Real Effects of Climate Policy:

Financial Constraints and Spillovers

Söhnke M. Bartram*, **Kewei Hou**†, **and Sehoon Kim**‡

Abstract

We document that localized policies aimed at mitigating climate risk can have unintended consequences due to regulatory arbitrage by firms. Using a difference-in-differences framework to study the impact of the California cap-and-trade program with US plant level data, we show that financially constrained firms shift emissions and plant ownership from California to other states. In contrast, unconstrained firms do not make such adjustments. Overall, neither constrained nor unconstrained firms reduce their total emissions when only a subset of their plants are affected by the cap-and-trade rule, undermining the effectiveness of the policy.

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* Research Fellow, Centre for Economic Policy Research (CEPR), London, UK, and Professor of Finance, University of Warwick, Warwick Business School, Department of Finance, Coventry CV4 7AL, United Kingdom, Phone: +44 (24) 7657 4168, E-mail: s.m.bartram@wbs.ac.uk.

† Ric Dillon Endowed Professor in Investments, The Ohio State University, 820 Fisher Hall, 2100 Neil Avenue, Columbus, OH 43210, Phone: +1 (614) 292-0552, E-mail: hou.28@osu.edu.

‡ Assistant Professor of Finance, University of Florida, Warrington College of Business, PO Box 117168, Gainesville, FL 32611-7168, Phone: +1 (352) 273-1866, E-mail: sehoon.kim@warrington.ufl.edu.

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Abstract

We document that localized policies aimed at mitigating climate risk can have unintended consequences due to regulatory arbitrage by firms. Using a difference-in-differences framework to study the impact of the California cap-and-trade program with US plant level data, we show that financially constrained firms shift emissions and plant ownership from California to other states. In contrast, unconstrained firms do not make such adjustments. Overall, neither constrained nor unconstrained firms reduce their total emissions when only a subset of their plants are affected by the cap-and-trade rule, undermining the effectiveness of the policy.

"Climate policy advocates need to do a much better job of quantitatively analyzing economic costs and the actual, rather than symbolic, benefits of their policies. Skeptics would also do well to focus more attention on economic and policy analysis… We need to know what effect proposed policies have and at what cost. Scientific, quantifiable or even vaguely plausible cause-and-effect thinking are missing from much advocacy for policies to reduce carbon emissions."

David R. Henderson and John H. Cochrane, *July 2017, Wall Street Journal*

1 Introduction

Climate change is among the most intensely debated socio-economic issues of current times.[1] As a response to potential catastrophe risks from climate change, governments around the world are pushing for various forms of regulations to curb greenhouse gas emissions.[2] However, there is far from a consensus on what the optimal policy approach might be, and as a result climate policies are highly fragmented across the jurisdictions in which they are designed and implemented. More importantly, it is unknown whether such localized yet uncoordinated policies are able to internalize potential externalities that may impede addressing climate change as a global phenomenon or simply distort allocations in the economy. An example is the United States, where at the beginning of 2013, California became the first and only state to put an extensive mandatory carbon regulation in place in the form of a cap-and-trade system that applies universally to all industrial greenhouse gas emissions.[3] Exploiting the introduction of the California cap-and-trade rule, we investigate the internal resource allocation responses by firms and the real but unintended spillover effects of localized climate policies that arise from the importance of financial constraints. Our study helps understand the interplay between climate policy and firm behavior, and informs policy makers regarding the effectiveness of climate regulation.

[1] The economic consequences of climate change have recently garnered much interest among financial economists. See, among others, Addoum, Ng, and Ortiz-Bobea (2019), Akey and Appel (2019), Bernstein, Gustafson, and Lewis (2019), Engle, Giglio, Kelly, Lee, and Stroebel (2019), Forster and Shive (2019), Krueger, Sautner, and Starks (2019), and Painter (2019).

[2] See Figure 1 for recent trends in carbon emissions from the use of fossil fuels and global temperatures, and Figure 2 for a map of implemented or planned carbon pricing regulations around the world, as of 2016.

[3] Most climate regulations in the United States thus far have left states with much discretion in implementing federal standards (e.g. Clean Air Act) or have largely been confined to the electricity production industry. Since 2009, nine states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont) have been part of the Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade program that applies only to fossil fuel power plants generating 25MW or more. States have also been adopting varying versions of Renewable Portfolio Standards (RPS) requiring increased production of energy from renewable energy sources. From 2003 to 2010, the Chicago Climate Exchange (CCX) was available for voluntary emissions trading, but ceased trading due to inactivity.

Using detailed data on plant level greenhouse gas emissions and parent company ownership from mandatory reporting to the US Environmental Protection Agency (EPA) hand-matched to Compustat covering 2,806 industrial plants and 511 publicly listed non-utility and non-governmental firms over the period 2010 to 2015, we show that the 2013 California cap-and-trade rule has real spillover effects across the United States due to firm financial constraints. Specifically, we employ a difference-in-differences (DID) framework and find that while financially constrained firms reduce greenhouse gas emissions from plants located in California by 35% relative to plants in other states, they significantly increase emissions from plants in other states by 29% more compared to those owned by firms without a presence in California. In contrast, we find no evidence that unconstrained firms adjust emissions in response to the new regulation, neither in California nor in other states.

We also find that compared to unconstrained firms, constrained firms are less likely to invest in plants in California (14.5% more likely to close and 8% less likely to open a plant), while they are more likely to invest in plants in other states (18% more likely to open and 6% less likely to close). However, these adjustments at the extensive margin are somewhat weaker than the emission shifts at plants already in place. The differences in responses between constrained and unconstrained firms are statistically significant across a host of financial constraint measures. Finally, we provide evidence that firms whose assets are partially affected by the regulation do not reduce their firm-wide emissions. In fact, constrained firms increase their total emissions by as much as 18%. Overall, our main results are consistent with the internal reallocation of corporate pollutive activities and resources to avoid regulatory costs in the face of limited access to external financing, and highlight the hidden costs of environmental policies through financial channels.

Our economic hypothesis is that financially constrained firms reallocate their emissions and plant ownership away from California to other states in the face of heightened regulatory costs that alter the relative net expected returns across plants. The costs of external capital for constrained firms render profitable emission projects mutually exclusive, and these firms reallocate as they find the net returns from internal reallocations more attractive than the returns from optimal levels of emissions in California after the regulatory change.[4]

[4] This conjecture is rooted in studies of the relationship between financial frictions and the value of internal capital allocation, which have argued that the contribution of internal capital markets to firm value and hence the value of

Empirically, the additional costs of emissions to firms under the California cap-and-trade rule amounts to 15 basis points of the median firm's total assets and is comparable to the interest obligations on its short-term debt. We hypothesize that this increase in regulatory cost stemming from some of the firms' operations distorts the ranking of net returns on capital across plants, incentivizing constrained firms to reallocate even though emitting in California might remain profitable. Looking at emissions and ownership stakes in plants as outcome variables, we show that this is indeed strongly the case for reallocations of emissions across plants already in place, and to a lesser degree also true for changes in plant ownership.

Our conjecture and findings are consistent with criticisms by the media and small business owners that the increased regulatory costs from the cap-and-trade rule are not large enough to constitute significant deterrents to emissions for firms with deep pockets, but raise the burden for less financially capable players which may cause emission leakages.[5] Anecdotal evidence also supports the economic importance of the spillover effects we uncover. For example, Valero Energy, a major petroleum products company that was just recovering from large operating losses after the financial crisis in the early 2010s, strongly objected to the implementation of the cap-and-trade rule. It rallied other firms and warned citizens with placards at their California gas pumps that "the cap-and-trade rule would be a loss of two blue-collar jobs for every one green job created" and that "if the legislation is passed, you will pay the price… Cap-and-trade will cost you 77 cents or more a gallon".[6]

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corporate diversification is greater when external financial constraints are higher (see Billett and Mauer, 2003; Matvos and Seru, 2014; Matvos, Seru, and Silva, 2018). It has also been documented that the propagation of economic shocks through firm internal networks are stronger with tighter financial constraints, consistent with optimal resource reallocations (see Giroud and Mueller, 2019).

[5] In July 2017, as the cap-and-trade rule was about to be extended, the California state executive director of the National Federation of Independent Business (NFIB) stated on behalf of 22,000 small business members that as "California has been experimenting with cap-and-trade policies… jobs are moving to neighboring states with much more relaxed laws… Some believe cap-and-trade only impacts big businesses that buy and sell carbon credits, but the truth is that small businesses and consumers all pay the ultimate price." An October 2017 Wall Street Journal opinion piece, "The fatal flaw in California's cap-and-trade program" by Richard Sexton and Steven Sexton, criticized the cap-and-trade rule for its inability to effectively curtail carbon leakage and its failure to levy large enough burdens to large firms.

[6] See "Valero pumps up cap-and-trade debate" in CS News (September 2009), "Why did Valero launch a campaign against California's climate law?" in Los Angeles Times (October 2010), and "New energy outfoxes old in California" in The New York Times (November 2010) for media reference of Valero's reaction to California's cap-and-trade policy.

After the rule went into effect at the beginning of 2013, Valero reduced emissions by one of its largest Californian refineries in Los Angeles County by 8% over the next three years, but sharply increased emissions by some of its largest refineries in other states, for example in New Orleans LA and Jefferson TX, by more than 10%.

We interpret our findings as optimal responses by firms to increased regulatory costs as a function of their financial constraints. Hence, we are comfortable with the fact that constrained and unconstrained firms are not randomly assigned their constraint characteristics, insofar as the assignment is not related to whether firms own plants covered by the California cap-and-trade rule in a way that permits confounding explanations for why firms respond to the rule as we document. Nevertheless, we exclude a number of alternative channels that may confound the interpretation of our results. To eliminate the possibility of reverse causality whereby financial constraints are affected by the introduction of the cap-and-trade rule or firm responses to it, or omitted variables simultaneously affecting constraints and firm responses, we measure financial constraints based on information reported strictly before our sample period and at least 3 years before the effective start date of the cap-and-trade rule. We also rule out explanations concerning observed or unobserved plant characteristics such as their industry purpose, maximum capacity, or technological obsoleteness by controlling for plant fixed effects, and preclude the effects of common time trends by controlling for year fixed effects. As further robustness checks, we also report results controlling for firm-by-plant fixed effects in the Appendix. Finally, we also control for firm characteristics that may be related to how much greenhouse gas firms are prone to release, such as the firm's property and plants or R&D stock. In short, we set a high bar to refute our conclusion that the cap-and-trade rule entails spillover effects due to the internal reallocation by financially constrained firms.

Our study contributes to a recent and growing body of research on climate risk and firm behavior by focusing on the internal allocation of plant level emissions within firms driven by their financial constraints, thus providing a unique channel for the real effects of climate regulation. In particular, our findings highlight the importance of climate-related regulatory risks for firms, consistent with perceptions by institutional investors regarding their portfolio firms (see Krueger, Sautner, and Starks, 2019). Also closely related to our work are recent papers linking financial incentives and corporate environmental policies. For example, Forster and Shive (2019) find that short-termist pressure for financial performance from outside investors force public firms to emit more greenhouse gases than private firms. Kim and Xu (2018) also show that financial constraints exacerbate toxic pollution by firms due to the costs of waste management, and that this effect is stronger when regulatory monitoring is weak. In a similar vein, Akey and Appel (2019) find that firm subsidiaries are more likely to increase toxic emissions when parent companies have better liability protection for their subsidiaries' environmental clean-up costs, consistent with the binding effects of higher financial burdens associated with abatement. Complementing these studies, our findings highlight the reallocative effects of financial constraints inducing firms to internally shift their pollutive resources across plants under heightened regulatory costs, which in turn distort the outcome of regional environmental policies. Interestingly, while Akey and Appel (2019) find the effects of limited liability to be driven by lower "green" investments rather than by reallocation across plants, we show that the reallocation of greenhouse gas emissions and ownership stakes across plants are prominent responses by firms to climate policy, particularly when financial constraints are high.

More broadly, our study makes an important contribution to the debate in economics since the 1970s about the impact of climate change and how to counter it with policy (see Nordhaus, 1977a; 1977b), by providing concrete evidence on the real spillover effects from localized climate policies. With the recent rise of interest in climate change, more researchers are evaluating or prescribing energy related policies and are studying their implications (see Fabra and Reguant, 2014; Fowlie, Greenstone, and Wolfram, 2018; Marin, Marino, and Pellegrin, 2018; Khan, Knittel, Metaxoglou, and Papineau, 2019). An important aspect of climate policies, as with energy policies in general, is that they are prone to externalities because they are implemented locally while their outcomes impact climate change globally. While much attention has been paid to the implications and potential distortions arising from coordination problems in climate change policy, most of these studies are based on model simulations using parameter estimates (see Nordhaus and Yang, 1996; Martin, Muûls, De Preux, and Wagner, 2014; Nordhaus, 2015; Fowlie, Reguant, and Ryan, 2016; Bushnell, Holland, Hughes, and Knittel, 2017). On the other hand, empirical evidence that speaks to the economic magnitudes and channels of externalities from coordination issues of climate change policy is scarce, and our study aims to fill this gap.

While empirical analysis of the economic impact and spillover effects of localized environmental policies across countries have garnered interest in the "pollution haven" literature in environmental economics, most of these studies have been limited to aggregate level cross-industry or cross-country analysis (see, among others, Cole and Elliott, 2005; Ederington, Levinson, and Minier, 2005; Levinson and Taylor, 2008; Kellenberg, 2009; Wagner and Timmins, 2009), indirect inference through the location and size of plants rather than pollutive activities per se (see Becker and Henderson, 2000), or self-reported survey data on CO_2 emissions aggregated at the firm-country level (see Ben-David, Kleimeier, and Viehs, 2018). Moreover, these studies have not focused on climate change policy, which differs from general environmental policies in that its explicit objective is to solve the problem of global warming rather than local pollution, the effectiveness of which critically hinges on the identification of unintended consequences across regulatory jurisdictions. Our paper has several key distinctions from these studies: (a) We utilize mandatorily reported data on plant level CO_2e greenhouse gas emissions and parent ownership, (b) we are able to exploit both within and between plant variation by focusing on the introduction of a local policy in the middle of our sample period whose clear mandate is to curb greenhouse gas emissions in one state but not others such that a DID analysis is possible, (c) we provide the first climate policy evaluation directly relevant for policy makers in the United States, (d) and most importantly, we emphasize firm financial constraints as an important economic channel for our results.

Remedying policies to climate change risk are heatedly debated. Such policies have important implications for the behavior of private industrial firms and how they respond to regulatory frictions, which are of key interest to financial economists. Understanding these effects are important to guide policy makers to internalize externalities that may otherwise result in unintended consequences and more effectively coordinate solutions to climate change. Given the importance of a sound evaluation of the efficacy and real effects of climate policy, it is surprising how little empirical work has been done on this front. This paper aims to take the debate on climate change, climate policy, and corporate environmental responsibility one step closer in this direction.

Our paper is organized as follows. In Section 2, we summarize the relevant details of the California cap-and-trade rule and develop our economic hypotheses. We describe our data sources and summarize the composition and characteristics of our sample in Section 3. Section 4 motivates our empirical research design, while Section 5 presents our results. We conclude in Section 6 with a brief summary and some policy guidance.

2 Background and Hypothesis Development

2.1 California Cap-and Trade

At the beginning of 2013, the state of California's Air Resources Board started enforcing a state-wide carbon cap-and-trade rule to reduce greenhouse gas emissions. Covering all electric power plants and industrial plants that emit 25,000 metric tons or more of carbon dioxide equivalents (CO_2e) per year, the California cap-and-trade was the first multi-sector cap-and-trade program in North America.[7] The California cap-and-trade rule is based on an allocation of capped allowances with specific year vintages and the market trading of those allowances. At the allocation stage, allowances are distributed to plants through a combination of quarterly held auctions and free allowances. Firms are then required to pay off their plants' emissions using these and additional allowances they may buy via market transactions, according to a vintage specific schedule laid out by the program.[8] Given this institutional structure, the question is whether the cap-and-trade rule constitutes a significant regulatory cost for firms with affected plants. We demonstrate in a number of ways that this is likely the case for firms that are financially constrained.

Table 1 presents publicly available aggregate data on quarterly allowance auctions (Panel A), free allocations (Panel B), and market transactions (Panel C) made available by the California Air Resources Board. Panel A shows that in every quarterly auction starting in 11/2012 for 2013 vintage allowances, current vintage allowances are completely sold out, there are more bids than available current vintages, and the settlement price for current vintages is always higher than the initial reserve price despite the reserve price being increased every year. Furthermore, Panel B indicates that the free allowance allocations leave substantial room for further incentives to bid in auctions or purchase at market prices. For example, in 2014, the average plant receives free

[7] In 2014, the California cap-and-trade program was linked with the cap-and-trade program in Quebec, Canada. As of 2015, total aggregate emissions covered by the rule in California (Quebec) was approximately 400 (60) million metric tons. In 2015, the program was extended to fuel distributors emitting more than 25,000 metric tons.

[8] For example, calendar year 2013 emissions are required to be paid off to at least a third by November 2014 and in full by November 2015. Calendar year 2014 emissions must be paid in full by November 2015. Calendar year 2015 (2016) emissions are to be paid in at least a third by November 2016 (2017) and in full by November 2018. Calendar year 2017 emissions are to be paid in full by November 2018, and the schedule goes on. No calendar year's emissions can be paid with future vintage allowances (i.e. firms cannot borrow from the future to pay today, though they can buy future vintages in advance).

allowances to emit 349 thousand metric tons of greenhouse gas. However, the median plant in our sample emits 690 thousand metric tons (see Panel B of Table 3), which means the plant must acquire the rights to emit the difference of 341 thousand metric tons either by bidding in auctions or buying them from other market participants. Assuming an average price of $12 per metric ton, the cost of doing so amounts to $4.1 million. Since the median firm owns three plants, the total costs to the firm from extra emissions beyond its free allowances amounts to $6.2 million, conservatively assuming half of its plants are located in California.[9] This is a non-trivial cost, which is in the order of 15 basis points of the firm's total assets, 3% of its net profits, and comparable to the interest obligations on its short-term debt assuming an interest rate of 2%. Finally, Panel C of Table 1 shows that the aggregate magnitudes of market transactions are comparable to those of the free allocations or auctions, and that the transaction prices not only hover above the contemporaneous auction settlement prices but also steadily increase over time. Figure 3, which plots the time series of emission allowance futures prices for each vintage, corroborates the evidence on price trends of market transaction.

Put together, Table 1 and Figure 3 suggest that the increase in costs of emitting greenhouse gases due to the introduction of the California cap-and-trade rule is substantial and sufficiently high for financial constraints to matter. However, this does not mean that these costs will affect unconstrained firms as well. Given the magnitude of the estimated costs, we conjecture that while it may be large for firms with high incremental financing costs, it may not be important for firms with deep pockets. This motivates our hypotheses for how the California cap-and-trade rule will affect greenhouse gas emissions and plant ownership by firms, and the role of financial constraints as the economic channel. We elaborate on the intuition in the following section.

2.2 Hypothesis Development

Economic theory posits that firms will allocate capital to places where net returns are positive as long as they are financially unconstrained to do so. If firms are financially constrained, however, they can only allocate capital to a limited set of profitable options among several mutually exclusive investment opportunities. For such

[9] Given that there are 161 plants and 85 firms in the sample (see Table 2), the actual number of Californian plants owned by one firm with a presence in California is close to 2. The total costs to the median firm from extra emissions then amounts to $8.2 million, or 20 basis points of its total assets.

constrained firms, the distribution and ranking of the net returns of projects are important, even when they are all economically viable. Regional regulation, such as the state-wide cap-and-trade system in California, introduces perturbations to the distribution of net returns across regions and thus motivates capital reallocation for profit maximizing firms that are financially constrained. Our hypotheses concern the direction and magnitude of this reallocation.

In our context, firms that have a plant presence both in California and in other states are geographically diversified, and thus can use their internal networks to reallocate their resources when the profile of net expected returns change across their segments due to the increase in regulatory costs from the new cap-and-trade-rule. However, if firms have access to frictionless borrowing, they would accommodate the change without shifting resources across plants since their costs of external capital would be low enough to afford all emission projects as long as their net expected returns remain positive. In contrast, financially constrained firms that are geographically diversified would reallocate resources away from plants that are subject to higher regulatory costs to plants they own elsewhere, as their costs of external capital would be too high to finance costly emissions when the net returns from internally reallocating their resources would be greater.

To further clarify why financially unconstrained firms would not reallocate emissions whereas constrained firms would, it is worth noting a natural corollary to their capital budgeting decisions explained above: Unconstrained firms are likely to be at capacity wherever it is profitable to produce while constrained firms are likely to have excess capacity, or under-utilization, at relatively less profitable locations. Several studies provide empirical support for this notion. Von Kalckreuth (2006), for example, uses UK survey data to show that financially constrained firms take longer to close capacity gaps. Dasgupta, Li, and Yan (2019) demonstrate in the context of inventory that constrained firms are more likely to carry a surplus over to unfavorable times. As such, to the extent that the reallocation of emissions is achieved by shifting production resources, unconstrained firms have neither the need nor means to reallocate emissions across plants they have in place as long as emitting in California remains profitable, whereas constrained firms do.

Figure 4 illustrates this intuition by plotting the revenues and costs from varying quantities of emissions. Suppose an imperfectly competitive market with downward sloping marginal (average) revenues mr (ar), and costs that depend on the locale of production. Firms that operate a plant in California face marginal (average) costs mc_{ca} (ac_{ca}) and an optimum point I with average costs a and emission quantity d. The net return from the California plant is equal to the size of the blue area bordered by a and d, denoted by A. Once the California cap-and-trade rule is implemented, the cost functions move upward to mc'_{ca} and ac'_{ca} for quantities above the amount of the free allocations, shifting the optimum to I' where average costs are higher at b and quantity is lower at e. The net return remains positive though smaller than before, equal to the size of the lighter blue area bordered by b and e, denoted by A'. Since the net return is still positive, firms with unlimited access to capital will continue to emit despite the higher costs, as they will continue to allocate capital to all profitable projects.[10]

However, I' is an undesirable equilibrium for financially constrained firms because the net returns are smaller than before (i.e. $A' < A$), so they reallocate their resources from California to other states where there are investment opportunities with larger net returns that previously did not seem as attractive. For example, if the costs from emitting in other states follow cost functions mc_{oth} and ac_{oth}, constrained firms will reallocate from I to I'' since the size of its net return, denoted by B and originally no larger than A, is now greater than A'. On the other hand, I and I'' are not mutually exclusive options for unconstrained firms to begin with, so they would have invested in both projects ex-ante since they are both profitable. Therefore, unconstrained firms would not reallocate as the relative ranking of I' and I'' is irrelevant for them. Empirically, these predictions imply that the cap-and-trade rule will push constrained firms to not only reduce emissions from plants in California by more than unconstrained firms (d for constrained firms vs d–e for unconstrained firms), but also increase emissions from plants in other states by more (f for constrained firms vs no increase for unconstrained firms).[11]

[10] The assumption that the net return from emitting in California after the implementation of the cap-and-trade rule remains positive is supported by state level GDP growth data. In Table 11, we document that California not only exhibits higher growth compared to other states by a large margin during the years when the cap-and-trade rule is in effect, but also that the acceleration in GDP growth compared to the previous period is greater in California than in other states.

[11] In Figure 4, the cost curve in other states lie below that of California. If this were not the case and mc_{oth} were identical to mc_{ca}, the figure would still suggest a sharper decrease in California emissions by constrained firms than by

In other words, the value of internal reallocation would be greater for financially constrained firms when the costs of emissions are increased due to policy changes. The motivation of this hypothesis is grounded in the literature in finance on the value of internal capital markets in the face of financial frictions (for early studies, see Gertner, Scharfstein, and Stein, 1994; Lamont, 1997; Stein, 1997; Shin and Stulz, 1998). In this literature, it has been shown that the contribution of internal capital markets to firm value and hence the value of corporate diversification is greater when external financial constraints are higher, for example when there are large dislocations in financial markets (see Billett and Mauer, 2003; Matvos and Seru, 2014; Matvos, Seru, and Silva, 2018). Our hypothesis is also consistent with Giroud and Mueller (2019) who find that the propagation of economic shocks through firm internal networks are stronger with tighter financial constraints, consistent with a model of optimal within-firm resource allocation.

This economic rationale leads to two key research questions with regards to the effect of climate policy on firms that we investigate in this paper: (1) Do local climate policy changes (such as the introduction of the California cap-and-trade rule) affect firms' internal resource allocations and environmental policies such as their greenhouse gas emissions and ownership stakes across plants? (2) Are firms' reallocation responses to policy affected by their financial constraints? In the following sections, we describe the data and construction of our sample, and formulate the empirical methodology that we use to test these hypotheses.

3 Data and Sample

3.1 Data

In October 2009, the EPA published the Greenhouse Gas Reporting Program (GHGRP) mandating that sources that emit 25,000 metric tons or more of carbon dioxide equivalent greenhouse gases per year must

unconstrained firms, and a corresponding sharp increase in emissions from other states by constrained firms by the amount of d instead of f. In this scenario, the central prediction that motivates our main hypothesis remains unchanged, and unconstrained firms would still not reallocate. Figure 4, however, raises the possibility that the overall level of firm emissions could increase as a result of the regulation due to the reallocation by constrained firms. We formally test this hypothesis in Section 5.4.

report their emissions, compliant with the estimation methodologies prescribed by the EPA.[12] Once the submitted information is verified by the EPA, the data is made publicly available through the Facility Level Information on GHGs Tool (FLIGHT), providing plant level information on the identity, geographic location, parent company ownership, NAICS industry code of the plant, as well as the quantity of greenhouse gas emissions on an annual basis starting in 2010 for large plants that meet the reporting requirements. Our sample period extends from 2010 to 2015 - three years before and after the beginning of the California cap-and-trade program - and the initial sample covers approximately 9,200 unique plants.[13]

To analyze the impact of financial constraints, we hand-match the EPA plant level dataset with annual financial accounting data from Compustat based on the names of parent companies. To be included in our merged sample, we require that firms have positive assets and sales greater than $10 million. While utilities and governmental firms may be significant greenhouse gas emitters, common measures of financial constraints may not matter for them in the same way as they do for typical industrial firms. For this reason, we exclude not only financial firms (SIC 6000–6999), but also utilities (SIC 4900–4999) and governmental firms (SIC 9000–9999). The final sample is an unbalanced panel of 2,806 plants and 511 firms over the sample period 2010 to 2015.

We collect standard variables from Compustat to be used as controls or to compute financial constraint measures such as total assets, PP&E, capital expenditures, short-term debt, long-term debt, cash, cash flow, profitability, Tobin's Q, dividends, repurchases, long-term (i.e. bond) and short-term (i.e. commercial paper) credit ratings. We take the difference between the observation year and founding year as firm age as in Jovanovic and Rousseau (2001). We also compute R&D stock using the perpetual inventory method, where we initialize R&D capital stock at zero and accumulate R&D expenses with a depreciation rate of 15% (see Hall, Jaffe, and

[12] While GHGRP reporters have some discretion over which of the EPA-approved methods to use when reporting emission quantities, this selection is unlikely to affect our conclusion as the reporting responsibility falls to the plant rather than the parent company. Moreover, it is hard to explain why plants would change reporting methods resulting in not only a decline in reported emissions from California, but also an increase in reported emissions from other states.

[13] We do not include the years 2016 and 2017, which include potentially confounding events such as the signing of the Paris Agreement and the subsequent withdrawal by the United States, as well as additional legislative packages signed by the state of California seeking to reduce greenhouse gas emissions and other air pollutants.

Trajtenberg, 2005). All continuous financial variables are winsorized at the top and bottom 1% before a financial constraint index is computed. A detailed list of variable definitions is included in the Appendix of the paper.

3.2 Measuring Financial Constraints

Since an important part of our study is to establish an economic channel through which financial constraints determine how firms respond to climate policy, measuring financial constraints is a critical step in our paper. Based on the financial accounting information from Compustat, we employ six alternative measures of financial constraints commonly used in the literature. They are the Kaplan-Zingales index (see Kaplan and Zingales, 1997; Lamont, Polk, and Saá-Requejo, 2001), the Hadlock and Pierce (2010) index, the Whited and Wu (2006) index, firm size, payout, and credit (i.e., bond or commercial paper) ratings (see Almeida, Campello, and Weisbach; 2004). In addition, we combine the six variables into a composite indicator that is our primary measure of financial constraints.

For the Kaplan-Zingales, Hadlock-Pierce, and Whited-Wu indices, as well as firm size and payout, firms are assigned percentile rankings based on each measure every year. We then use the six years strictly before our sample period (i.e. fiscal years 2003–2008) to compute time-series average percentile rankings for each firm and each measure. Based on these average rankings, firms are categorized as financially constrained if they are above the median for the Kaplan-Zingales, Hadlock-Pierce, and Whited-Wu indices, and if they are below the median for firm size and payout.

For credit ratings, we first examine long-term bond ratings and short-term commercial paper ratings separately. If a firm did not have a bond (commercial paper) rating as of the most recent year of the 2003–2008 pre-sample period but had on average positive long-term (short-term) debt during this period, the firm is categorized as "long-term (short-term)" financially constrained. If the firm did have a bond (commercial paper) rating as of the most recent year of the six-year pre-sample period or had on average zero long-term (short-term) debt during this period, then the firm is "long-term (short-term)" unconstrained. If a firm is either long-term or short-term credit constrained, the firm is classified as constrained based on ratings and unconstrained otherwise.

Finally, we construct a composite measure of all six proxies of financial constraints. For the composite indicator, a firm is categorized as constrained if the majority of the six proxies classify the firm as being constrained; otherwise the firm is unconstrained. For all of our financial constraint measures, firms are classified strictly before they enter the sample period, thus ruling out reverse causality concerns or omitted variables simultaneously affecting the evolution of constraints and firm responses to policy.

3.3 Sample Statistics

Table 2 illustrates the geographical distribution of our sample of plants and firms owning these plants. The intersection of the EPA and Compustat universes covers firms and plants in virtually all states. Over the sample period, the average annual emissions per plant is approximately 289 thousand metric tons, implying the average annual aggregate amount to be 810 million metric tons. According to the EPA, the average amount of greenhouse gas emissions from the US industrial sector over this period was 1,430 million metric tons. Hence, approximately 57% of all industrial greenhouse gas emissions can be attributed to plants owned by our sample of public firms.

The focal state of our study, California, ranks third among all states in terms of the number of firms with a plant presence (i.e., 85 firms, or 17% of all firms, of which 70 also own a plant in other states), fourth in terms of the number greenhouse gas emitting plants (i.e., 161 plants), and seventh in terms of average annual emissions per plant (i.e., 398 thousand metric tons). In short, California is a significant source of greenhouse gas emissions and takes up a sizable portion of the plants and firms in our sample, despite its dominance in the high-tech industry. Understandably, the most important alternative state in the sample is Texas, a state whose weight in the US fossil fuel industry is disproportionately high. Approximately 14% of our sample firms (i.e., 70 out of 511) and 82% of firms with a plant in California (i.e., 70 out of 85) are geographically diversified in the sense they have a presence both in California and in other states. This final observation motivates our hypothesis that a policy curbing emissions in California alone could very well have spillover effects to other states that do not have such a comprehensive program in place.

Panel A of Table 3 describes the characteristics of the sample firms. The size of firms and amount of greenhouse gas they emit are both positively skewed, consistent with the fact that a smaller number of large firms own more plants that generate emissions. The average (median) firm emits 1,584 (277) thousand metric tons, and has total assets of $17.3 ($4.2) billion. R&D spending and R&D capital stock are both skewed to the right as well, as many industrial firms have little R&D. The firms in our sample tend to hold a significant portion of their assets in the form of property, plant, and equipment (47% of assets), have more long-term borrowing than short-term (28% versus 3% of assets), pay a substantial portion of their earnings out either as dividends or via repurchases (49% of earnings before extraordinary items), and on average are less than 30 years old.

Our sample is well balanced in terms of the composition of financially constrained and unconstrained firms, based on whether firms have long-term (> 1 year) or short-term (< 1 year) credit ratings. Approximately 45% of sample firms do not have a long-term bond rating and more than 75% do not have a short-term commercial paper rating, roughly consistent with Almeida, Campello, and Weisbach (2004). This bolsters our confidence in adopting the method of categorizing firms as financially constrained or unconstrained based on their cross-sectional rankings of constraint measures, which is commonplace in the literature but often subject to criticism that objectively unconstrained firms can be misclassified as relatively constrained.

Panel B of Table 3 shows the distribution of plant emissions and ownership. Plant emissions are skewed to the left: While the average plant emits 289 thousand metric tons of greenhouse gas, more than half of the plants emit substantially more given a median of 690 thousand metric tons per year. For almost all plants, ownership is concentrated in one firm. In other words, there are rarely cases where multiple firms share and operate the same plant. The average (median) firm owns six (three) plants; the positive skewness is consistent with the distribution of firm assets and emissions shown in Panel A.

Next, we formulate our empirical strategy to test the hypothesis that the California cap-and-trade rule differentially incentivizes financially constrained firms to reallocate emissions and reconfigure plant ownership using the EPA-Compustat merged sample dataset.

4 Empirical Methodology: Difference-in-Differences

We exploit variation in treatment of the California cap-and-trade rule in the cross-section (i.e., plants in California versus other states; or firms that own plants in California versus firms that do not) and time-series (i.e., before and after 2013) to implement difference-in-differences (DID) regressions at the firm-plant-year level.

If the trends in emissions for treated plants (i.e., located in California; or owned by a firm with operations in California) and non-treated plants (i.e., located outside of California; or owned by a firm without any presence in California) are parallel prior to the implementation of the California cap-and-trade, the DID estimates will plausibly isolate the effects of the rule itself, insofar as there are no confounding events that occur coincidentally with the introduction of the cap-and-trade rule. During our sample period from 2010 to 2015, the 2013 California cap-and-trade rule was indeed the only notable climate policy introduced to curb industrial greenhouse gas emissions.[14] It is also worth noting that anticipation about the cap-and-trade rule prior to its implementation is unlikely to be an issue, as there is no economic benefit to the firm from preemptively reallocating their emissions when profits from emitting in California are still high before the introduction of a regulatory cost. The absence of such anticipatory adjustments is empirically evident in the emission trends, which we discuss next.

We first begin by comparing the emissions of plants in and outside of California. A visual inspection of emission trends helps motivate our strategy. As our main hypotheses are aimed at examining the reallocation of emissions within firm internal networks, we focus our inspection on the sample of firms that are geographically diversified (i.e., have plants both in California and in other states). The first chart in Panel A of Figure 5 plots the time trends of firm-plant level emissions (in thousand metric tons), showing that emissions from

[14] It was the first major regulation enforced to achieve the emission reduction objectives initially outlined and required by the landmark California state law AB 32, which was signed in 2006. After 2015, AB 32 was further strengthened by several subsequent legislative bills (e.g. SB 32 and AB 197 in 2016; AB 398 and AB 617 in 2017). Aside from AB 32, the governor of California signed SBX1 2 in 2011, requiring that one third of the state's electricity come from renewable sources by 2020, and in 2014, the energy efficiency requirements for newly constructed buildings were tightened pursuant to updated Green Building Standards. However, these policies are distinct from the cap-and-trade rule in their enforcement targets, intensity, and timing. Hence, the emission shifting between industrial plants that we identify around 2013 primarily correspond to the impact of the introduction of the cap-and-trade rule.

California and non-California plants are closely aligned prior to treatment such that the trends are parallel. However, unconditionally there is also no visible subsequent divergence after the rule is implemented.

This picture changes dramatically when the sample of geographically diversified firms is split into financially constrained and unconstrained firms, as shown in the first two charts in Panel A of Figure 6. For financially unconstrained firms, emissions from California and non-California plants move in parallel before the implementation of the cap-and-trade rule and largely maintain this pattern after 2013 as well. In sharp contrast, for constrained firms, the parallel trends before 2013 begin to diverge visibly afterwards. Post 2013, California plants owned by constrained firms reverse their prior upward trend and start reducing emissions, whereas non-California plants sharply increase emissions. These trends paint a clear picture that the California cap-and-trade rule has a large differential impact on how financially constrained and unconstrained firms allocate emissions across their plants located in California and in other states.

Motivated by these trends, we formally test whether California and non-California plants adjust their emissions differentially in response to the cap-and-trade rule, using the following regression specification:

$$Log(1+Emissions_{i,j,t}) = \alpha + \beta CalPlant_j \times After_t + \gamma' X_{i,t} + a_j + b_t + \varepsilon_{i,j,t} \tag{1}$$

where $Log(1+Emissions_{i,j,t})$ is the logarithm of metric tons of greenhouse gases emitted by firm i at plant j. $CalPlant_j$ is an indicator variable equal to 1 if plant j is located in California and 0 otherwise. $After_t$ is an indicator equal to 1 if the year is 2013 or after and 0 otherwise. $X_{i,t}$ denotes a vector of firm level control variables such as PP&E and R&D stock. Finally, a_j and b_t each denote plant fixed effects and year fixed effects, respectively. The variables $CalPlant_j$ and $After_t$ are not included by themselves in the regressions as they are subsumed by the fixed effects. In the Appendix, we further report results controlling for firm-by-plant fixed effects as robustness checks. This model evaluates the impact of the cap-and-trade scheme on the emissions by firms from plants they own in California as compared to plants located in other states. To study the impact of financial constraints on how firms respond to the cap-and-trade rule, we estimate the DID model in Equation (1) separately for constrained and unconstrained firms, and evaluate whether the coefficients on the interaction term $CalPlant_j \times After_t$ are significantly different in the two models.

While Equation (1) provides for a test of whether the California cap-and-trade rule has a significant effect on emissions from California plants relative to non-California plants, it does not fully disentangle whether the effect is driven by emission spillovers to plants in other states that would not have occurred otherwise. To further identify such a spillover effect, it is useful to compare the emissions from plants outside of California owned by firms that also have plants in California with a counterfactual group of non-California plants owned by firms without any operations in California.

Such a visual comparison of emission trends clearly suggests strong spillover effects contingent on financial constraints. The second chart in Panel A of Figure 5 plots the emission trends of non-California plants owned by firms with and without a California presence. In this unconditional plot, the parallel trends assumption holds, but there are no visible changes in the post-trends either. In the plots that condition the sample based on financial constraints, shown in the second row of Panel A of Figure 6, the pre-trends are similarly parallel for both unconstrained and constrained firms. However, during the post 2013 period, constrained firms with California plants substantially increase emissions from their non-California plants, whereas there are no changes for plants owned by constrained firms without exposure to California or unconstrained firms regardless of their California exposure. Altogether, the illustrative evidence from Figures 5 and 6 is consistent with a strong spillover effect from financially constrained firms with assets exposed to the California cap-and-trade rule shifting their emissions to other states.[15]

These trends validate an additional DID regression to formally test the spillover effect, where we replace the plant level treatment dummy $CalPlant_j$ in Equation (1) with a firm level dummy $DivFirm_{it}$ that is an indicator for whether a firm owns plants both in California and in other states during a given year or not. Since $DivFirm_{it}$ is not subsumed by fixed effects, it is also included as a regressor by itself.[16] We run this firm-plant-year level regression on a subsample of non-California plants. This specification effectively tests for spillover

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[15] Moreover, paired *t*-tests as suggested by Roberts and Whited (2013) reveal that the average emission growth rates during the pre-cap-and-trade period of 2010-2012 are not statistically different between treatment and control plants, but are significantly different during the post-period of 2013-2015.

[16] In robustness checks reported in the Appendix, where we control for firm-by-plant fixed effects, the term $DivFirm_{it}$ is dropped.

effects by studying whether plants outside of California exhibit changes after the cap-and-trade rule is implemented depending on whether the parent companies' assets are affected by the rule. This specification is written as follows, and estimated separately for constrained and unconstrained firms.

$$Log(1+Emissions_{i,j,t}) = \alpha + \beta_1 DivFirm_{i,t} + \beta_2 DivFirm_{i,t} \times After_t + \gamma' X_{i,t} + a_j + b_t + \varepsilon_{i,j,t} \tag{2}$$

As an alternative to comparing coefficients from separate DID regressions on constrained and unconstrained subsamples, we run pooled regressions by including a *Constrained*$_i$ dummy in an expanded triple difference framework. The triple difference specifications can be written as follows:

$$\begin{aligned} Log(1+Emissions_{i,j,t}) = \alpha &+ \beta_1 Constrained_i + \beta_2 Constrained_i \times After_t \\ &+ \beta_3 CalPlant_j \times Constrained_i + \beta_4 CalPlant_j \times After_t \\ &+ \beta_5 CalPlant_j \times Constrained_i \times After_t + \gamma' X_{i,t} + a_j + b_t + \varepsilon_{i,j,t} \end{aligned} \tag{3}$$

and

$$\begin{aligned} Log(1+Emissions_{i,j,t}) = \alpha &+ \beta_1 Constrained_i + \beta_2 DivFirm_{i,t} + \beta_3 Constrained_i \times After_t \\ &+ \beta_4 DivFirm_{i,t} \times Constrained_i + \beta_5 DivFirm_{i,t} \times After_t \\ &+ \beta_6 DivFirm_{i,t} \times Constrained_i \times After_t + \gamma' X_{i,t} + a_j + b_t + \varepsilon_{i,j,t} \end{aligned} . \tag{4}$$

This method overcomes issues related to model fit or misspecification that may be compounded by comparing coefficients across multiple models, and enables the econometrician to control for differences across other coefficients in the model as well. We use both methods, separate and pooled regressions, for the analyses on emissions and focus on the pooled regression method in subsequent plant ownership tests or placebo tests.

In the following section, we present and discuss the results based on our data and empirical design. Motivated by our central hypotheses, we focus our study on contrasting emission and plant ownership responses of California versus non-California plants for the sample of geographically diversified firms, and comparing the responses of non-California plants owned by geographically diversified versus undiversified firms. Hence, we concentrate our discussions on the internal reallocations by geographically diversified firms and the resulting spillovers to other states.

5 Results

In this section, we present empirical evidence pursuant to our economic hypotheses, DID methodology, and data outlined in the previous sections. We begin by presenting unconditional evidence on firms' emission responses to the introduction of the California cap-and-trade rule, and then move on to analyzing the impact of variations in financial constraints.

5.1 Unconditional Tests

In Table 4, we report results from unconditional tests without exploiting the heterogeneity in financial constraints across firms. These results help us understand the overall effects of the California cap-and-trade rule, and provide further motivation to explore the financial constraints channel through which they manifest.

We start with univariate results in Panel A. For each firm-plant, we first compute emissions growth as the difference between post–2013 and pre–2013 average emissions, scaled by the full sample period mean. We then divide our sample of plants into treatment and control groups, and compare the mean emissions growth between the two groups by reporting the difference of their means and its corresponding *t*-statistic. Treatment is defined under two alternative schemes, each corresponding to a subpanel in Panel A. In the first scheme, we define treatment at the plant level based on their location, where we define California plants as the treatment group and plants in other states as the control group. We focus on the subsample of geographically diversified firms that have plants both in California and in other states. The unconditional difference of emissions growth between California and non-California plants is –6%. While this raw difference is not statistically significant (*t*-statistic of –1.03), it is weakly significant in multivariate analyses that control for a host of control variables and fixed effects, as discussed below. In the second scheme, we focus on plants outside of California and define treatment at the firm level based on whether firms own plants in California, i.e., whether they have asset exposure to the cap-and-trade rule or not. The unconditional difference of the change in emissions between non-California plants owned by diversified and non-diversified firms is positive (5% pts) and statistically significant (*t*-statistic of 2.2). Overall, the univariate results indicate a modest decline in emissions from California plants and a sharp increase in emissions from plants located in other states as a result of the implementation of the California cap-and-trade rule.

In Panel B of Table 4, we report multivariate results from running the regressions in Equations (1) and (2), where we control for other observable characteristics and several dimensions of unobserved heterogeneities such as plant and year fixed effects. The first four columns (1)-(4) show results from running Equation (1) on the subsample of firms that are geographically diversified, where the dependent variable is the logarithm of emissions (*Log(1+Emissions)*) and treatment is whether a plant is located in California (*CalPlant*). Four variations of this specification are implemented: (i) without fixed effects or controls, (ii) with year fixed effects, (iii) with plant and year fixed effects, and (iv) with both fixed effects as well as controls (henceforth the main specification).[17] As controls, we include firm level PP&E and R&D stock, both scaled by total assets. The adjusted R^2 jumps from below 0.01 to over 0.85 as plant fixed effects are included, highlighting the fact that idiosyncratic differences across plants, such as industry classification, maximum capacity, or technological obsoleteness, explain an important portion of the variation in greenhouse gas emissions.

The key coefficient of interest is on the interaction term *CalPlant* × *After*, which captures the differential treatment effect of the introduction of the cap-and-trade rule on emissions. The sign on this coefficient is consistently negative across all four specifications, and the magnitude is also fairly similar even though the plant fixed effects subsume a small portion of its explanatory power. The coefficient on the interaction term is negative (–0.155) and significant at the 10% level controlling for both plant and year fixed effects as well as firm level controls. In terms of economic magnitude, the result indicates that firms reduce emissions from California plants by 15.5% more than from non-California plants.[18]

The next four columns (5)-(8) in Panel B examine whether part of this treatment effect can be explained by reallocations or spillovers to plants outside of California by focusing on the sample of plants located in other states. As in Equation (2), the *CalPlant* treatment dummy is replaced by a firm level *DivFirm* indicator for whether the parent firm has a plant presence in California and is thus exposed to the cap-and-trade regulation.

[17] In Table A.1 of the Appendix, we also report results controlling for firm-by-plant and year fixed effects. The results are economically and statistically similar to those in Table 4.

[18] In the full sample, however, the coefficient is less than half in size (–0.064) and statistically insignificant. This implies that the impact of the cap-and-trade rule on California emissions is roughly confined to firms with plants in other states as well, but that the policy is not meaningfully effective in reducing emissions otherwise.

The results indicate strong and significant spillover effects. The coefficient on *DivFirm* × *After* is positive and highly significant at the 1% level in all four specifications. Controlling for fixed effects and firm level variables, non-California plants owned by firms exposed to the California cap-and-trade rule increase emissions by 13.1% more than plants owned by non-diversified firms.

Overall, the results in Table 4 strongly suggests unintended consequences of the cap-and-trade rule in the form of spillover effects due to reallocation motives of firms whose assets are "partially" affected by the regulation. Moreover, we confirm in untabulated analysis that any significant reduction in emissions from California plants are mainly driven by the reallocation by geographically diversified firms who correspondingly increase their emissions from plants in other states. Otherwise, there is no meaningful evidence that the cap-and-trade rule effectively reduces emissions. An important economic question that arises from this finding is what frictions motivate firms to shift resources internally across their plants, because in a frictionless world firms could simply raise more capital to absorb the increased costs of emissions as long as operating in California yields positive net returns. As discussed earlier, we hypothesize that financial constraints constitute an important friction that provides an economic channel for such reallocations and spillover effects.

5.2 The Impact of Financial Constraints

We now implement our DID regression strategy to explore the financial constraints channel. In Table 5, we run our DID regressions with plant and year fixed effects as well as firm controls, separately for financially constrained and unconstrained firms.[19] We use our composite indicator as well as six proxies (i.e. Kaplan-Zingales, Hadlock-Pierce, Whited-Wu, firm size, payout, and credit rating) for financial constraints, and report results for each of these measures. To statistically compare the effects across constrained and unconstrained groups, we test for differences in the coefficients on the *CalPlant* × *After* or *DivFirm* × *After* interaction terms.

In Panel A, we take the sample of geographically diversified firms that operate plants both in and outside of California and run regressions based on Equation (1), where we compare the changes in emissions

[19] In Table A.2 of the Appendix, we also report results controlling for firm-by-plant and year fixed effects. The results are similar to Table 5, both economically and statistically.

from California plants with non-California plants using the interaction term *CalPlant* × *After*. These regressions show that constrained firms reduce their emissions from California plants more compared to plants in other states, whereas unconstrained firms do not. According to our composite constraint measure, constrained firms reduce emissions from California plants by 35% more (significant at 10%) compared to non-California plants, whereas this effect is a statistically insignificant 3% for unconstrained firms. The difference between the responses by constrained and unconstrained firms is statistically significant at 10% with a *p*-value of 0.07. This result is economically robust across all six constraint proxies, and statistically robust for the Hadlock-Pierce index and payout ratio in particular.[20]

In Panel B, we estimate Equation (2) with *DivFirm* as the treatment dummy, where we compare emissions between plants outside California owned by firms with and without a California presence. We run this regression again separately for the sample of constrained and unconstrained firms, and formally compare the coefficients on *DivFirm* × *After* across the two models. The results are consistent with a strong spillover effect where financially constrained firms significantly increase their emissions from plants outside California if part of their assets are exposed to the increased regulatory burden of the California cap-and-trade rule. Under our composite measure, constrained firms with plants in California increase emissions by 29% more (significant at 1%) than those without plants in California. For unconstrained firms, the relative change in emissions is only –9% (only weakly significant at 10%). The difference between the responses by constrained and unconstrained firms is highly significant with a *p*-value close to zero. This finding is economically and statistically robust across all measures of financial constraints except for the Whited-Wu index, for which the result is still economically consistent. The differences of the effects between constrained and unconstrained firms are significant at 1% for the Kaplan-Zingales index, Hadlock-Pierce index, payout, and rating, and significant at 5% for firm size.

[20] Given the spillover effects illustrated earlier, one econometric concern is that the negative coefficient on the *CalPlant* × *After* term could partially capture the increase of emissions in other states rather than the decrease of emissions in California. We address this issue by running an alternative specification where we compare California plant emissions between geographically diversified firms (i.e. firms that shift emissions to other states) and undiversified firms (i.e. firms that cannot shift emissions to plants in other states). In untabulated results, we find a decrease in California plant emissions by geographically diversified firms as compared to undiversified firms, which is of similar magnitude though weaker in statistical significance due to lack of power.

As discussed in the previous section, we also use alternative specifications where the sample of constrained and unconstrained firms are pooled together and a *Constrained*$_i$ dummy is included in a triple difference regression, instead of running separate regressions and comparing coefficients from the two models (see Equations (3) and (4)). This helps avoid biases of comparing coefficients from distinct regression models with varying degrees of model fit and misspecification, and it also enables us to control for differences in the other coefficients across the two models. Table 6 reports the results from these pooled triple difference regressions. Similar to the previous table, the results comparing emissions from California and non-California plants owned by geographically diversified firms based on the *CalPlant* indicator are reported in Panel A, and the tests for spillover effects comparing non-California plant emissions by diversified and non-diversified firms using the *DivFirm* indicator are reported in Panel B.[21]

In Panel A of Table 6, the main coefficient of interest is on the triple interaction term *CalPlant* × *After* × *Constrained*, which captures how firms change their emissions from plants in California relative to plants in other states depending on whether they are financially constrained or not. We expect the coefficient on this term to be negative, as constrained firms are expected to reduce emissions in California by more. Also relevant is the coefficient on *CalPlant* × *After*, which in this context measures how unconstrained firms behave. Since there are virtually no responses by unconstrained firms based on the results reported in Table 5, we expect this coefficient not to be significantly different from zero, or at most only weakly negative. The results confirm that this is the case. Panel A shows that for firms with plants both in and outside of California, the coefficient on the triple interaction term is economically large and negative (for all measures) and statistically significant (at 10% for the composite indicator, 5% for Hadlock-Pierce, 10% for size). The magnitude of the coefficient, for example –0.39 in the case of the composite indicator, is also consistent with the size of the difference between constrained and unconstrained firms in Table 5 (coefficients of –0.35 and –0.03, respectively). The coefficient

[21] In Table A.3 of the Appendix, we also report results controlling for firm-by-plant and year fixed effects. The results are economically similar to Table 6 for the results comparing emissions from California and non-California plants owned by geographically diversified firms (Panel A), and both economically and statistically robust for the tests on spillover effects to non-California plants by comparing geographically diversified and non-diversified firms (Panel B).

on *CalPlant* × *After*, on the other hand, is small and insignificant for all constraints measures, consistent with our prior.

In Panel B of Table 6, we similarly examine the coefficients on *DivFirm* × *After* × *Constrained* and *DivFirm* × *After*. Drawing from the results in Table 5, we expect the triple interaction term to be positive and significant as constrained firms are more likely to shift their emissions to other states if their assets are exposed to the California cap-and-trade rule. We also expect the double interaction term not to be significantly different from zero as unconstrained firms should not exhibit differential changes in their plants outside of California. Our results strongly confirm these predictions. The coefficient on *DivFirm* × *After* × *Constrained* is positive and large in magnitude (for all measures) and also statistically significant (at 1% for the composite measure, 5% for Kaplan-Zingales, 10% for Hadlock-Pierce, 10% for size, and 1% for rating). In the case of the composite measure, for example, the magnitude of the coefficient, 0.34, closely matches the size of the difference in the coefficients of 0.29 and –0.09 for constrained and unconstrained firms in Table 5, respectively. The coefficient on *DivFirm* × *After* is indistinguishable from zero across all measures except for payout, also largely consistent with our prediction.

In summary, our results provide strong and consistent evidence that (a) firms owning plant operations both in California and in other states reduce emissions from their plants in California relative to plants in other states, (b) that these firms increase emissions from their plants in other states relative to firms with no presence in California, and (c) that these effects are almost exclusively due to their financial constraints and thus their incentives to internally reallocate emissions.

5.3 Plant Ownership Reallocation

A closely related question that arises from our results is whether firms not only shift emissions, but also go as far as to reconfigure the geographical distribution of their plant ownership profiles in response to higher regulatory costs in California due to the cap-and-trade rule. If the present value of all current and expected regulatory costs in the future are sufficiently high, then not only will firms shift their emission activities across plants they already have in place, but they should also be willing to incur the high fixed costs of closing or selling existing plants and opening or acquiring new ones. On the other hand, given the lumpy nature of financing and investment decisions, changes in variable and marginal operating costs due to the cap-and-trade rule may not suffice to induce responses such as large investments or divestments of fixed assets. While Figures 5 and 6 suggest that there are unlikely to be dramatic and large shifts in the level of ownership in fixed assets such as plants, it is theoretically possible that there will be marginal adjustments along this dimension as well. In this section, we test this prediction by using firm-plant level closure or opening decisions as categorical dependent variables.

Table 7 presents the results from these tests. We employ three distinct methodologies. First, we define two binary variables, *Close* and *Open*, and use them as dependent variables in a linear probability model analogous to the pooled regression models in Equation (3) and (4).[22] *Close* is defined broadly as an indicator equal to 1 if one of the following are true (and 0 otherwise): In a given year, (a) the firm reduces its fractional ownership in a plant it has in place, or (b) a plant that was owned by a firm is no longer owned by that firm. *Open* is conversely defined to be equal to 1 (and 0 otherwise) if: (a) The firm increases its fractional ownership in an existing plant, or (b) a plant that was not owned by a firm is now owned by that firm. We include plant and year fixed effects in the linear probability model estimations, and report marginal effects as results.[23]

While the linear probability model has the advantage of being able to control for high dimensional fixed effects, it has the disadvantage of losing information when the available categories of decisions are more than binary. In our context of analyzing plant ownership decisions, for example, the relevant alternatives to closing an existing plant are twofold: To keep an existing plant, or open a new plant. To fully internalize this set of information in our analysis, we alternatively estimate multinomial logit models using a categorical variable equal to –1 for plant closure, 0 for no change, and +1 for plant opening. We set "no change" as the base case and estimate the probabilities of either a plant closure or opening with respect to that base case. While we keep

[22] We obtain consistent results with regressions according to Equations (1) and (2) run separately for financially constrained and unconstrained firms. These results are untabulated to conserve space.

[23] In Table A.4 of the Appendix, we also report results controlling for firm-by-plant and year fixed effects. The results are economically similar to Table 7 for the results comparing closure/openings of California and non-California plants, and both economically and statistically robust for the tests on spillover effects to the closure/openings of non-California plants by comparing geographically diversified and non-diversified firms.

the model specification analogous to Equations (3) and (4), we drop the fixed effects as logit models have difficulty converging for estimations with a high dimension of regressors. Marginal effects are reported.

The first two columns of Panel A of Table 7 report results from estimating linear probability models of geographically diversified firms' plant closure and opening decisions in California relative to their decisions in other states, analogous to Equation (3). The results show that financially constrained firms are 15% more likely (significant at 1%) to close a plant in California, whereas unconstrained firms are unaffected in their likelihood of adjusting plant ownership. Under the linear probability model, there is no symmetric effect on the firms' decisions to open a plant. According to the multinomial logit estimations for the sample of diversified firms in the next two columns, constrained firms are 18% more likely to close (statistically not significant) and 8% less likely to open (significant at 5%) a plant in California. The results from both specifications can be summarized as firms being relatively more likely to close an existing plant in California rather than open a new one.

Panel B of Table 7 reports results from analyzing firms' plant closure and opening decisions in other states, as a function of their geographical diversification (i.e. presence in California) and financial constraints, analogous to Equation (4). Both results from linear probability models and multinomial logits are strongly consistent with constrained firms with a presence in California being significantly less likely to close (–6% in both models and significant at 1%) and also significantly more likely open new plants (13% and 18%, both significant at 1%) in states other than California.

Overall, our analysis of plant ownership changes by firms in response to the California cap-and-trade rule suggests that beyond internal reallocations of greenhouse gas emissions, there are also adjustments along the extensive margin where firms show a higher probability of shifting their plant ownership profiles away from California towards other states. While the levels of plant ownership do not exhibit much variation over time (see Figures 5 and 6), we document significant changes in the probabilities of marginal adjustments to the ownership of plants. Nonetheless, we take the results above as weaker evidence on plant ownership reallocation compared to our findings on emission reallocation across plants in place, consistent with the discrete and lumpy nature of financing and investment activities.

5.4 Firm-wide Total Emissions

A critical policy implication from the reallocation results thus far is that the California cap-and-trade rule may not lead to the desired reduction in global greenhouse gas emissions. To the contrary, it might result in an increase in emissions rather than a reduction, undermining the goal of climate policy to combat global warming as a consequence of climate change. For example, if the costs of emissions are lower in other states than in California as illustrated in Figure 4, the predicted reallocation may result in an overall increase in emissions. In this section, we test this possibility by examining firm level total emissions. Specifically, we aggregate plant emissions within firms and compare the changes in total emissions due to the implementation of the cap-and-trade rule between financially constrained and unconstrained firms. Furthermore, we contrast the results for geographically diversified firms that have plants in California affected by the rule with undiversified firms that are either unaffected or cannot easily reallocate because their operations are not geographically dispersed. The results are reported in Table 8, where we run firm level regressions as follows:

$$Log(1+Firm\,Total\,Emissions_{i,t}) = \alpha + \beta_1 After_t + \beta_2 Constrained_i \times After_t + \gamma' X_{i,t} + c_i + \varepsilon_{i,t}\,. \quad (5)$$

Log(1+Firm Total Emissions$_{i,t}$) is the logarithm of metric tons of greenhouse gases emitted by firm *i* in year *t*. $After_t$ is an indicator equal to 1 if the year is 2013 or later, and 0 otherwise. To test whether financially constrained and unconstrained firms increase or reduce emissions differently, we also include $Constrained_i$, a firm level dummy variable equal to 1 if firm *i* is financially constrained based on our composite measure and 0 otherwise, and its interaction with $After_t$. $X_{i,t}$ denotes a vector of firm level control variables such as PP&E and R&D stock. Finally, c_i denotes firm fixed effects. While we are interested in the coefficients for both $After_t$ and $After_t \times Constrained_i$ to infer increases or reductions in emissions, we also alter the specification to include year fixed effects and drop $After_t$ to ensure robustness of the rest of the coefficients. We estimate this regression for a group of geographically diversified firms that have plants both in California and in other states as well, and a group of undiversified firms that either do not have plants in California or do not have operations in other states.

Columns (1) and (2) of Table 8 show that firms with plants both in and outside of California *increase* their total emissions. The coefficient on *After* × *Constrained* is as large as 0.28 and significant at 5%, whereas the coefficient on *After* is –0.09 and statistically insignificant. This implies that financially constrained firms significantly increase their firm-wide emissions by approximately 18% after the implementation of the cap-and-trade rule. These regressions fail to show an overall reduction in firm level emissions in response to the cap-and-trade rule, but highlight an increase for constrained firms.

This contrasts with the insignificant changes for both constrained and unconstrained firms in the undiversified group, as shown in columns (3) and (4). Undiversified firms do not significantly change their overall emissions around the time the California cap-and-trade rule was implemented, regardless of whether they are financially constrained (i.e. coefficients on *After* × *Constrained* of 0.11 and 0.12, not statistically significant) or unconstrained (i.e. coefficient on *After* of 0.09, not statistically significant).

In short, we find no evidence that firms reduce their overall greenhouse gas emissions as a result of the introduction of the California cap-and-trade rule. To the contrary, the evidence suggests that a subset of financially constrained firms with plants both in California and in other states increase their total emissions, consistent with spillover effects from the cap-and-trade rule resulting in outcomes contradictory to climate policy objectives.

5.5 Impact on Sectoral Employment and GDP

We have thus far documented spillover effects from the California cap-and-trade rule with respect to plant level greenhouse gas emissions and ownership driven by firm financial constraints, and we have shown its impact on firm-wide total emissions. How is this related to broad economic outcomes such as economic activity and employment? This is an important question for economists and policy makers who are interested in the macroeconomic impact of such climate policies. To provide insight into this issue, we conduct state-sector level analyses using employment and real GDP data downloaded from the Bureau of Economic Analysis (BEA).

Specifically, we draw from our emission and ownership reallocation results thus far and hypothesize that the California cap-and-trade rule may differentially lower employment and economic activity in affected industries in California compared to other states. We also conjecture that this relative economic contraction from the "polluting" industry may be compensated for by growth from other industries that take its place.

We first define a plant's industry as the narrowest NAICS code with at least 50 plants in the entire cross-section each year, and map this to the narrowest available 2-4 digit NAICS industry classification for which the BEA publicly reports state level employment and GDP. We then collapse the data to state-sector-year level where we broadly categorize sectors as either "emission sector" or "non-emission sector". All BEA industries with greenhouse gas emitting plants are pooled together to comprise the emission sector, and all remaining industries are grouped as the non-emission sector. We then aggregate employment (total number of full- and part-time wage earning workers) and GDP (inflation adjusted with respect to 2009 dollars) up to each state-sector-year, and run the following regressions:

$$Y_{s,t} = \alpha + \beta Cal_s \times After_t + a_s + b_t + \varepsilon_{s,t} \tag{6}$$

$$\begin{aligned} Y_{s,k,t} = \alpha &+ \beta_1 Cal_s \times After_t + \beta_2 Cal_s \times After_t \times EmissionsSector_k + \beta_3 Cal_s \times EmissionSector_k \\ &+ \beta_4 After_t \times EmissionSector_k + \beta_5 EmissionSector_k + a_s + b_t + \varepsilon_{s,t} \end{aligned} \tag{7}$$

where Equation (6) is a state-year level regression run for the emission sector and non-emission sector separately. $Y_{s,t}$ is either log(1+Employment) or log(1+GDP), Cal_s is a state level dummy indicating whether the state is California or not, and $After_t$ is an indicator for whether the year is 2013 or later. Equation (7) is a pooled state-sector-year level regression where we combine the two sector samples and include a sector dummy, $EmissionSector_k$. In both regressions we control for state fixed effects, a_s, and year fixed effects, b_t.

Table 9 reports the regression results. The first three columns document a sizable impact of the California cap-and-trade rule on sectoral employment. The negative coefficient on $Cal \times After$ in column (1) implies a 14% greater reduction in employment (significant at 5%) in the emission sector in California compared to other states. In sharp contrast, column (2) shows that employment increases by 9% more in the non-emission sector in California compared to other states. Column (3) confirms the statistical significance of the difference between the emission and non-emission sectors in a pooled regression. The coefficient on *Cal* × *After* of 0.08 and *Cal* × *After* × *EmissionSector* of -0.20 are both statistically significant at 1%.

The next three columns show weak evidence on GDP growth. Column (4) shows that there is a marginal and statistically insignificant reduction of 5% in the economic output from the sector of industries impacted by the California cap-and-trade rule. On the other hand, column (5) shows that GDP in the non-emission sector increases significantly by 8% (significant at 1%). However, the pooled regression in the last column suggests that the difference between the emission and non-emission sectors is not statistically significant. While the coefficient on *Cal* × *After* is positive (i.e., 0.04) and *Cal* × *After* × *EmissionSector* is negative (-0.07), consistent with the signs from the separate regressions, neither of these is significant.

Overall, the results suggest that there is a macroeconomic tradeoff effect from the California cap-and-trade rule. Industries impacted by the regulation in California exhibit decreases in employment and GDP relative to other states, consistent with lower plant emissions and higher likelihood of plant closures in California documented in the previous sections. At the same time, there is a countervailing relative growth in employment and GDP from the non-emission sector comprised of "clean" industries. However, we are agnostic about the eventual welfare implications of these results and caution the reader that these macroeconomic outcomes should be interpreted as relative reallocations not only across industries but also across regulatory jurisdictions.

5.6 Robustness Checks

In this section, we perform several additional tests to corroborate and sharpen the interpretation of our main results, and discuss the potential of alternative confounding explanations.[24]

5.6.1 The Impact of Reallocation and Compliance Costs on Spillovers

If financially constrained firms reallocate emissions across states to avoid the increase in regulatory costs stemming from the cap-and-trade rule in California, the costs associated with reallocating emissions would undo the benefits of avoiding tighter emission rules and should dampen the strength of the spillover effects. On the

[24] While we focus mostly on plant emissions as the outcome variable in most of the tests in this section to conserve space, we confirm in untabulated analysis that our results on plant ownership outcomes are also robust.

other hand, additional costs associated with compliance efforts such as the development or acquisition of abatement technology would exacerbate leakage.

To explore these predictions within the limitations of the data, we conduct indirect tests using proxies for reallocation and compliance costs. Specifically, we assume that reallocation costs are lower when firms shift emissions toward plants located in states nearby California or states where environmental or climate related regulatory costs are lower. We also conjecture that compliance costs are greater for firms that had previously made little R&D or capital expenditure investments beyond their regular needs as they would likely lack and therefore have to invest in abatement technologies necessary to operate under the newly enforced regulation. Using these proxies, we show that the magnitude and significance of emission spillovers are stronger when the costs of reallocating emissions are lower and when the costs of complying are higher, consistent with our interpretation that constrained firms reallocate to avoid regulatory costs.

In the first four columns of Table 10, we rerun our main regressions according to Equations (3) and (4) on subsamples consisting of plants in California and plants located elsewhere where reallocating from California is likely cheaper or costlier. In the first two columns, the subsamples are based on the distance of plants from California. The "Close" sample comprises plants located in California and plants in nearby states defined as being within three adjacent states. The "Far" sample includes plants in California and plants in distant, or non-nearby, states. In the next two columns, the subsamples are based on the environmental regulation stringency of states according to the 50 State Index of Energy Regulations published by the Pacific Research Institute for Public Policy (PRI).[25] The "Low" sample consists of California plants and plants in lower ranked (i.e. less regulated) states, and the "High" sample includes plants in California and plants in higher ranked states. We hypothesize that firms reallocating emissions across plants in the "Close" or "Low" sample should shift

[25] The PRI 50 State Index of Energy Regulations is an ordinal index computed using an average score of seven components quantifying different aspects of the restrictiveness and economic efficiency of each state's regulatory environment on a 10-point scale. For more information, visit https://www.pacificresearch.org/wp-content/uploads/2017/06/50StatesEnergy_FirstFinalWeb.pdf.

emissions more intensely as they are likely to enjoy lower reallocation costs than firms reallocating within the "Far" or "High" samples, respectively.[26]

The regression results provide some empirical support for this hypothesis. In particular, the regressions comparing emissions from California and non-California plants owned by geographically diversified firms (Panel A), California plants appear to emit less by more when compared to plants in nearby than distant states (i.e. coefficient on *CalPlant* × *After* × *Constrained* of –0.44 at 10% significance for "Close" sample, whereas –0.36, not significant, for "Far" sample), and also when compared to plants in low regulation than high regulation states (i.e. coefficient on *CalPlant* × *After* × *Constrained* of –0.47 at 5% significance for "Low" sample, whereas –0.33, not significant, for "High" sample).

More importantly, similar and stronger contrasts are found in the spillover analysis comparing emissions from non-California plants owned by geographically diversified and non-diversified firms (Panel B). The emission spillovers are much more pronounced to plants located in closer than farther states (i.e. coefficient on *DivFirm* × *After* × *Constrained* of 0.59 at 1% significance for "Close" sample, whereas 0.22 at 5% significance for "Far" sample) and also much sharper to plants in low regulation than high regulation states (i.e. coefficient on *DivFirm* × *After* × *Constrained* of 0.52 at 1% significance for "Low" sample, whereas 0.19 at 10% significance for "High" sample). The differences between the spillover effects in the low and high reallocation cost samples are highly significant with *p*-values in the range of 1-2%.

In the last two columns of Table 10, we similarly run regressions on subsamples consisting of plants owned by firms that had made negative abnormal R&D and Capex investments prior to entering the sample ("Low"), and plants owned by firms with positive ex-ante abnormal investments in R&D and Capex ("High"). Abnormal ex-ante R&D and Capex investments are computed for each firm by taking the time-series average of the residuals from the following firm-year level regression over the pre-sample period from 2003 to 2008,

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[26] As an alternative to the PRI index, we use the political alignment of states based on presidential election outcomes (e.g. Democrat or Republican) as a proxy for environmental or climate regulation stringency, and find consistent results in untabulated analysis.

$$\frac{R\,\&\,D_{i,t}+Capex_{i,t}}{Assets_{i,t-1}}=\alpha+\beta_1 Constrained_{i,t-1}+\beta_2\log(Assets_{i,t-1})+\beta_3 ROA_{i,t-1}+a_{f,t}+\varepsilon_{i,t} \quad (8)$$

where we control for whether firm *i* is constrained in a given year *t*, the firm's asset size and profitability, and its growth opportunities or peer benchmarks in its industry *f* by including an industry-by-year fixed effect.[27] We hypothesize that firms that had previously not invested in R&D or capital expenditures beyond normal business needs should shift emissions more sharply as they would otherwise likely have to incur additional costs from investments in abatement technology to comply with the new regulation.

The results confirm our hypothesis. Firms with low ex-ante abnormal investments in R&D and Capex are more likely to reallocate emissions, resulting in lower emissions from their California plants (i.e. coefficient on *CalPlant* × *After* × *Constrained* of –0.64 at 5% significance for "Low" sample, whereas –0.07, not significant, for "High" sample) and stronger emission spillovers to non-California plants (i.e. coefficient on *DivFirm* × *After* × *Constrained* of 0.35 at 1% significance for "Low" sample, whereas 0.16, not significant, for "High" sample).

While we acknowledge the limitations of our proxies (e.g. there is no detailed information available on the precise nature of abnormal R&D and Capex or how much of it is tied to abatement), these results are broadly consistent with the idea that reallocation and compliance costs play an important role in how intensely constrained firms shift emissions to avoid the regulatory cost arising from the California cap-and-trade rule.

5.6.2 Are Firms Reallocating to Chase Better Growth Opportunities?

One concern that could be raised is that our evidence on cross-state reallocation of emissions might be driven not by the higher regulatory costs of operating greenhouse gas emitting plants in California due to the introduction of the cap-and-trade rule, but simply by better growth prospects associated with some plants and not others. For example, if investment opportunities in California were waning whereas the economies of other states are growing faster, it would make sense for firms with limited access to external capital to shift their productive resources toward these more promising states. Our findings would be consistent with this alternative

[27] Using a simpler industry-demeaned measure of R&D and Capex investment also gives similar results.

"opportunity chasing" story. To evaluate this argument, we construct and characterize measures of growth opportunities and evaluate the robustness of our results controlling for them.

The first measure is state level annual real GDP growth from private industries in the state the plant is located in, using GDP data from the BEA. While GDP growth captures the overall economic activity and growth within the plant's local economy at the state level, it reflects realized values rather than expectations and becomes a noisier estimate of expected growth opportunities at more granular levels (e.g., state-industry). Therefore, we construct a second forward looking measure as the median Tobin's Q of firms that own plants in the same state and industry as the plant of interest, and also primarily operate in that industry, where industry is defined as the narrowest NAICS code with at least 50 plants each year. This market-based measure provides the added benefit of summarizing growth opportunities at the state-industry level. Panel A of Table 11 reports the population-weighted cross-state averages of these two measures separately for California and other states, each year over our sample period from 2010 to 2015.

According to GDP growth, California outperformed other states by a large margin in terms of economic growth during the post California cap-and-trade rule period of 2013 to 2015. The average annual growth rate of California over this period was 4.1%, the fourth highest of all U.S. states. In the period before the cap-and-trade rule from 2010 to 2012, by contrast, California's average growth rate was 2.1%, ranking below the twentieth fastest growing state. In other words, California was not only among the fastest growing states during the period after the introduction of its carbon trading scheme, but also among the states whose growth rates vastly improved compared to the period before the regulation (i.e., a significant increase of 2% points, in contrast to no significant increase in other states). According to median Tobin's Q, which better captures market assessments of the growth prospects specific to the plants' locale and industry, growth opportunities in California and other states were not very different before (i.e., 1.32 vs 1.36) or after (i.e., 1.38 vs 1.40) the introduction of the California cap-and-trade rule. At the minimum, there is no evidence that investment opportunities were better in other states compared to California during the latter half of the sample period.

For the opportunity chasing story to hold one must assume that firms responded to the lower realized growth rates during 2010 to 2012 and made reallocation decisions for the following years from 2013 to 2015 whilst oblivious to the improving prospects in California and ignoring the contemporaneous changes in cross-state economic growth during this period. One must also assume that Tobin's Q was uninformative for firms in gauging growth opportunities across their plants. These seem like unreasonable assumptions. Rather, the illustrative evidence largely goes against the alternative explanation that firms reallocated resources simply to capture better growth opportunities in other states, but is more consistent with constrained firms having re-allocated *despite* higher expected growth in California due to their lack of financial flexibility to exploit such opportunities and increased regulatory costs. The growth trends also support our assumption that the net re-turns from emitting in California remain large enough such that unconstrained firms would have little incentive to shift emissions as constrained firms do.

In Panel B of Table 11, we employ regressions augmented from Equations (3) and (4) to examine how growth opportunities explain plant emissions, and whether our results are sensitive to controlling for them. For both GDP growth and Tobin's Q, we include the measure itself as well as its interaction with a *Constrained* dummy (based on our composite constraint measure) to allow constrained and unconstrained firms to respond to growth prospects differentially. As both of these measures vary across states and over time, we do not interact them with *CalPlant* or *After* but do interact them with *DivFirm* as detailed below.

The first three regressions of Panel B compare emissions for California and non-California plants based on the sample of geographically diversified firms. The regressions suggest that neither GDP growth nor Tobin's Q significantly affects emissions regardless of whether firms are constrained or not, and that the effects of the cap-and-trade rule on emissions are robust to controlling for both growth measures as well as their interactions with *Constrained*. The coefficient on the triple interaction term *CalPlant* × *After* × *Constrained* is –0.37 and signif-icant at 10%, comparable to –0.39 in Table 6.

The last three specifications study spillovers to non-California Plants comparing geographically diversified and non-diversified firms. To allow geographically diversified firms to respond to growth prospects differentially, we further interact GDP growth and Tobin's Q with *DivFirm* × *Constrained* and *DivFirm*. In comparison to the first three specifications, the coefficient on *Q* × *Constrained* is now positive and significant. For both growth proxies, their interactions with *DivFirm* load positively, while their interactions with both *DivFirm* and *Constrained* load negatively. Controlling for all of the growth opportunity variables and their respective interaction terms, the spillover effect remains both economically and statistically robust. The coefficient on the triple interaction term *DivFirm* × *After* × *Constrained* is 0.30 and significant at 1%, comparable to 0.34 in Table 6.

In short, resource shifting by firms toward plants that face better growth opportunities does not explain our results on the spillover effects from the California cap-and-trade rule.

5.6.3 Placebo Tests

Another potential critique of our approach is that the DID design could be picking up spurious changes over time that happen to affect California more than the average state, but might also be occurring in other economically important states with a large presence of greenhouse gas emitting plants. We argue that this is unlikely the case, because in the absence of similarly extensive and costly climate regulation programs in other states, it is difficult to justify why there would be a significant change in the emissions across plants in one state relative to other states that is mainly driven by firms with operations in that one state, and why the reallocation would be conditioned by their financial constraints.

Notwithstanding this argument, we conduct placebo tests to rule out this concern. We use two alternative states that are the most important greenhouse gas emitters aside from California, i.e., Texas and Louisiana (see Table 2), as placebo states. We test whether geographically diversified firms (i.e., firms with a presence both in the placebo state and in other states) reduce plant emissions in the placebo state compared to other states, whether these firms create emission spillovers in other states, and whether these effects are related to firm financial constraints. To this end, we employ pooled triple difference regressions as in Equations (3) and (4) with our composite constraint indicator. To conserve space, we omit the full sample results and focus on the cross-state reallocation of geographically diversified firms and spillover effects to other states.

Table 12 reports the results from using Texas and Louisiana as placebo states. For each placebo state, we run two regressions following Equations (3) and (4) as in Table 6. For both placebo states, we do not find results similar to our main findings. There is neither any indication that plants in a placebo state reduce emissions by more than plants in other states, nor any evidence that there are spillover effects from a placebo state to other states, nor any observable effects driven by financial constraints. Given the large number of observations in the placebo tests that are comparable to those in our main analysis, the lack of evidence is unlikely a result of low statistical power. In short, our results do not seem to be driven by confounding factors coinciding with the introduction of the California cap-and-trade rule that affect other major greenhouse gas emitting states in a similar way.

6 Conclusion

In this paper, we study the internal resource allocation responses by firms that lead to real, unintended spillover effects of localized climate policies driven by the financial constraints of firms who operate large greenhouse gas emitting plants. Using a detailed plant level dataset on greenhouse gas emissions and parent company ownership made available by the US EPA and hand-matched to Compustat, we show that the California cap-and-trade rule introduced at the beginning of 2013 has real spillover effects across other US states through firm financial constraints.

Motivated by the finance literature, we hypothesize that financially constrained firms reallocate their greenhouse gas emissions and plant ownership away from California to other states in the face of heightened regulatory costs that alter the relative net expected returns across plants. The intuition is that the costs of external capital for constrained firms render profitable emission projects mutually exclusive, and that these firms reallocate as they find the net returns from internal reallocations more attractive than the returns from optimal levels of emissions in California after the regulatory change. We document strong evidence for reallocations of emissions across plants already in place, and to a lesser degree also for changes in plant ownership. The overall consequence of this reallocation is that firms show no evidence of reducing their total emissions, and in fact that constrained firms strictly increase their emissions firm-wide. Our results are consistent with the internal reallocation of corporate pollutive activities and resources to avoid regulatory costs in the face of limited access to external financing, highlighting the hidden costs of environmental policies through financial channels.

Our study makes a significant contribution to the understanding of the interplay between climate policy and firm behavior, and provides a stepping-stone towards more effectively coordinated solutions to climate change by informing policy makers of the potential externalities from regionally segmented climate policies. This is important because if localized climate policies prove ineffective even within one country, they are unlikely to have the intended effect of reducing emissions on a global scale across countries. Our findings point to two policy guidelines: (1) Given the geographically diversified nature of firms' operations, climate policies should be harmonized across jurisdictions in order to minimize leakages. (2) Given that financially constrained firms have stronger incentives to reallocate, policymakers should carefully devise appropriately differentiated subsidies to mitigate distortions from implementing climate policies (e.g. green bonds; tax breaks).

Finally, this paper also contributes to the growing field of corporate environmental policies by focusing on the internal plant level emission activities and resource allocations within firms, thus providing a unique channel for the real effects of climate policy through the importance of firm financial constraints.

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Figure 1: Global Carbon Emissions and Temperature Changes

The figure shows the time-series of worldwide total carbon emissions from fossil fuel consumption and cement production (thick solid line, left axis) and the global land-ocean surface temperature index (thin line with markers, right axis). Total carbon emissions data is from Boden, Marland, and Andres (2017), and global temperature index data is from the NASA Goddard Institute for Space Studies (GISS). The temperature index is computed as deviations from the mean over a base period. Details regarding its computation can be found at https://data.giss.nasa.gov/gistemp/.

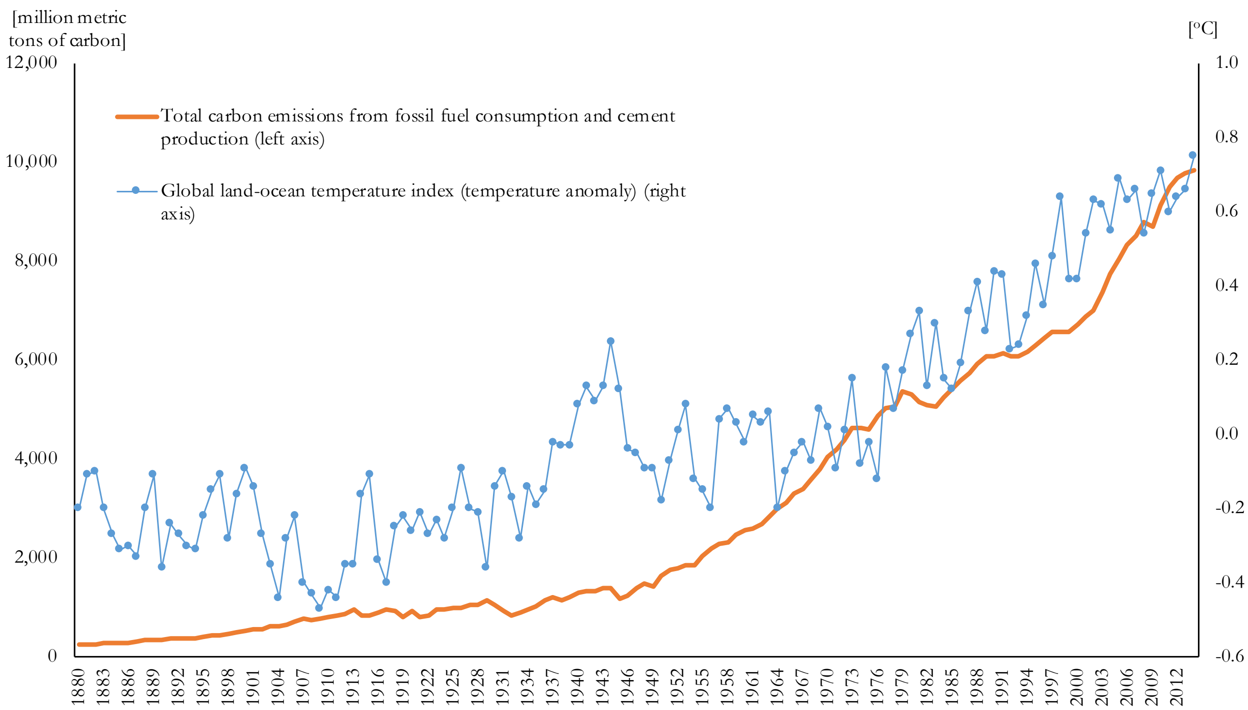


Figure 2: Climate Policies Around the World

This figure shows major climate policies such as carbon emission trading rules or carbon taxes implemented in various countries and states. The map shows existing, emerging and potential regional, national and subnational carbon pricing initiatives (ETS and tax). The figure is reproduced from World Bank and Ecofys (2016, pages 4 and 5).

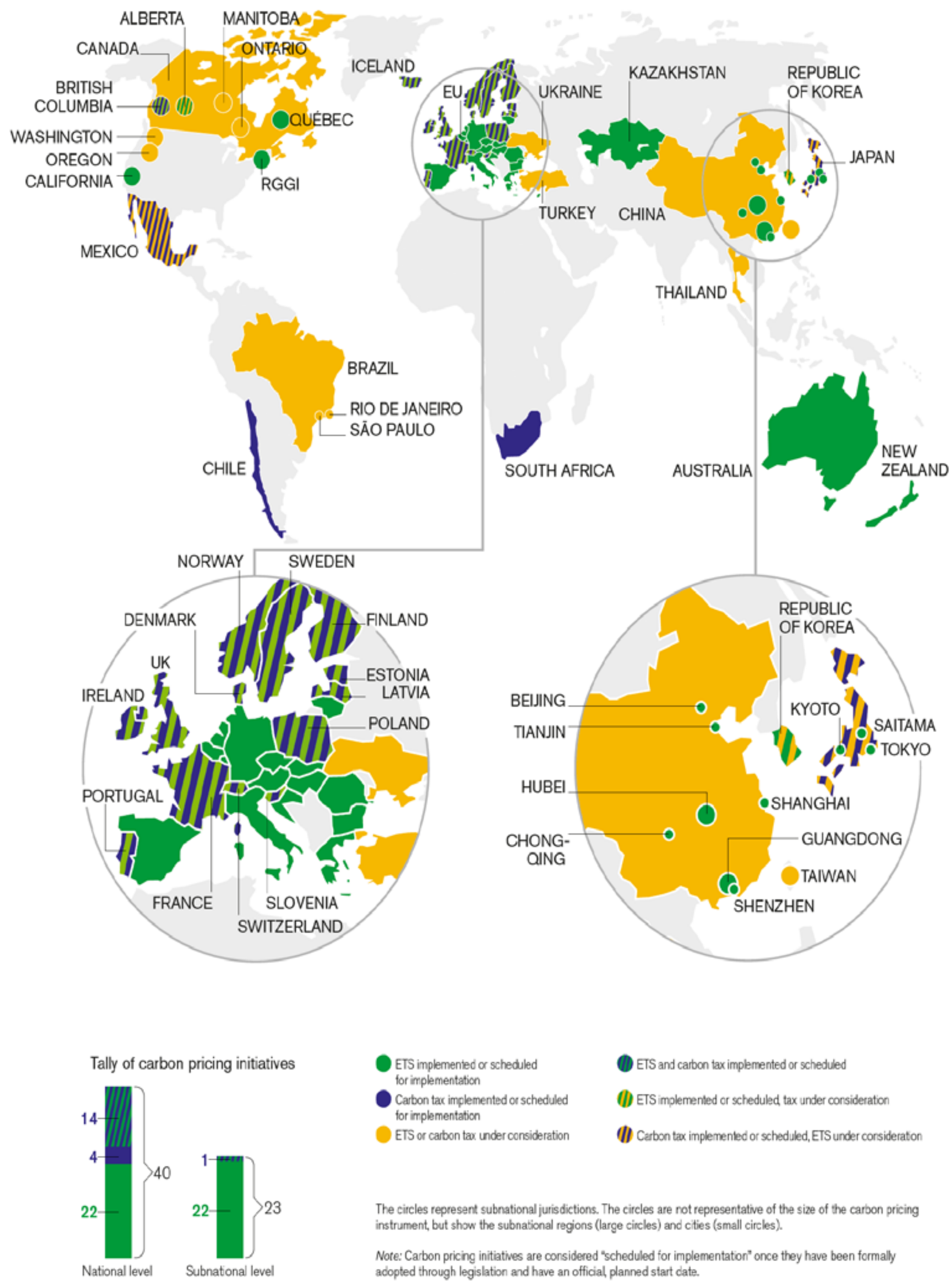


Figure 3: Transaction Prices and Volume of California Carbon Allowance Futures

The figure shows California carbon allowance future prices along with their trading volumes. Transaction prices (in $/metric ton) are shown on the left axis, while trading volume (in thousands of metric tons of CO_2) is shown on the right axis. The graph shows data for futures contracts with different expiration dates (December 2013, December 2014, December 2015, December 2016). The vertical lines mark the periods in which the different futures contracts are traded, as well as the introduction of the California cap-and-trade system at the beginning of 2013. The data is from the Climate Policy Initiative & Intercontinental Exchange.

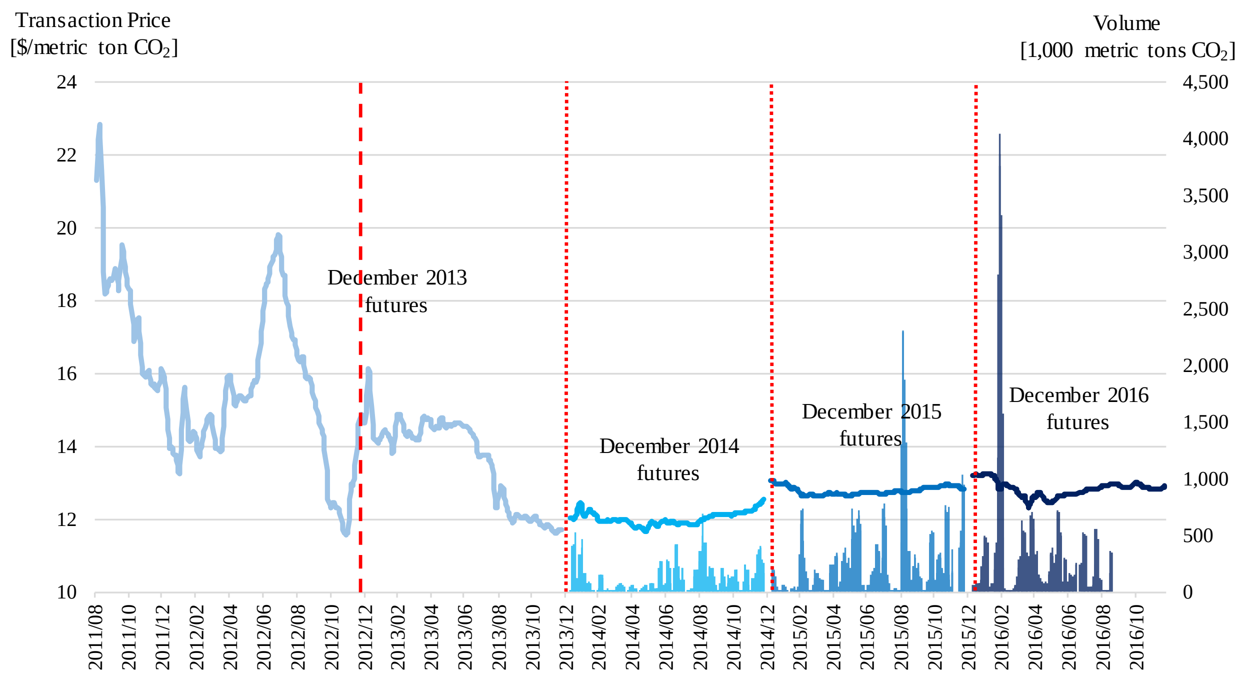


Figure 4: Economic Framework

The figure illustrates the economic channel of the main hypothesis. Revenues and costs (p) are plotted on the vertical axis, and emissions and production quantities (q) are plotted on the horizontal axis. Marginal and average revenue curves (solid black), denoted *mr* and *ar*, are downward sloping consistent with an imperfectly competitive market. Marginal and average cost curves are plotted for three scenarios. mc_{ca} and ac_{ca} represent the pre-cap-and-trade costs of producing and emitting in California. mc'_{ca} and ac'_{ca} denote the post-cap-and-trade costs of emitting in California, which are tilted upward from the pre-policy curves for emission quantities above the free allocation amount. mc_{oth} and ac_{oth} are the cost curves should firms reallocate their emissions exceeding the free allocation amount to other states. *I*, *I′*, and *I″* each denote the equilibrium with the optimal amount of emissions in California before the cap-and-trade rule, in California after the cap-and-trade rule, and in other states, respectively.

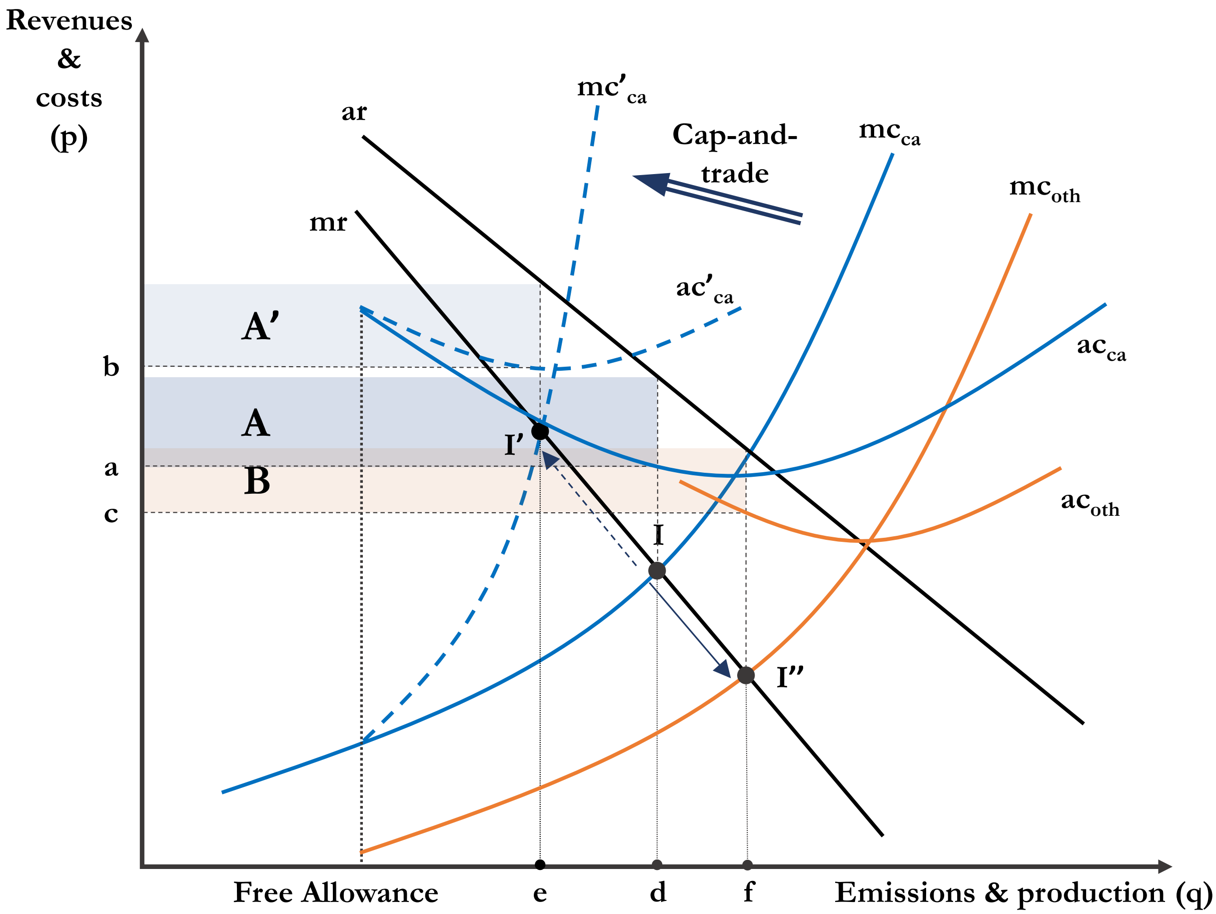
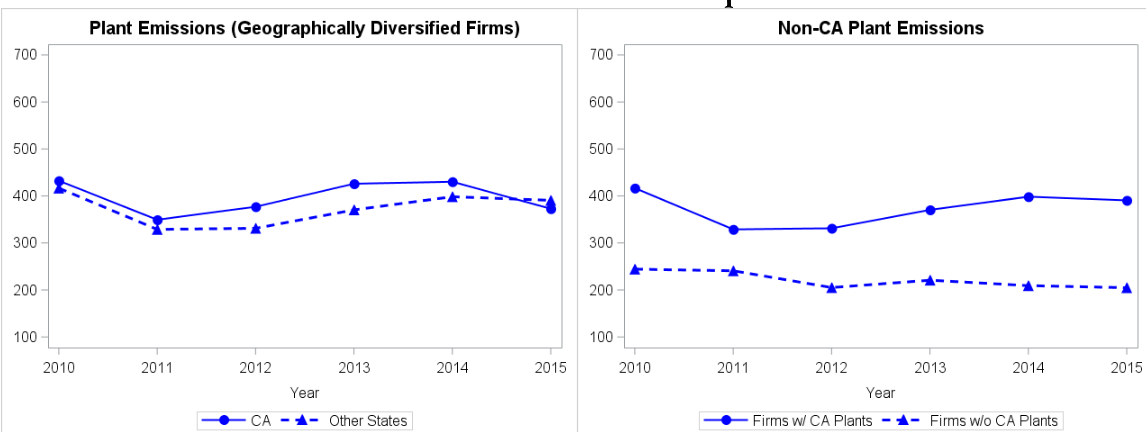


Figure 5: Unconditional Average Responses to Cap-and-Trade

The figure shows average plant emissions (Panel A) and plant ownership (Panel B) during the sample period 2010–2015, i.e. before and after the enactment of the California cap-and-trade program at the beginning of 2013. Outcome variables of the treatment and control group are plotted as solid and dotted lines, respectively. Panel A shows two graphs: Emissions (thousand metric tons) of plants in California and in other states based on geographically diversified firms; and emissions of non-California plants for firms with and without plants in California. Panel B shows two graphs: Plant ownership (number of plants owned by firm) of plants in California and in other states based on geographically diversified firms; and plant ownership of non-California plants for firms with and without plants in California.

Panel A: Plant Emission Responses



Panel B: Plant Ownership Responses

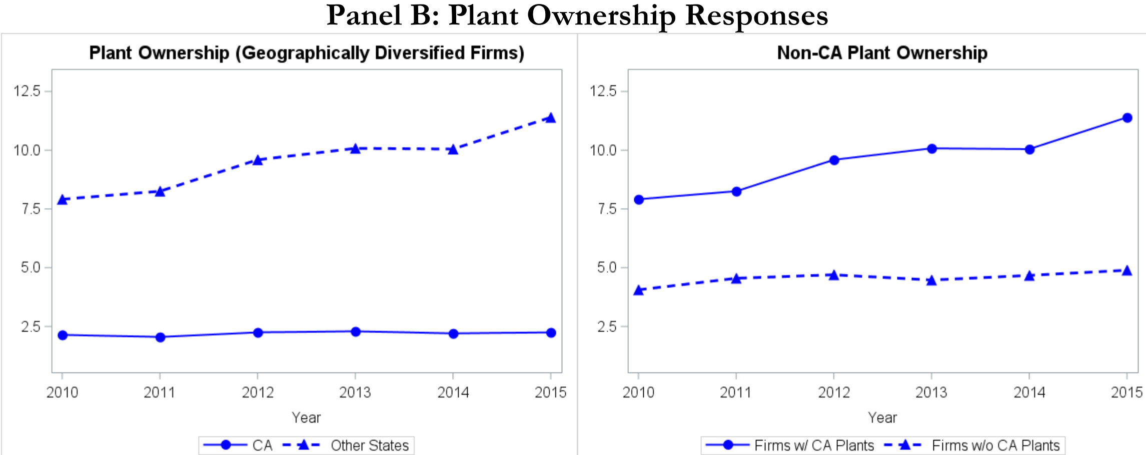
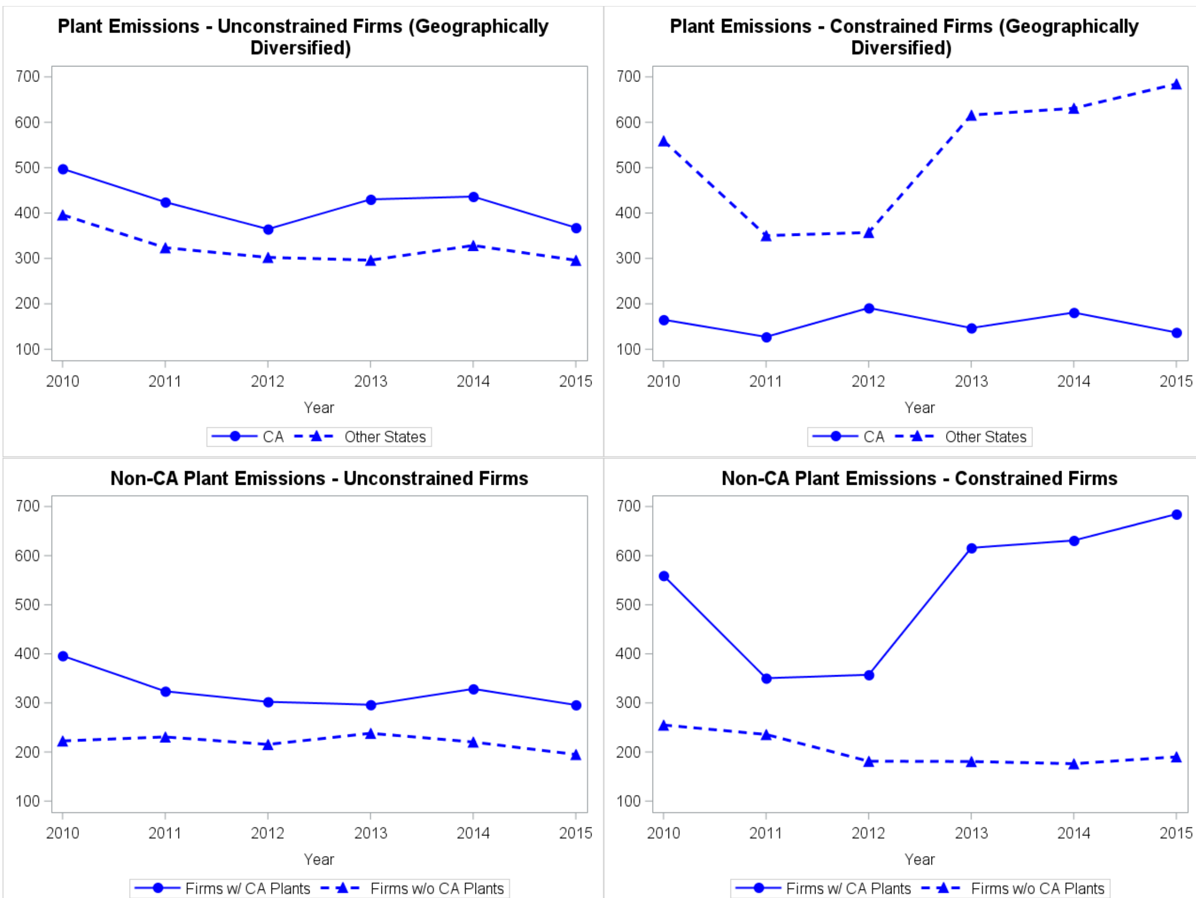


Figure 6: Average Responses of Constrained vs Unconstrained Firms

The figure shows average plant emissions (Panel A) and plant ownership (Panel B) separately for constrained and unconstrained firms during the sample period 2010–2015, i.e. before and after the enactment of the California cap-and-trade program at the beginning of 2013. Outcome variables of the treatment and control group are plotted as solid and dotted lines, respectively. Separately for constrained and unconstrained firms, Panel A shows two sets of graphs: Emissions (in thousand metric tons) of plants in California and in other states based on geographically diversified firms; and emissions of non-California plants for firms with and without plants in California. Separately for constrained and unconstrained firms, Panel B shows two sets of graphs: Plant ownership (measured as number of plants owned by a firm) of plants in California and in other states based on geographically diversified firms; and plant ownership of non-California plants for firms with and without plants in California.

Panel A: Plant Emission Responses



(continued)

Figure 6: Average Responses of Constrained vs Unconstrained Firms (continued)

Panel B: Plant Ownership Responses

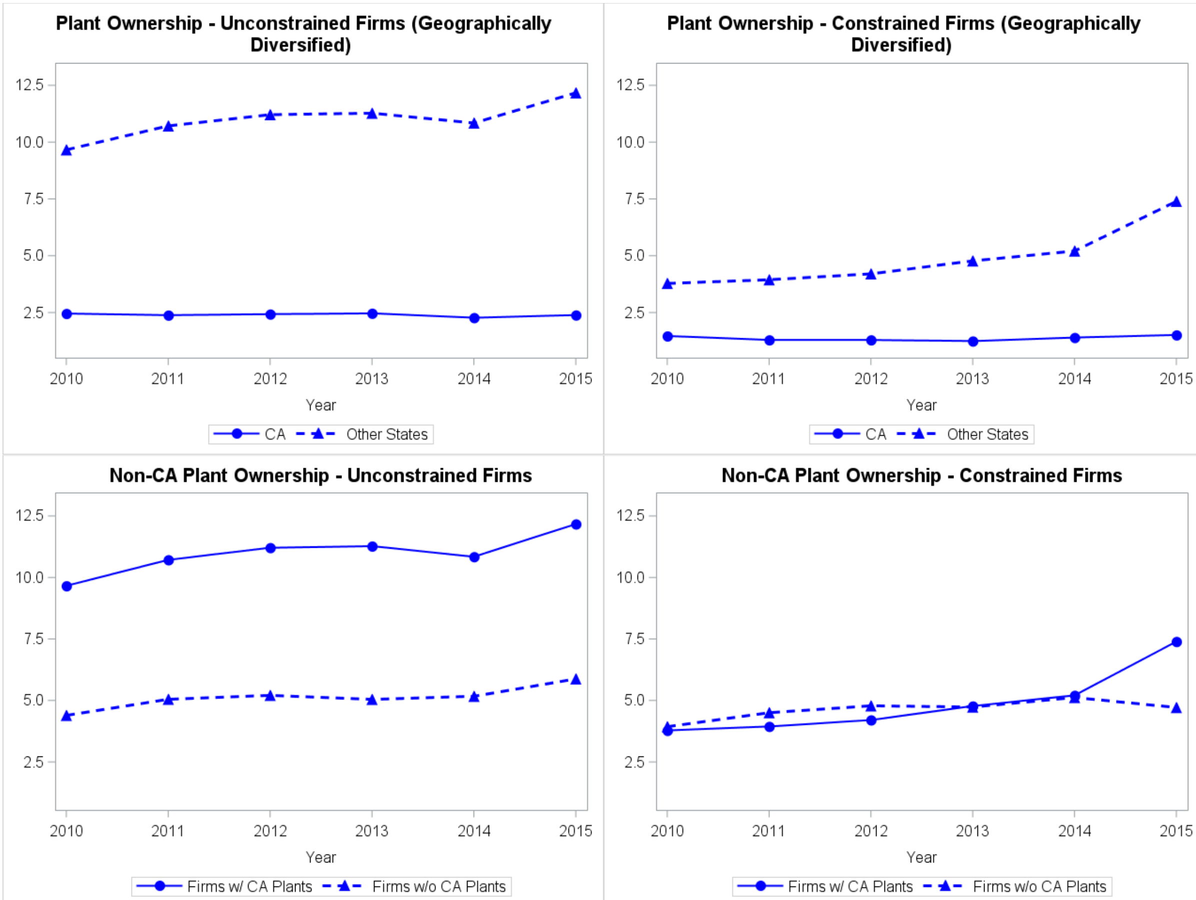


Table 1: Allowance Auctions, Allocations, and Transactions of California Cap-and-Trade

The table shows descriptive statistics on allowance auctions, allocations and transactions of California carbon allowances pursuant to the cap-and-trade program. With regards to allowance auctions, Panel A shows for different auction periods the number of bidders, available and sold quantities, the ratio of the number of bids to available quantities, the reserve price and settlement price. Panel B summarizes available data on the quantities of free allocations to industrial plants. Panel C shows for different years and allowance vintages the number of transactions, quantities and weighted average prices (for combined California and Quebec market). Data are from the California Air Resources Board.

Panel A: Allowance Auctions

Auction period		Number of bidders (organizations)	Available (thousand metric tons)	Sold (thousand metric tons)	Bids /Available	Reserve price ($/metric ton)	Settlement price ($/metric ton)
2012/11	Current vintage	73	23,126	23,126	1.06	10.00	10.09
	Future (3yr) vintage		39,450	5,576	0.14	10.00	10.00
2013/02	Current vintage	91	12,925	12,925	2.49	10.71	13.62
	Future (3yr) vintage		9,560	4,440	0.46	10.71	10.71
2013/05	Current vintage	81	14,522	14,522	1.78	10.71	14.00
	Future (3yr) vintage		9,560	7,515	0.79	10.71	10.71
2013/08	Current vintage	79	13,865	13,865	1.62	10.71	12.22
	Future (3yr) vintage		9,560	9,560	1.69	10.71	11.10
2013/11	Current vintage	77	16,615	16,615	1.82	10.71	11.48
	Future (3yr) vintage		9,560	9,560	1.64	10.71	11.10
2014/02	Current vintage	71	19,539	19,539	1.27	11.34	11.48
	Future (3yr) vintage		9,260	9,260	1.11	11.34	11.38
2014/05	Current vintage	74	16,947	16,947	1.46	11.34	11.50
	Future (3yr) vintage		9,260	4,036	0.44	11.34	11.34
2014/08	Current vintage	71	22,473	22,473	1.14	11.34	11.50
	Future (3yr) vintage		9,260	6,470	0.70	11.34	11.34
2014/11*	Current vintage	83	23,071	23,071	1.73	11.34	12.10
	Future (3yr) vintage		10,787	10,787	1.92	11.34	11.86
2015/02	Current vintage	87	73,611	73,611	1.14	12.10	12.21
	Future (3yr) vintage		10,432	10,432	1.02	12.10	12.10
2015/05	Current vintage	97	76,932	76,932	1.16	12.10	12.29
	Future (3yr) vintage		10,432	9,812	0.94	12.10	12.10
2015/08	Current vintage	88	73,429	73,429	1.28	12.10	12.52
	Future (3yr) vintage		10,431	10,431	1.78	12.10	12.30
2015/11	Current vintage	91	75,113	75,113	1.14	12.10	12.73
	Future (3yr) vintage		10,432	10,432	1.32	12.10	12.65

*: Joint auction with Quebec cap-and-trade from this point onward

(continued)

Table 1: Allowance Auctions, Allocations, and Transactions of California Cap-and-Trade (continued)

Panel B: Free Allocations to Industrial Plants

	2013	2014	2015
Allocation (thousand metric tons)	53,895	54,394	55,827
Number of plants	139	156	159
Per-plant allocation	388	349	351

Panel C: Market Transactions and Prices

Allowance vintage	Number of transactions	Thousand metric tons	Weighted avg price
2014 (Obligations from 2013 emissions due)			
2013	228	12,984	12.23
2014	338	33,588	11.98
Current total	**566**	**46,571**	**12.05**
2015	3	775	12.58
2016	35	12,012	11.92
2017	54	21,330	11.73
Future total	**92**	**34,117**	**11.82**
2015 (Obligations from 2014 emissions due)			
2013	87	6,385	12.51
2014	248	29,417	12.62
2015	444	112,921	12.68
Current total	**779**	**148,723**	**12.66**
2016	44	21,982	12.72
2017	60	20,699	12.65
2018	62	27,543	12.61
Future total	**166**	**70,223**	**12.66**
2016 (Obligations from 2015 emissions due)			
2013	23	1,237	12.50
2014	33	5,612	12.75
2015	431	65,652	12.72
2016	333	62,882	12.75
Current total	**820**	**135,383**	**12.74**
2017	21	11,352	12.88
2018	25	14,308	12.83
2019	8	2,820	12.77
Future total	**54**	**28,480**	**12.85**

Table 2: Number of Plants and Firms by State

The table shows the number of sample plants located in each state, the number of sample firms operating in each state, as well as the average plant emissions (in thousands of metric tons) and the average firm assets (in $ billions). States are sorted in descending order by the number of firms. The table also shows the totals across all states and firms with plants both in California and other states. The data is from the intersection of the EPA and Compustat databases. The sample period is 2010–2015.

State	Number of plants	Number of firms	Avg. emissions (thousand metric tons)	Avg. firm assets ($ billions)	State	Number of plants	Number of firms	Avg. emissions (thousand metric tons)	Avg. firm assets ($ billions)
Texas	587	174	300.53	20.51	Mississippi	24	23	304.41	17.17
Louisiana	225	104	326.50	28.09	New Jersey	19	21	394.75	50.88
California	**161**	**85**	**398.04**	**28.58**	Utah	29	20	180.06	35.49
Pennsylvania	133	73	276.87	24.47	Missouri	20	19	153.21	53.84
Illinois	88	70	707.61	21.42	Oregon	18	18	59.32	12.38
Ohio	95	68	371.01	24.22	Alaska	39	14	468.66	44.45
Oklahoma	170	59	222.70	19.49	North Dakota	16	13	224.44	18.93
Colorado	142	54	147.48	19.09	Nebraska	16	13	174.52	13.50
Indiana	61	50	529.68	24.70	Massachusetts	14	13	104.52	35.73
Michigan	67	48	246.03	30.99	Nevada	13	11	306.27	24.78
Alabama	59	47	254.41	22.52	Arizona	10	11	157.88	27.75
West Virginia	83	41	183.99	17.04	Idaho	16	10	51.44	24.78
Kentucky	53	37	314.86	16.78	Connecticut	13	10	121.26	51.72
Virginia	52	35	172.63	18.71	Maine	8	9	308.75	5.25
Tennessee	34	35	337.94	20.68	Montana	6	9	555.58	31.60
Minnesota	40	34	203.50	19.81	South Dakota	5	7	124.51	14.49
Kansas	36	33	293.43	18.47	Maryland	4	7	293.81	6.35
Georgia	36	30	158.02	27.75	Delaware	4	5	694.94	24.84
Wisconsin	34	30	111.38	14.63	Puerto Rico	4	5	70.97	39.58
Iowa	34	29	308.23	19.87	Hawaii	3	3	332.37	44.81
New Mexico	52	28	155.69	38.24	Vermont	1	1	39.33	11.04
Arkansas	44	28	125.15	14.49	Virgin Islands	1	1	36.10	34.67
New York	30	27	239.04	26.20	New Hampshire	1	1	18.24	104.57
North Carolina	39	26	370.64	12.92					
South Carolina	26	26	182.72	14.69	**All States**	**2,806**	**511**	**288.97**	**17.25**
Wyoming	65	24	191.91	23.54					
Florida	43	24	325.11	22.08	**Firms with Cal &**				
Washington	33	24	247.03	21.16	**Non-Cal Plants**	**948**	**70**	**424.03**	**29.22**

Table 3: Firm and Plant Characteristics

The table presents sample summary statistics of firm characteristics (Panel A) and plant characteristics (Panel B). In Panel A, emissions (in thousand metric tons) are summed across plants owned by a firm and reported as a firm-level measure. Total assets are in $ billions. Property, plant, and equipment (PP&E), capital expenditures, short-term and long-term debt, cash, and cash flow are shown as a fraction of total assets. Profitability is return on assets (ROA). Tobin's Q is the market value of assets divided by the book value of assets. R&D is scaled by sales. R&D stock is calculated using the perpetual inventory method (Hall, Jaffe, and Trajtenberg, 2005). Payout ratio is cash dividends plus repurchases divided by income before extraordinary items. Firm age is the difference between the observation year and founding year as in Jovanovic and Rousseau (2001). The panel reports the number of firm-year observations, average, standard deviation, minimum, 25th percentile, median, 75th percentile, and maximum values for these variables. The panel also reports the number of firm-year observations with and without a long-term or short-term bond rating. Panel B presents summary statistics for plant level carbon emissions and ownership structure. Carbon emissions are in thousand metric tons. Ownership structure is measured as the fraction of a plant owned by a firm, the number of plants owned by a firm, and the number of firms sharing ownership in a plant. The panel shows the number of plant-year observations, average, standard deviation, minimum, 25th percentile, median, 75th percentile, and maximum of each variable. Emissions and plant ownership data is from EPA. Accounting data are from Compustat. The sample period is 2010–2015.

Panel A: Summary Statistics of Firm Characteristics

	Firm-year obs.	Average	Std. dev.	Minimum	25th percentile	Median	75th percentile	Maximum
Emissions (thousand metric tons)	2,303	1,584.42	4,039.64	0.03	69.43	277.16	1,208.48	65,101.03
Total assets ($ billions)	2,303	17.28	27.85	0.03	1.50	4.18	18.96	111.03
PP&E	2,302	0.47	0.25	0.00	0.27	0.44	0.67	0.95
Capital expenditures	2,232	0.10	0.13	0.00	0.03	0.05	0.11	0.73
Short-term debt	2,302	0.03	0.05	0.00	0.00	0.01	0.03	0.59
Long-term debt	2,295	0.28	0.19	0.00	0.15	0.25	0.38	1.11
Cash	2,302	0.09	0.10	0.00	0.02	0.06	0.13	0.73
Cash flow	2,233	0.14	0.11	-0.67	0.09	0.13	0.19	0.66
Profitability	2,233	0.05	0.11	-0.95	0.01	0.05	0.09	0.55
Tobin's Q	2,086	1.46	0.57	0.49	1.07	1.33	1.69	5.03
R&D	2,303	0.02	0.05	0.00	0.00	0.00	0.01	0.90
R&D stock	2,303	0.11	0.44	0.00	0.00	0.00	0.07	8.00
Payout ratio	2,303	0.49	1.34	-6.03	0.00	0.28	0.79	9.52
Firm age	2,303	27.02	20.82	1.00	9.00	20.00	46.00	65.00
Bond rating (long-term, >1yr)								
No rating	1,047							
Rated	1,256							
Bond rating (short-term, <1yr)								
No rating	1,776							
Rated	527							

Panel B: Plant Level Carbon Emissions and Ownership Structure

	Plant-year obs.	Average	Std. dev.	Minimum	25th percentile	Median	75th percentile	Maximum
Carbon emissions (thousand metric tons)	13,679	288.97	628.75	0.00	339.71	690.18	2,038.08	4,466.38
Ownership								
Fraction of plant owned by a firm (percent)		91.12	22.86	0.00	100.00	100.00	100.00	100.00
Number of plants owned by a firm		5.94	10.54	1.00	1.00	3.00	6.00	142.00
Number of firms owning a plant		1.15	0.45	1.00	1.00	1.00	1.00	6.00

Table 4: Plant Emission Responses to California Cap-and-Trade Rule

Panel A presents univariate evidence on the differences in emissions growth around the introduction of the California cap-and-trade rule (calculated as [mean(after) – mean(before)]/mean) between California and non-California plants for geographically diversified firms, and between non-California plants owned by geographically diversified and undiversified firms, as well as their corresponding *t*-statistics. Panel B presents results from firm-plant level difference-in-difference (DID) regressions. Columns (1)-(4) compare California and non-California plants based on geographically diversified firms. Columns (5)-(8) study spillovers to non-California Plans comparing geographically diversified and non-diversified firms. The dependent variable is log (1+Emissions). The treatment indicator CalPlant equals to 1 if the plant is located in California and 0 otherwise. The After indicator is equal to 1 if the time period is 2013 or onward and 0 otherwise. The firm-level dummy DivFirm is an indicator for whether a firm owns plants both in California and in other states during a given year or not. Control variables include PP&E, R&D Stock as well as plant and year fixed effects. Coefficients and their respective standard errors adjusted for clustering at the plant level are reported. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. Number of observations and adjusted R^2 are also reported.

Panel A: Univariate Evidence on Differences in Emissions Growth

	California vs non-California plants (Geographically diversified firms)				Spillovers to non-California plants (Diversified vs undiversified firms)			
	California	Other states	Diff.	t-stat.	Diversified	Undiversified	Diff.	t-stat.
	-0.13	-0.07	-0.06	-1.03	-0.07	-0.12	0.05	2.20

Panel B: Plant Emission Responses to California Cap-and-Trade Rule

	Dependent Variable: Log(1+Emissions)							
	California vs non-California plants (Geographically diversified firms)				Spillovers to non-California plants (Diversified vs undiversified firms)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CalPlant x After	-0.210	-0.206	-0.161*	-0.155*				
	(0.132)	(0.132)	(0.093)	(0.094)				
CalPlant	0.034	0.030						
	(0.220)	(0.220)						
DivFirm x After					0.165***	0.156***	0.140***	0.131***
					(0.059)	(0.059)	(0.038)	(0.038)
DivFirm					0.170**	0.176**	-0.155	-0.159
					(0.081)	(0.081)	(0.106)	(0.105)
After	-0.083*				-0.249***			
	(0.048)				(0.032)			
PP&E				-0.203*				-0.295***
				(0.108)				(0.068)
R&D stock				-0.006				0.017
				(0.006)				(0.012)
Plant FE	No	No	Yes	Yes	No	No	Yes	Yes
Year FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Observations	4,166	4,166	3,961	3,961	12,846	12,846	12,521	12,511
Adjusted R^2	0.001	0.001	0.862	0.862	0.008	0.010	0.745	0.746

Table 5: Firm Financial Constraints and Plant Emission Responses: Separate Regressions by Constraint Groups

The table presents results from DID regressions, separately for subsamples of financially constrained and unconstrained firms. A number of measures for financial constraints are used: Our composite measure, the Kaplan-Zingales index (following Kaplan and Zingales, 1997; Lamont, Polk, and Saá-Requejo, 2001), Whited-Wu (2006) index, Hadlock-Pierce (2010) index, size (firm assets), payout ratio, and rating. *p*-values from one sided *t*-tests comparing coefficients on the interaction term between constrained and unconstrained firms are reported as well. Results in Panel A compare California and non-California plants based on geographically diversified firms. Panel B studies spillovers to non-California Plants comparing geographically diversified and non-diversified firms. The dependent variable is log (1+Emissions). The treatment indicator CalPlant equals to 1 if the plant is located in California and 0 otherwise. The After indicator is equal to 1 if the time period is 2013 or onward and 0 otherwise. The firm-level dummy DivFirm is an indicator for whether a firm owns plants both in California and in other states during a given year or not. Control variables include PP&E, R&D Stock as well as plant and year fixed effects. Coefficients and their respective standard errors adjusted for clustering at the plant level are reported. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. *p*-values from one-sided *t*-tests comparing the coefficients on the interaction term (CalPlant x After in Panel A, and DivFirm x After in Panel B) between constrained and unconstrained firms are reported as well. The table also reports the number of observations and the adjusted R^2.

Panel A: California vs Non-California Plants (Geographically Diversified Firms)

	Dependent Variable: Log(1+Emissions)													
	Composite		Kaplan-Zingales		Hadlock-Pierce		Whited-Wu		Size		Payout		Rating	
	High	Low	High	Low	High	Low	High	Low	Small	Large	Low	High	Unrated	Rated
CalPlant x After	-0.353*	-0.030	-0.209	-0.128	-0.548**	-0.043	-0.229	-0.115	-0.440	-0.056	-0.463**	-0.122	-0.115	-0.078
	(0.208)	(0.079)	(0.151)	(0.121)	(0.263)	(0.086)	(0.379)	(0.076)	(0.322)	(0.080)	(0.230)	(0.085)	(0.169)	(0.098)
PP&E	-0.626	1.072	-0.743**	1.478	-2.712***	0.835	-1.584**	0.904	-1.162	0.217	-0.662	0.639	-2.228**	1.171*
	(0.434)	(1.092)	(0.366)	(1.384)	(0.746)	(0.534)	(0.633)	(0.899)	(0.775)	(0.589)	(0.479)	(0.860)	(0.997)	(0.637)
R&D stock	2.532	-8.065**	1.283	-15.322***	44.981**	-5.794*	-4.017*	-8.680*	-2.601	-8.534**	-0.031	-0.405	2.381	-8.408**
	(3.476)	(3.902)	(1.580)	(5.851)	(18.339)	(3.128)	(2.144)	(4.628)	(2.568)	(3.925)	(2.691)	(3.228)	(2.903)	(3.932)
CalPlant x After: Con<Uncon?		0.073		0.338		0.034		0.384		0.124		0.082		0.425
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	973	2,187	1,456	1,604	469	2,685	440	2,646	279	2,866	994	2,152	1,062	2,096
Adjusted R^2	0.904	0.827	0.921	0.816	0.903	0.864	0.835	0.876	0.881	0.858	0.910	0.865	0.907	0.841

(continued)

Table 5: Firm Financial Constraints and Plant Emission Responses: Separate Regressions by Constraint Groups (continued)

Panel B: Spillovers to Non-California Plants (Diversified vs Undiversified Firms)

	Dependent Variable: Log(1+Emissions)													
	Composite		Kaplan-Zingales		Hadlock-Pierce		Whited-Wu		Size		Payout		Rating	
	High	Low	High	Low	High	Low	High	Low	Small	Large	Low	High	Unrated	Rated
DivFirm x After	0.292***	-0.089*	0.278***	0.069	0.264***	-0.003	0.129	-0.006	0.260**	0.003	0.350***	0.064	0.237***	-0.015
	(0.065)	(0.046)	(0.067)	(0.054)	(0.078)	(0.044)	(0.139)	(0.040)	(0.123)	(0.042)	(0.063)	(0.045)	(0.068)	(0.048)
DivFirm	-0.414**	-0.010	0.189	-0.165	-0.317**	-0.072	0.076	-0.142	-0.300	-0.098	-0.272***	0.137	-0.274**	-0.005
	(0.210)	(0.121)	(0.170)	(0.164)	(0.161)	(0.122)	(0.160)	(0.127)	(0.215)	(0.114)	(0.102)	(0.128)	(0.124)	(0.133)
PP&E	-0.447***	0.382	-1.295***	-0.262	-0.292*	-0.152	-0.550***	0.519	-0.355***	-0.147	-0.566***	0.373	-0.459**	0.100
	(0.132)	(0.423)	(0.419)	(0.234)	(0.153)	(0.200)	(0.148)	(0.351)	(0.114)	(0.318)	(0.152)	(0.297)	(0.178)	(0.230)
R&D stock	-0.014	-1.089	-0.009	-2.038	0.004	0.042	-0.001	-0.035	-0.025	0.048	-0.024	-0.438	-0.001	-0.246
	(0.035)	(1.329)	(0.036)	(1.569)	(0.050)	(0.053)	(0.042)	(0.059)	(0.037)	(0.077)	(0.039)	(0.921)	(0.036)	(0.806)
DivFirm x After: Con>Uncon?		0.000		0.008		0.001		0.175		0.024		0.000		0.001
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,929	4,969	4,437	5,823	5,078	5,801	4,832	5,527	4,280	6,550	5,230	5,491	5,984	4,820
Adjusted R^2	0.718	0.779	0.712	0.749	0.700	0.778	0.673	0.819	0.689	0.774	0.712	0.803	0.717	0.774

Table 6: Firm Financial Constraints and Plant Emission Responses: Pooled Regressions with Constraint Dummies

The table reports results from pooled triple difference regressions. Results in Panel A compare California and non-California plants based on geographically diversified firms. Panel B studies spillovers to non-California Plants comparing geographically diversified and non-diversified firms. The dependent variable is log (1+Emissions). The treatment indicator CalPlant equals to 1 if the plant is located in California and 0 otherwise. The After indicator is equal to 1 if the time period is 2013 or onward and 0 otherwise. The firm-level dummy DivFirm is an indicator for whether a firm owns plants both in California and in other states during a given year or not. The firm-level dummy Constrained is an indicator for whether a firm is financially constrained according to each financial constraint measure, i.e. alternatively our composite measure, the Kaplan-Zingales (KZ) index, Whited-Wu (WW) index, Hadlock-Pierce (HP) index, size, payout ratio, and rating. Control variables include PP&E, R&D Stock as well as plant and year fixed effects. Coefficients and their respective standard errors adjusted for clustering at the plant level are reported. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The table also reports the number of observations and the adjusted R^2.

Panel A: California vs Non-California Plants (Geographically Diversified Firms)

	Dependent Variable: Log(1+Emissions)						
	Composite	KZ	HP	WW	Size	Payout	Rating
CalPlant x After x Const.	-0.391*	-0.156	-0.605**	-0.206	-0.607*	-0.253	-0.162
	(0.219)	(0.193)	(0.299)	(0.397)	(0.350)	(0.243)	(0.179)
CalPlant x After	-0.021	-0.072	-0.013	-0.095	-0.067	-0.067	-0.072
	(0.077)	(0.118)	(0.092)	(0.075)	(0.081)	(0.085)	(0.102)
CalPlant x Constrained	0.341	-0.605	0.523	1.905**	1.022	-1.256**	2.493***
	(0.922)	(0.515)	(1.146)	(0.855)	(0.907)	(0.599)	(0.855)
After x Constrained	0.107	0.059	-0.045	-0.144	0.150	-0.148*	0.064
	(0.072)	(0.065)	(0.100)	(0.163)	(0.127)	(0.075)	(0.081)
Constrained	-1.710**	-1.458***	-0.597	-1.607**	-2.278***	0.494	-1.970**
	(0.805)	(0.479)	(1.107)	(0.780)	(0.804)	(0.551)	(0.768)
PP&E	0.058	-0.319	-0.799	-0.521	0.034	-0.725	-0.470
	(0.543)	(0.518)	(0.592)	(0.623)	(0.521)	(0.645)	(0.647)
R&D stock	-5.056	-6.917**	-3.256	-5.851*	-5.973*	-1.119	-4.567
	(3.219)	(3.261)	(3.206)	(3.296)	(3.255)	(2.791)	(3.243)
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,162	3,062	3,162	3,091	3,147	3,162	3,162
Adjusted R^2	0.855	0.859	0.851	0.853	0.857	0.853	0.853

(continued)

Table 6: Firm Financial Constraints and Plant Emission Responses: Pooled Regressions with Constraint Dummies (continued)

Panel B: Spillovers to Non-California Plants (Diversified vs Undiversified Firms)

	Dependent Variable: Log(1+Emissions)						
	Composite	KZ	HP	WW	Size	Payout	Rating
DivFirm x After x Const.	0.342***	0.221**	0.189*	0.166	0.228*	0.114	0.232***
	(0.080)	(0.087)	(0.103)	(0.143)	(0.131)	(0.089)	(0.084)
DivFirm x After	-0.056	0.071	0.010	0.020	0.025	0.084*	0.009
	(0.045)	(0.055)	(0.044)	(0.039)	(0.043)	(0.047)	(0.047)
DivFirm x Constrained	-0.696***	-0.121	-0.330	-0.234	-0.461*	-0.034	-0.502**
	(0.250)	(0.240)	(0.297)	(0.245)	(0.279)	(0.236)	(0.225)
After x Constrained	-0.359***	-0.267***	-0.289***	-0.295***	-0.302***	-0.234***	-0.242***
	(0.053)	(0.070)	(0.055)	(0.058)	(0.060)	(0.058)	(0.053)
DivFirm	0.060	-0.072	-0.032	-0.028	-0.041	-0.088	0.032
	(0.122)	(0.161)	(0.124)	(0.129)	(0.119)	(0.148)	(0.131)
Constrained	0.280**	-0.072	0.141	0.088	-0.001	0.331*	0.217*
	(0.125)	(0.076)	(0.086)	(0.149)	(0.126)	(0.170)	(0.123)
PP&E	-0.428***	-0.503***	-0.424***	-0.372***	-0.422***	-0.489***	-0.343**
	(0.120)	(0.140)	(0.123)	(0.121)	(0.126)	(0.133)	(0.161)
R&D stock	-0.014	0.016	0.002	-0.004	-0.013	-0.017	-0.017
	(0.036)	(0.036)	(0.036)	(0.035)	(0.039)	(0.038)	(0.040)
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,993	10,373	10,987	10,468	10,938	10,775	10,993
Adjusted R^2	0.730	0.728	0.729	0.726	0.730	0.728	0.729

Table 7: Plant Ownership Responses to California Cap-and-Trade Rule

The table presents results from linear probability and multinomial logit regressions of plant closure and opening decisions. In linear probability models, the dependent variables are indicators for whether a firm closes (opens) a plant or not. In multinomial logits, the dependent variable is a categorical variable equal to –1 for plant closure, 0 for no ownership change, and +1 for plant opening. Panel A compares California and non-California plants based on geographically diversified firms. Panel B studies spillovers to non-California Plants comparing geographically diversified and non-diversified firms. Definitions of explanatory variables are as in Table 6. For multinomial logits, coefficients report marginal effects with respect to discrete changes from 0 to 1 for indicator variables, and unit changes at the means for continuous variables. Standard errors are adjusted for clustering at the plant level. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The table also reports the number of observations, adjusted R^2, and pseudo R^2.

Panel A: California vs Non-California Plants (Geographically Diversified Firms)

	Linear probability		Multinomial logits (base: no change)	
	Close	Open	Close	Open
CalPlant x After x Const.	0.145***	-0.002	0.181	-0.080**
	(0.055)	(0.070)	(0.129)	(0.032)
CalPlant x After	-0.036	0.036	-0.014	0.042
	(0.036)	(0.044)	(0.024)	(0.045)
CalPlant x Constrained	-0.159	-0.140	0.001	0.008
	(0.099)	(0.093)	(0.030)	(0.047)
After x Constrained	-0.053***	0.061**	-0.029	0.135***
	(0.020)	(0.029)	(0.019)	(0.046)
CalPlant			0.018	0.013
			(0.017)	(0.026)
After			-0.076***	-0.081***
			(0.015)	(0.018)
Constrained	0.093	0.015	-0.032***	-0.052***
	(0.072)	(0.080)	(0.012)	(0.019)
PP&E	-0.310***	0.185	0.072**	0.229***
	(0.112)	(0.151)	(0.034)	(0.032)
R&D stock	-0.629	4.952***	-0.376	0.139**
	(0.640)	(1.500)	(0.267)	(0.055)
Plant FE	Yes	Yes	No	No
Firm FE	No	No	No	No
Year FE	Yes	Yes	No	No
Observations	2,518	2,735	3,062	3,062
Adjusted R^2	0.381	0.132		
Pseudo R^2			0.050	0.050

(continued)

Table 7: Plant Ownership Responses to California Cap-and-Trade Rule (continued)

Panel B: Spillovers to Non-California Plants (Diversified vs Undiversified Firms)

	Linear probability		Multinomial logits (base: no change)	
	Close	Open	Close	Open
DivFirm x After x Const.	-0.063***	0.125***	-0.058***	0.182***
	(0.023)	(0.033)	(0.016)	(0.064)
DivFirm x After	-0.005	-0.010	-0.023	0.006
	(0.016)	(0.021)	(0.017)	(0.022)
DivFirm x Constrained	-0.044	0.007	-0.063***	-0.058***
	(0.039)	(0.062)	(0.010)	(0.017)
After x Constrained	0.046***	-0.066***	0.038**	-0.016
	(0.013)	(0.016)	(0.018)	(0.016)
DivFirm	0.037**	-0.082***	0.061***	-0.016
	(0.019)	(0.027)	(0.017)	(0.012)
After			-0.065***	-0.089***
			(0.016)	(0.015)
Constrained	0.080***	-0.116***	0.054***	0.009
	(0.029)	(0.035)	(0.010)	(0.010)
PP&E	0.131***	0.008	0.094***	0.260***
	(0.046)	(0.045)	(0.019)	(0.022)
R&D stock	0.859***	0.090***	0.128***	0.122**
	(0.054)	(0.018)	(0.041)	(0.059)
Plant FE	Yes	Yes	No	No
Firm FE	No	No	No	No
Year FE	Yes	Yes	No	No
Observations	8,353	9,524	10,053	10,053
Adjusted R^2	0.406	0.244		
Pseudo R^2			0.054	0.054

Table 8: Firm Level Total Emissions

The table presents results from firm level regressions testing whether firms affected by the California cap-and-trade rule increase their overall emissions, and whether financial constraints affect their overall responses. Columns (1) and (2) test whether firms with plants both in California and also in other states change their overall emissions after the implementation of the cap-and-trade rule. Columns (3) and (4) test whether a group of firms without any plants in California or only operate in California change their total emissions. The dependent variable is log(1+firm total emissions), where firm total emissions are computed by summing up emissions across all plants owned by a firm in a given year. After is an indicator equal to 1 if the time period is 2013 or onward and 0 otherwise. Constrained is an indicator for whether a firm is financially constrained according to our composite measure. Control variables include PP&E, R&D Stock as well as firm and year fixed effects. Coefficients and standard errors adjusted for clustering at the firm level are reported. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The table also reports the number of observations and adjusted R^2.

Dependent Variable: Log(1+Firm total emissions)				
	Firms with plants in both CA and other states		Firms without plants in both CA and other states	
	(1)	(2)	(3)	(4)
After x Constrained	0.270**	0.276**	0.108	0.123
	(0.123)	(0.123)	(0.095)	(0.094)
After	-0.094		0.089	
	(0.094)		(0.082)	
PP&E	-0.648	-0.576	-0.167	0.147
	(0.693)	(0.662)	(0.380)	(0.377)
R&D stock	0.803	1.071	0.064	0.073**
	(1.992)	(1.975)	(0.046)	(0.037)
Firm FE	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes
Observations	254	254	1,684	1,684
Adjusted R^2	0.973	0.972	0.863	0.870

Table 9: Impact on Sectoral GDP and Employment

The table examines whether the California cap-and-trade rule differentially impacts employment and GDP in affected industries in California compared to other states, and whether growth from other industries countervails this effect. A plant's industry is defined as the narrowest NAICS code with at least 50 plants in the entire cross-section each year, and mapped to the narrowest available 2-4 digit NAICS industry classification for which the BEA publicly reports state level employment and GDP. The data is collapsed to state-sector-year level where sectors are categorized as either "emission sector" or "non-emission sector". All BEA industries with greenhouse gas emitting plants are pooled together to comprise the emission sector, and all remaining industries are grouped as the non-emission sector. Employment (number of wage earning workers) and GDP (inflation adjusted with respect to 2009 dollars) are aggregated up to each state-sector-year. Columns (1)-(3) report results with log(1+Wage employment) as the dependent variable, and columns (4)-(6) use log(1+GDP) as the dependent variable. For each dependent variable, separate regressions are run for the emission sector and non-emission sector, and then the two sectors are included together in a pooled regression. Cal is a state level dummy indicating whether the state is California or not, and After is an indicator for whether the year is 2013 or later. EmissionSector indicates whether the sector is comprised of industries with greenhouse gas emitting plants. State and year fixed effects are controlled for. Standard errors are adjusted for clustering at the state level. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The table also reports the number of observations and adjusted R^2.

Dependent Variable	log(1+Wage employment)			log(1+GDP)		
	Emission sector	Non-emission sector	Pooled	Emission sector	Non-emission sector	Pooled
	(1)	(2)	(3)	(4)	(5)	(6)
Cal x After	-0.138**	0.092***	0.078***	-0.046	0.075***	0.044
	(0.068)	(0.007)	(0.016)	(0.039)	(0.026)	(0.042)
Cal x After x EmissionSector			-0.203***			-0.073
			(0.074)			(0.067)
Cal x EmissionSector			0.932***			0.548**
			(0.249)			(0.231)
After x EmissionSector			-0.064			-0.127*
			(0.074)			(0.067)
EmissionSector			-2.215***			-1.034***
			(0.249)			(0.231)
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	299	288	589	299	287	588
Adjusted R^2	0.953	0.997	0.857	0.990	0.953	0.847

Table 10: The Impact of Reallocation and Compliance Costs on Spillovers

The table presents results from subsample regressions of Equations (3) and (4). In the first two columns, the subsamples are based on the distance of plants from California. The "Close" sample comprises plants located in California or nearby (i.e. within three adjacent states). The "Far" sample includes plants in California and in distant states. In the next two columns, the subsamples are based on the stringency of state environmental regulation. The "Low" sample comprises plants located in California and in less regulated states. The "High" sample includes plants in California and in heavily regulated states. In the last two columns, the subsamples are based on abnormal R&D and Capex investments of firms prior to the sample period, where abnormal R&D and Capex investment is computed as the within-firm average of the residuals from regression equation (8) over the period 2003-2008. The "Low" sample comprises plants owned by firms with negative ex-ante abnormal investments. The "High" sample comprises plants owned by firms with positive ex-ante abnormal investments. The dependent variable is log (1+Emissions). Panel A compares California and non-California plants based on geographically diversified firms. Panel B studies spillovers to non-California Plants comparing geographically diversified and non-diversified firms. CalPlant equals to 1 if the plant is located in California and 0 otherwise. After is an indicator equal to 1 if the time period is 2013 or onward and 0 otherwise. Constrained is an indicator for whether a firm is financially constrained according to our composite measure. DivFirm is a dummy equal to 1 if a firm owns a plant in California as well as in other states in a given year, and 0 otherwise. Control variables include PP&E, R&D Stock as well as plant and year fixed effects. Coefficients and their respective standard errors adjusted for clustering at the plant level are reported. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. *p*-values from one-sided *t*-tests comparing the coefficients on the triple interaction terms between subsamples are reported as well. The table also reports the number of observations and adjusted R^2.

	Dependent Variable: Log(1+Emissions)					
	Distance from California		Environmental Regulation Stringency		Prior Abnormal R&D and Capex	
	Close	Far	Low	High	Low	High
Panel A: California vs Non-California Plants						
CalPlant x After x Const.	-0.437*	-0.361	-0.472**	-0.327	-0.637**	-0.067
	(0.244)	(0.220)	(0.227)	(0.225)	(0.273)	(0.439)
CalPlant x After	0.011	-0.028	0.003	-0.040	0.152	-0.054
	(0.106)	(0.075)	(0.088)	(0.079)	(0.142)	(0.079)
p: Subsample1>Subsample2 ?		0.409		0.325		0.135
Observations	1,569	2,205	1,984	1,790	1,614	1,536
Adjusted R^2	0.861	0.858	0.827	0.893	0.889	0.931
Panel B: Spillovers to Non-California Plants						
DivFirm x After x Const.	0.588***	0.221**	0.515***	0.191*	0.351***	0.162
	(0.143)	(0.095)	(0.116)	(0.109)	(0.094)	(0.145)
DivFirm x After	-0.144*	0.008	-0.131*	0.027	-0.024	-0.004
	(0.083)	(0.051)	(0.072)	(0.055)	(0.065)	(0.050)
p: Subsample1>Subsample2 ?		0.016		0.021		0.137
Observations	3,893	7,100	5,298	5,695	5,443	5,414
Adjusted R^2	0.701	0.751	0.678	0.783	0.775	0.741
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Other Terms	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Table 11: Do Emissions Chase Growth Opportunities?

The table examines whether changes in emissions after the implementation of the California cap-and-trade rule are explained by variations in growth opportunities associated with plants. We employ two measures of growth opportunities: (1) annual private industry real GDP growth of the state the plant is located in, and (2) median Tobin's Q of firms that own a plant in the same state and industry as the plant and primarily operate in that industry. Panel A reports the population-weighted cross-state average real GDP growth and median Tobin's Q (first averaged within states) over our sample period from 2010 to 2015. The averages for the Before (2010–2012) and After (2013–2015) periods are shown, as well as the difference between the two and its corresponding *t*-statistic. State level GDP data is downloaded from the Bureau of Economic Analysis. The first three columns of Panel B compare emissions for California and non-California plants based on geographically diversified firms, controlling for GDP growth and Tobin's Q. The dependent variable is log (1+Emissions). The first two columns each have either GDP growth or Tobin's Q as its explanatory variable as well as its interaction with the firm level Constrained dummy based on our composite constraint measure. The third column includes all growth opportunity variables and adds the main variables as in Table 7 and 8: CalPlant (equal to 1 if the plant is located in California and 0 otherwise), After (equal to 1 if the time period is 2013 or onward and 0 otherwise), Constrained (indicator for whether a firm is financially constrained according to our composite measure), and their interaction terms. The last three columns of Panel B study spillovers to non-California plants comparing geographically diversified and non-diversified firms. The sample is restricted to plants located outside of California, and the variable CalPlant is replaced with DivFirm (indicates whether a firm owns plants both in California and in other states during a given year or not). GDP growth and Tobin's Q are further interacted with DivFirm x Constrained and Divfirm. Control variables include PP&E, R&D Stock as well as plant and year fixed effects. Standard errors are adjusted for clustering at the plant level. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The table also reports the number of observations and adjusted R^2.

Panel A: Growth Opportunities in California and Other States

State	2010	2011	2012	2013	2014	2015	Before (2010-2012)	After (2013-2015)	After–Before	t-stat.
State GDP growth (%)										
California	1.60	1.50	3.10	2.90	4.40	4.90	2.07	4.07	2.00	2.52
Other States	2.70	2.01	2.43	1.99	2.68	2.79	2.38	2.49	0.11	0.34
Diff	-1.10	-0.51	0.67	0.91	1.72	2.11	**-0.31**	**1.58**	**1.89**	**3.00**
Median Tobin's Q										
California	1.29	1.36	1.31	1.34	1.42	1.38	1.32	1.38	0.06	1.94
Other States	1.34	1.41	1.34	1.35	1.43	1.43	1.36	1.40	0.04	1.04
Diff	-0.05	-0.05	-0.03	0.00	0.00	-0.06	**-0.04**	**-0.02**	**0.02**	**1.12**

(continued)

Table 11: Do Emissions Chase Growth Opportunities? (continued)

Panel B: Controlling for Growth Opportunities

	Dependent Variable: Log(1+Emissions)					
	California vs Non-California Plants (Geographically Diversified Firms)			Spillovers to Non-California Plants (Diversified vs Undiversified Firms)		
	(1)	(2)	(3)	(4)	(5)	(6)
%ΔGDP	-0.005		-0.004	-0.000		0.001
	(0.007)		(0.007)	(0.008)		(0.009)
%ΔGDP x Constrained	-0.017		-0.009	0.001		-0.002
	(0.013)		(0.011)	(0.011)		(0.012)
%ΔGDP x DivFirm				0.026**		0.022*
				(0.011)		(0.013)
%ΔGDP x DivFirm x Const.				-0.049**		-0.023
				(0.020)		(0.018)
Q		0.084	0.092		-0.024	-0.136*
		(0.087)	(0.091)		(0.066)	(0.075)
Q x Constrained		-0.118	-0.134		0.485***	0.513***
		(0.166)	(0.160)		(0.105)	(0.116)
Q x DivFirm					0.044	0.285**
					(0.088)	(0.142)
Q x DivFirm x Constrained					-0.367**	-0.480**
					(0.168)	(0.213)
CalPlant x After x Const.			-0.369*			
			(0.216)			
CalPlant x After			-0.011			
			(0.078)			
CalPlant x Constrained			0.325			
			(0.913)			
DivFirm x After x Const.						0.303***
						(0.083)
DivFirm x After						-0.070
						(0.045)
DivFirm x Constrained						0.003
						(0.371)
DivFirm						-0.332
						(0.240)
After x Constrained			0.110			-0.336***
			(0.073)			(0.052)
Constrained	-1.522***	-1.428***	-1.515*	0.059	-0.544***	-0.398*
	(0.452)	(0.509)	(0.818)	(0.138)	(0.185)	(0.204)
PP&E	0.020	0.012	0.074	-0.439***	-0.394***	-0.377***
	(0.482)	(0.499)	(0.549)	(0.120)	(0.120)	(0.120)
R&D stock	-4.558	-4.470	-4.833	0.020	-0.039	-0.058
	(3.134)	(3.200)	(3.259)	(0.035)	(0.052)	(0.050)
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,162	3,162	3,162	10,993	10,892	10,892
Adjusted R^2	0.855	0.855	0.855	0.728	0.728	0.730

Table 12: Placebo Tests

The table reports results from two sets of placebo tests, each using Texas and Louisiana as placebo treatment states. The dependent variable is log (1+Emissions). In each placebo test, the first column compares emissions from plants located in the Placebo state with emissions from non-Placebo plants based on a sample of geographically diversified firms. The second column studies spillovers to non-Placebo plants comparing geographically diversified and non-diversified firms. PlaceboPlant equals to 1 if the plant is located in the placebo state and 0 otherwise. The After indicator is equal to 1 if the time period is 2013 or onward and 0 otherwise. DivFirm indicates whether a firm owns plants both in the placebo state and in other states during a given year or not. The firm-level dummy Constrained is an indicator for whether a firm is financially constrained according to our composite measure. Control variables include PP&E, R&D Stock as well as plant and year fixed effects. Standard errors are adjusted for clustering at the plant level. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The table also reports the number of observations and adjusted R^2.

	Dependent Variable: Log(1+Emissions)			
	Placebo State: Texas		Placebo State: Louisiana	
	Placebo vs Control (Diversified firms)	Spillovers to Control Plants (Div. vs Undiv firms)	Placebo vs Control (Diversified firms)	Spillovers to Control Plants (Div. vs Undiv firms)
PlaceboPlant x After x Const.	0.022		0.019	
	(0.146)		(0.155)	
PlaceboPlant x After	-0.133*		-0.062	
	(0.071)		(0.122)	
PlaceboPlant x Constrained	-0.539		0.476	
	(0.349)		(0.374)	
DivFirm x After x Const.		-0.137		-0.001
		(0.091)		(0.097)
DivFirm x After		0.086*		-0.015
		(0.051)		(0.051)
DivFirm x Constrained		-0.066		0.542***
		(0.124)		(0.175)
DivFirm		0.403***		-0.213
		(0.130)		(0.131)
After x Constrained	-0.319***	-0.186***	-0.296***	-0.312***
	(0.067)	(0.064)	(0.080)	(0.060)
Constrained	0.358**	0.454***	0.274	-0.248*
	(0.180)	(0.156)	(0.224)	(0.150)
PP&E	-0.402*	-0.529***	-0.096	-0.537***
	(0.234)	(0.128)	(0.266)	(0.138)
R&D stock	-0.067	-0.016	0.136	-0.020
	(0.179)	(0.037)	(0.191)	(0.038)
Plant FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	6,420	8,788	4,648	9,943
Adjusted R^2	0.728	0.748	0.749	0.727

Appendix A: Variable Names and Definitions

The table shows the names, definitions, and data sources of the variables used in the study.

Variable Name	Definition	Source
Emissions	Facility greenhouse gas emissions quantity by firm (metric tons × firm ownership in facility)	EPA
Close	Indicator equal to 1 if firm reduces fractional ownership in plant or ceases ownership in plant, and 0 otherwise	EPA
Open	Indicator equal to 1 if firm increases fractional ownership in plant or begins ownership in plant, and 0 otherwise	EPA
Multinomial close/open	Categorical variable equal to -1 if plant closed or ownership is reduced, 0 if there is no plant ownership change, 1 if plant opened or ownership is increased	EPA
CalPlant	Indicator equal to 1 if the plant is located in California, and 0 otherwise	EPA
PlaceboPlant	Indicator equal to 1 if the plant is located in placebo state, and 0 otherwise	EPA
DivFirm	Indicator equal to 1 if firm owns plants both in California and in other states, and 0 otherwise	EPA
After	Indicator equal to 1 if the time period is 2013 or onward, and 0 otherwise	
Wage employment	Total number of full- and part-time wage earning workers in each state and industry	BEA
GDP	Gross domestic product by state and industry, inflation adjusted with respect to 2009 dollars	BEA
EmissionSector	Indicator equal to 1 if a sector is comprised of industries with greenhouse gas emitting plants, and 0 otherwise	
Total assets	Assets in $ billions (AT)	Compustat
Size	Log of total assets	Compustat
PP&E	Property, plant and equipment (gross)/Total assets (PPEGT/AT)	Compustat
Capital expenditures	Capital expenditures/Total assets (CAPX/AT)	Compustat
Short-term debt	Debt in current liabilities/Total assets (DLC/AT)	Compustat
Long-term debt	Long-term debt/Total assets (DLTT/AT)	Compustat
Cash	Cash and short-term investments/Total assets (CHE/AT)	Compustat
Cash flow	Operating income before depreciation/Total assets (OIBDP/AT)	Compustat
Profitability	Income before extraordinary items/Total assets (IB/AT)	Compustat
Tobin's Q	Market value of assets (Total assets (AT) + Market value of common equity (CSHO*$PRCC_F$) - Common equity (CEQ) - Deferred taxes (TXDB)) divided by 0.9·Book value of assets (AT)+0.1·Market value of assets	Compustat
R&D	Research and development expense/sales (XRD/SALE)	Compustat
R&D Stock	Perpetual inventory method with initial value of R&D capital stock set as zero and accumulating R&D expenses with a depreciation rate of 15%, scaled by total assets	Hall, Jaffe, and Trajtenberg (2005)
Payout Ratio	(Cash dividends + repurchases)/Income before extraordinary items ((DVP+DVC+PRSTKC)/ IB)	Compustat
Firm Age	Difference between observation year and founding year (annual, years)	Jovanovic and Rousseau (2001)
Long-term rating	Indicator equal to 1 if firm has rating on long-term (>1 year) obligations, and 0 otherwise	Compustat
Short-term rating	Indicator equal to 1 if firm has rating on short-term (<1 year) obligations, and 0 otherwise	Compustat
Kaplan-Zingales Index	-1.002·Cash flow + 0.283·Tobin's Q + 3.139·Total debt - 39.368·Dividends - 1.315·Cash	Kaplan and Zingales (1997); Lamont, Polk, and Saá-Requejo (2001)
Whited-Wu Index	-0.091·Cash flow - 0.062·Positive dividend dummy + 0.021·Long-term debt - 0.044·Size + 0.102·Industry sales growth - 0.035·Sales growth	Whited and Wu (2006)
Hadlock-Pierce Index	-0.737·Size + 0.043·Size^2 - 0.040·Age where Size is the log of Min(AT, $4.5 billion) and Age is Min(Firm age, 37 years) For Kaplan-Zingales, Hadlock-Pierce, and Whited-Wu, size, and payout, firms are assigned percentile rankings based on each measure every year. Using six years strictly before the sample period (i.e. fiscal years 2003-2008) time-series average percentile rankings are computed for each firm and each measure. Based on average rankings, firms are categorized as constrained if they are above median for Kaplan-Zingales, Hadlock-Pierce, and Whited-Wu, and if they are below median for size and payout.	Hadlock and Pierce (2010)
Financial constraints	For credit ratings, a firm is categorized as "long-term (short-term)" financially constrained if the firm did not have a bond (commercial paper) rating as of the most recent year of the 2003-2008 pre-sample period but had on average positive long-term (short-term) debt during this period. If the firm did have a bond (commercial paper) rating as of the most recent year of the six-year pre-sample period or had on average zero long-term (short-term) debt during this period, then the firm is "long-term (short-term)" unconstrained. If a firm is either long-term or short-term credit constrained, the firm is classified as constrained based on ratings and unconstrained otherwise.	Compustat
Composite	Indicator equal to 1 if firm is constrained according to majority of all six constraint measures, and 0 otherwise	Compustat

Table A.1: Plant Emission Responses to California Cap-and-Trade Rule

The table presents results from the firm-plant level difference-in-difference (DID) regressions. Results in the first four columns compare California and non-California plants based on all firms (geographically diversified firms). The last two columns study spillovers to non-California Plans comparing geographically diversified and non-diversified firms. The dependent variable is log (1+Emissions). The treatment indicator CalPlant equals to 1 if the plant is located in California and 0 otherwise. The After indicator is equal to 1 if the time period is 2013 or onward and 0 otherwise. The firm-level dummy DivFirm is an indicator for whether a firm owns plants both in California and in other states during a given year or not. Control variables include PP&E, R&D Stock as well as firm x plant and year fixed effects. Coefficients and their respective standard errors adjusted for clustering at the plant level are reported. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The table also reports the number of observations and the adjusted R^2.

Dependent Variable: Log(1+Emissions)						
	California vs Non-California Plants (All Firms)		California vs Non-California Plants (Geographically Diversified Firms)		Spillovers to Non-California Plants (Diversified vs Undiversified Firms)	
CalPlant x After	-0.061	-0.061	-0.176*	-0.171*		
	(0.089)	(0.090)	(0.095)	(0.096)		
DivFirm x After					0.169***	0.158***
					(0.035)	(0.035)
DivFirm					0.054	0.061
					(0.070)	(0.070)
PP&E		-0.405***		-0.099		-0.439***
		(0.097)		(0.075)		(0.102)
R&D stock		0.007		1.671		0.004
		(0.015)		(1.220)		(0.016)
Firm x Plant FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,784	12,773	3,825	3,825	11,996	11,985
Adjusted R^2	0.790	0.791	0.923	0.923	0.780	0.780

Table A.2: Firm Financial Constraints and Plant Emission Responses: Separate Regressions by Constraint Groups

The table presents results from DID regressions, separately for subsamples of financially constrained and unconstrained firms. A number of measures for financial constraints are used: Our composite measure, the Kaplan-Zingales index (following Kaplan and Zingales, 1997; Lamont, Polk, and Saá-Requejo, 2001), Whited-Wu (2006) index, Hadlock-Pierce (2010) index, size (firm assets), payout ratio, and rating. *p*-values from one sided *t*-tests comparing coefficients on the interaction term between constrained and unconstrained firms are reported as well. Results in Panel A compare California and non-California plants based on geographically diversified firms. Panel B studies spillovers to non-California Plants comparing geographically diversified and non-diversified firms. The dependent variable is log (1+Emissions). The treatment indicator CalPlant equals to 1 if the plant is located in California and 0 otherwise. The After indicator is equal to 1 if the time period is 2013 or onward and 0 otherwise. The firm-level dummy DivFirm is an indicator for whether a firm owns plants both in California and in other states during a given year or not. Control variables include PP&E, R&D Stock as well as firm x plant and year fixed effects. Coefficients and their respective standard errors adjusted for clustering at the plant level are reported. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. *p*-values from one-sided *t*-tests comparing the coefficients on the interaction term (CalPlant x After in Panel A, and DivFirm x After in Panel B) between constrained and unconstrained firms are reported as well. The table also reports the number of observations and the adjusted R^2.

Panel A: California vs Non-California Plants (Geographically Diversified Firms)

	Dependent Variable: Log(1+Emissions)													
	Composite		Kaplan-Zingales		Hadlock-Pierce		Whited-Wu		Size		Payout		Rating	
	High	Low	High	Low	High	Low	High	Low	Small	Large	Low	High	Unrated	Rated
CalPlant x After	-0.387*	-0.048	-0.209	-0.138	-0.410	-0.094	-0.537	-0.059	-0.545	-0.079	-0.458**	-0.025	-0.304*	-0.081
	(0.216)	(0.068)	(0.155)	(0.108)	(0.281)	(0.082)	(0.373)	(0.062)	(0.346)	(0.078)	(0.229)	(0.067)	(0.169)	(0.097)
PP&E	-0.550	0.195	-0.501	0.858	-0.683	-0.067	-0.789	0.296	-0.998	-0.187	-0.409	-0.074	-0.241	-0.019
	(0.439)	(0.416)	(0.408)	(0.701)	(0.502)	(0.365)	(0.507)	(0.388)	(0.794)	(0.358)	(0.550)	(0.270)	(0.426)	(0.425)
R&D stock	2.359	2.427*	1.287	1.963	24.337	2.320**	-4.800**	4.281***	-3.200	1.583	0.422	2.742**	1.970	2.201
	(3.499)	(1.275)	(1.568)	(1.767)	(17.982)	(1.179)	(2.282)	(1.517)	(2.840)	(1.188)	(2.796)	(1.294)	(2.415)	(1.431)
CalPlant x After: Con<Uncon?		0.067		0.354		0.140		0.103		0.094		0.035		0.126
Firm x Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	967	2,150	1,451	1,566	466	2,651	436	2,610	273	2,829	993	2,124	1,055	2,062
Adjusted R^2	0.904	0.940	0.921	0.933	0.912	0.930	0.851	0.950	0.882	0.931	0.911	0.937	0.941	0.920

(continued)

Table A.2: Firm Financial Constraints and Plant Emission Responses: Separate Regressions by Constraint Groups (continued)

Panel B: Spillovers to Non-California Plants (Diversified vs Undiversified Firms)

	Dependent Variable: Log(1+Emissions)													
	Composite		Kaplan-Zingales		Hadlock-Pierce		Whited-Wu		Size		Payout		Rating	
	High	Low	High	Low	High	Low	High	Low	Small	Large	Low	High	Unrated	Rated
DivFirm x After	0.290***	-0.008	0.271***	0.117***	0.258***	0.056	0.135	0.050	0.227*	0.058	0.341***	0.038	0.259***	0.053
	(0.066)	(0.038)	(0.067)	(0.043)	(0.079)	(0.040)	(0.142)	(0.035)	(0.126)	(0.038)	(0.064)	(0.038)	(0.054)	(0.044)
DivFirm	-0.312	0.177**	0.146	0.049	-0.330*	0.149**	0.068	0.166**	-0.316	0.150**	-0.110	0.142	-0.191	0.165**
	(0.222)	(0.074)	(0.164)	(0.069)	(0.183)	(0.076)	(0.177)	(0.084)	(0.248)	(0.073)	(0.083)	(0.105)	(0.156)	(0.080)
PP&E	-0.590***	-0.035	-1.453***	-0.110	-0.475*	-0.532**	-0.687***	0.051	-0.593**	-0.343	-0.916***	-0.120	-0.720**	-0.274
	(0.223)	(0.268)	(0.443)	(0.163)	(0.245)	(0.256)	(0.262)	(0.236)	(0.250)	(0.277)	(0.264)	(0.253)	(0.304)	(0.190)
R&D stock	0.001	-0.603	-0.008	-1.326	0.002	0.042	0.032	-0.032	-0.019	0.071	-0.005	0.176	0.000	0.273
	(0.035)	(1.329)	(0.037)	(1.627)	(0.044)	(0.053)	(0.040)	(0.054)	(0.039)	(0.060)	(0.037)	(0.945)	(0.037)	(0.795)
DivFirm x After: Con>Uncon?		0.000		0.027		0.011		0.281		0.100		0.000		0.002
Firm x Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,756	4,916	4,417	5,694	4,910	5,756	4,721	5,468	4,142	6,476	5,068	5,387	5,906	4,766
Adjusted R^2	0.721	0.857	0.718	0.825	0.708	0.838	0.673	0.882	0.685	0.835	0.713	0.841	0.724	0.844

Table A.3: Firm Financial Constraints and Plant Emission Responses: Pooled Regressions with Constraint Dummies

The table reports results from pooled triple difference regressions. Results in Panel A compare California and non-California plants based on geographically diversified firms. Panel B studies spillovers to non-California Plants comparing geographically diversified and non-diversified firms. The dependent variable is log (1+Emissions). The treatment indicator CalPlant equals to 1 if the plant is located in California and 0 otherwise. The After indicator is equal to 1 if the time period is 2013 or onward and 0 otherwise. The firm-level dummy DivFirm is an indicator for whether a firm owns plants both in California and in other states during a given year or not. The firm-level dummy Constrained is an indicator for whether a firm is financially constrained according to each financial constraint measure, i.e. alternatively our composite measure, the Kaplan-Zingales (KZ) index, Whited-Wu (WW) index, Hadlock-Pierce (HP) index, size, payout ratio, and rating. Control variables include PP&E, R&D Stock as well as firm x plant and year fixed effects. Coefficients and their respective standard errors adjusted for clustering at the plant level are reported. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The table also reports the number of observations and the adjusted R^2.

Panel A: California vs Non-California Plants (Geographically Diversified Firms)

	Dependent Variable: Log(1+Emissions)						
	Composite	KZ	HP	WW	Size	Payout	Rating
CalPlant x After x Const.	-0.347	-0.075	-0.313	-0.477	-0.500	-0.431*	-0.224
	(0.225)	(0.187)	(0.293)	(0.374)	(0.368)	(0.237)	(0.194)
CalPlant x After	-0.038	-0.129	-0.091	-0.053	-0.079	-0.023	-0.076
	(0.070)	(0.106)	(0.082)	(0.063)	(0.078)	(0.067)	(0.096)
After x Constrained	-0.006	-0.025	-0.015	-0.148	0.011	0.007	0.049
	(0.059)	(0.052)	(0.068)	(0.148)	(0.112)	(0.051)	(0.047)
PP&E	-0.224	-0.132	-0.153	-0.340	-0.228	-0.170	-0.081
	(0.306)	(0.326)	(0.307)	(0.336)	(0.320)	(0.283)	(0.316)
R&D stock	2.322*	2.020*	2.327**	0.825	0.791	2.192*	1.934
	(1.215)	(1.219)	(1.172)	(1.654)	(1.144)	(1.228)	(1.210)
Firm x Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,117	3,017	3,117	3,046	3,102	3,117	3,117
Adjusted R^2	0.928	0.927	0.928	0.928	0.929	0.928	0.928

(continued)

Table A.3: Firm Financial Constraints and Plant Emission Responses: Pooled Regressions with Constraint Dummies (continued)

Panel B: Spillovers to Non-California Plants (Diversified vs Undiversified Firms)

	Dependent Variable: Log(1+Emissions)						
	Composite	KZ	HP	WW	Size	Payout	Rating
DivFirm x After x Const.	0.295***	0.180**	0.193**	0.100	0.179	0.312***	0.211***
	(0.076)	(0.081)	(0.089)	(0.145)	(0.130)	(0.076)	(0.071)
DivFirm x After	-0.004	0.125***	0.054	0.060*	0.060	0.039	0.058
	(0.036)	(0.042)	(0.040)	(0.034)	(0.037)	(0.039)	(0.044)
DivFirm x Constrained	-0.502**	0.060	-0.489**	-0.110	-0.488*	-0.237*	-0.370**
	(0.233)	(0.176)	(0.197)	(0.194)	(0.257)	(0.136)	(0.174)
After x Constrained	-0.356***	-0.248***	-0.272***	-0.291***	-0.304***	-0.288***	-0.223***
	(0.054)	(0.071)	(0.057)	(0.059)	(0.061)	(0.061)	(0.055)
DivFirm	0.183**	0.047	0.166**	0.149*	0.156**	0.147	0.166**
	(0.076)	(0.068)	(0.077)	(0.085)	(0.074)	(0.104)	(0.082)
PP&E	-0.510***	-0.575***	-0.538***	-0.468**	-0.532***	-0.576***	-0.479***
	(0.180)	(0.187)	(0.179)	(0.187)	(0.181)	(0.180)	(0.180)
R&D stock	-0.000	-0.004	0.017	0.007	0.004	-0.004	0.006
	(0.036)	(0.036)	(0.036)	(0.034)	(0.039)	(0.036)	(0.036)
Firm x Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,672	10,111	10,666	10,189	10,618	10,455	10,672
Adjusted R^2	0.774	0.774	0.773	0.771	0.773	0.772	0.772

Table A.4: Plant Ownership Responses to California Cap-and-Trade Rule

The table presents results from linear probability estimations of plant closure and opening decisions. The dependent variables are indicators for whether a firm closes (opens) a plant or not. The first two columns compare California and non-California plants based on geographically diversified firms. The last two columns study spillovers to non-California Plants comparing geographically diversified and non-diversified firms. The treatment indicator CalPlant equals to 1 if the plant is located in California and 0 otherwise. The After indicator is equal to 1 if the time period is 2013 or onward and 0 otherwise. The firm-level dummy DivFirm is an indicator for whether a firm owns plants both in California and in other states during a given year or not. The firm-level dummy Constrained is an indicator for whether a firm is financially constrained according to our composite measure. Control variables include PP&E, R&D Stock as well as firm x plant and year fixed effects. Coefficients report marginal effects and standard errors are adjusted for clustering at the plant level. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The table also reports the number of observations and adjusted R^2.

	California vs Non-California Plants (Geographically Diversified Firms)		Spillovers to Non-California Plants (Diversified vs Undiversified Firms)	
	Close	Open	Close	Open
CalPlant x After x Const.	0.076	-0.054		
	(0.053)	(0.060)		
CalPlant x After	0.016	0.028		
	(0.028)	(0.045)		
DivFirm x After x Const.			-0.112***	0.133***
			(0.023)	(0.032)
DivFirm x After			0.016	-0.005
			(0.016)	(0.020)
DivFirm x Constrained			0.040	-0.235***
			(0.037)	(0.066)
DivFirm			0.006	-0.038
			(0.018)	(0.029)
After x Constrained	-0.037*	0.056*	0.071***	-0.079***
	(0.020)	(0.029)	(0.013)	(0.017)
PP&E	0.036	-0.193	0.056	-0.239***
	(0.074)	(0.137)	(0.054)	(0.073)
R&D stock	0.232	2.994**	1.160***	0.118***
	(0.599)	(1.500)	(0.328)	(0.009)
Firm x Plant FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	2,485	2,692	8,138	9,261
Adjusted R^2	0.361	0.185	0.324	0.253