre Avg Renew Cap	0.373***	-0.183***
	(3.84)	(-6.25)
Year FE	Yes	Yes
Firm FE	Yes	Yes
Obs.	63,486	63,486
Adj. R^2	0.68	0.86

Table 6: Spillover Effect of Cap-and-Trade on Asset Reallocation

This table presents regression estimates examining whether firms adjust their traditional power plant portfolios in outside regulated states when exposed to cap-and-trade programs. Panel A reports spillover effects on the number of traditional plants, traditional capacity, and traditional electricity generation. Panel B reports corresponding effects for renewable plants, renewable capacity, and renewable electricity generation. *Exposed* equals one for firms operating in states adjacent to cap-and-trade states prior to the implementation of the program, and zero otherwise. *Nearby State* indicates whether the state is located geographically close to cap-and-trade states. Fixed effects are used and indicated in each column. t-values are reported in parentheses. Statistical significance is denoted by *, **, and *** for the 10%, 5%, and 1% levels, respectively.

Panel A: Spillover Effect on Traditional Power Plants

	Log(No.Trad Plants)		Log (Trad Cap)		Log (Trad Gen)
	(1)	(2)	(3)	(4)	(5)
Exposed	-0.004**	-0.006*	-0.036***	-0.047***	-0.073***
	(-2.33)	(-2.02)	(-3.80)	(-2.98)	(-3.42)
Exposed × Nearby State		0.021		0.100	
		(1.13)		(1.10)	
Log(Market Value)	-0.000	-0.000	-0.005*	-0.005*	-0.006
	(-0.72)	(-0.70)	(-1.95)	(-1.93)	(-1.16)
Log(Total Asset)	0.004***	0.004***	0.026***	0.026***	0.055***
	(3.83)	(3.83)	(4.79)	(4.79)	(4.36)
Tobin's Q	0.000	0.000	0.001**	0.001**	0.001*
	(0.91)	(0.92)	(2.19)	(2.19)	(1.75)
Leverage	-0.001***	-0.001***	-0.007***	-0.007***	-0.014***
	(-3.74)	(-3.81)	(-4.47)	(-4.58)	(-3.26)
ROA	-0.003***	-0.003***	-0.017***	-0.017***	-0.034***
	(-3.97)	(-4.04)	(-4.59)	(-4.71)	(-3.58)
Market To Book	0.000***	0.000***	0.000***	0.000***	0.000***
	(4.09)	(4.03)	(4.48)	(4.36)	(4.07)
CAPEX	0.001	0.001	0.010**	0.010**	0.018
	(1.56)	(1.59)	(2.06)	(2.08)	(1.40)
Sale	0.000**	0.000**	0.000***	0.000***	0.000***
	(2.59)	(2.59)	(3.45)	(3.46)	(3.66)
RPS State	0.001	0.001	0.010	0.010	0.020
	(0.84)	(0.82)	(1.08)	(1.07)	(1.08)
Log(GDP)	-0.001	-0.002	0.007	0.003	0.035
	(-0.15)	(-0.24)	(0.16)	(0.06)	(0.40)
Log(Pop)	0.017	0.013	0.081	0.064	0.117
	(1.00)	(0.77)	(0.78)	(0.62)	(0.54)
Log(Temp)	0.004	0.003	0.019	0.015	0.167*
	(0.51)	(0.37)	(0.37)	(0.29)	(1.74)
Log(HDD)	-0.000	0.001	-0.008	-0.001	0.004
	(-0.13)	(0.30)	(-0.33)	(-0.04)	(0.09)
Log(CDD)	-0.002**	-0.003**	-0.009**	-0.014**	-0.021**
	(-2.58)	(-2.23)	(-2.37)	(-2.22)	(-2.31)
Year FE	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Obs.	236,837	236,837	236,837	236,837	236,793
Adj. R^2	0.07	0.07	0.09	0.09	0.08

Table 6 (continued): Spillover Effect of Cap-and-Trade on Asset Reallocation

Panel B: Spillover Effect on Renewable Power Plants

	Log(No.Renew Plants)		Log (Renew Cap)		Log (Renew Gen)
	(1)	(2)	(3)	(4)	(5)
Exposed	0.019***	0.015***	0.060***	0.048***	0.166***
	(5.57)	(3.44)	(5.06)	(3.00)	(5.36)
Exposed × Nearby State		0.034**		0.116**	
		(2.04)		(2.03)	
Log(Market Value)	-0.000	-0.000	-0.002	-0.002	-0.007
	(-0.63)	(-0.61)	(-1.08)	(-1.05)	(-1.27)
Log(Total Asset)	0.006***	0.006***	0.024***	0.024***	0.069***
	(4.85)	(4.85)	(5.46)	(5.46)	(5.72)
Tobin's Q	0.000	0.000	0.001**	0.001**	0.002**
	(1.05)	(1.05)	(2.67)	(2.67)	(2.24)
Leverage	-0.004***	-0.004***	-0.017***	-0.017***	-0.050***
	(-7.05)	(-7.02)	(-6.26)	(-6.24)	(-6.53)
ROA	-0.009***	-0.009***	-0.034***	-0.034***	-0.101***
	(-6.21)	(-6.18)	(-5.53)	(-5.51)	(-5.76)
Market To Book	0.000***	0.000***	0.000***	0.000***	0.000***
	(5.11)	(5.09)	(3.69)	(3.62)	(3.93)
CAPEX	0.005***	0.005***	0.018***	0.018***	0.050***
	(3.10)	(3.12)	(3.71)	(3.74)	(3.29)
Sale	0.000***	0.000***	0.000***	0.000***	0.000***
	(3.06)	(3.06)	(3.29)	(3.29)	(3.20)
RPS State	0.007**	0.006*	0.023*	0.023*	0.068**
	(2.08)	(1.98)	(1.92)	(1.83)	(2.23)
Log(GDP)	-0.001	-0.002	0.036	0.031	0.023
	(-0.05)	(-0.13)	(0.75)	(0.61)	(0.16)
Log(Pop)	0.083**	0.077**	0.211	0.191	0.780**
	(2.28)	(2.13)	(1.53)	(1.38)	(2.17)
Log(Temp)	-0.012	-0.013	-0.002	-0.006	0.003
	(-0.50)	(-0.55)	(-0.03)	(-0.10)	(0.02)
Log(HDD)	-0.004	-0.002	0.007	0.015	0.000
	(-0.63)	(-0.32)	(0.31)	(0.80)	(0.00)
Log(CDD)	0.001	-0.001	-0.000	-0.006	0.009
	(0.55)	(-0.22)	(-0.02)	(-0.88)	(0.57)
Year FE	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Obs.	236,837	236,837	236,837	236,837	236,768
Adj. R^2	0.13	0.13	0.14	0.14	0.14

Table 7: The Effect of Cap-and-Trade on Firm Outcomes

This table reports the effects of cap-and-trade regulation on firm outcomes. *Treated* equals one for firms operating in states adjacent to cap-and-trade states prior to the implementation of the program, and zero otherwise. The dependent variables include green patenting activity, firm size , capital expenditures, ESG score, profitability, leverage, and Tobin's Q. Control variables are with one-year lags. Fixed effects are used and indicated in each column. *t*-values are reported in parentheses. Statistical significance is denoted by *, **, and *** for the 10%, 5%, and 1% levels, respectively.

	Log(Green Patent)	Log(Total Asset)	CAPEX	ESG Score	ROA	Leverage	Tobin's Q
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treated	0.093**	0.025*	0.018*	-0.167	0.014	-0.007	-0.540
	(2.20)	(1.89)	(1.94)	(-0.53)	(0.12)	(-0.07)	(-1.01)
Log(Total Asset)$_{t-1}$	-0.006	0.761***	-0.031***	-0.162	2.338	-2.103	-4.805
	(-0.16)	(30.96)	(-2.70)	(-0.60)	(1.37)	(-1.38)	(-1.37)
Tobin's Q_{t-1}	-0.071**	0.048***	0.013***	0.092	2.271	-2.061	-6.182
	(-2.49)	(3.45)	(2.77)	(1.34)	(1.28)	(-1.28)	(-1.13)
Leverage$_{t-1}$	0.019	-0.163***	0.009	0.051	-6.593**	6.451***	22.125**
	(0.53)	(-4.14)	(0.50)	(0.06)	(-2.45)	(2.63)	(2.41)
ROA$_{t-1}$	-0.260**	-0.072	0.099***	-0.570	2.779	-2.540	-4.368
	(-2.57)	(-0.97)	(3.68)	(-0.91)	(0.90)	(-0.91)	(-0.52)
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)	(-1.92)
Log(Market Value)$_{t-1}$	0.063**	0.066***	0.015**	0.041	-1.301	1.174	
	(2.05)	(4.32)	(2.36)	(0.22)	(-1.38)	(1.39)	
CAPEX$_{t-1}$	-0.041	0.087**	0.186***	1.006	-0.737	0.878	4.183
	(-0.75)	(1.97)	(3.93)	(1.16)	(-0.67)	(0.74)	(0.76)
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