Rewiring Supply Chains Through Uncoordinated Climate Policy*

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Abstract

We show that climate transition risk can significantly disrupt global supply chains. Following the introduction of California's cap-and-trade program, we find that regulated suppliers are more likely to lose customer relationships than otherwise similar unregulated peers. These effects are strongest for suppliers operating in highly competitive markets and producing standardized inputs, where customer switching costs are low. Relationship losses lead to persistent declines in supplier revenues, assets, and employment. The resulting supply chain reconfiguration reflects uncoordinated climate policies and is consistent with carbon leakage: customers that source away from cap-and-trade regions increase the aggregate carbon footprint of their supply chains.

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1 Introduction

Over recent decades, governments have increasingly implemented climate policies to curb carbon emissions, generating a fragmented regulatory landscape across jurisdictions. This lack of coordination exposes firms to heterogeneous climate transition risk arising from the tightening of climate policies, which creates incentives for climate regulatory arbitrage, commonly referred to as carbon leakage. Previous research shows that firms respond to these incentives by relocating production and emissions from regulated to unregulated jurisdictions in order to mitigate policy-induced disruptions to economic activity (Ben-David, Jang, Kleimeier, and Viehs, 2021; Bartram, Hou, and Kim, 2022). An equally important but less studied form of carbon leakage may operate through the reconfiguration of supply chains. Specifically, customers may reallocate input sourcing away from suppliers exposed to high climate transition risk in order to reduce supply chain uncertainty about future supplier reliability (Cosbey, Droege, Fischer, and Munnings, 2019). Such sourcing decisions can reshape buyer–supplier relationships, alter trade patterns, and shift the geographic distribution of emissions along global supply chains.

Consistent with this supply-chain channel of carbon leakage, we show that, following the introduction of California's cap-and-trade program, relationships involving treated suppliers are 11 percentage points more likely to terminate than comparable relationships involving control suppliers. The magnitude is economically meaningful: the effect corresponds to roughly 29% standard deviations of the relationship-termination outcome. The estimates are robust to including customer $\times$ year fixed effects, which compare, within a given year, the same customer's propensity to end relationships with treated versus control suppliers and thereby absorb unobserved shocks to customer demand.

An alternative explanation for the higher likelihood of relationship termination among suppliers subject to cap-and-trade is that suppliers relocate production out of California rather than customers reallocating sourcing. For example, Bartram et al. (2022) show that

financially constrained firms shift operations to plants in other states, which may lead them to form new business relationships closer to those locations. We address this alternative explanation in two ways: the effect remains significant among treated suppliers operating exclusively in California, where relocation is unlikely, and among financially unconstrained suppliers, for whom relocation incentives are weaker. Together, these results indicate that heterogeneous carbon policies can induce supply-chain reconfiguration in response to climate transition risk, consistent with a supply-chain channel of carbon leakage.

Ex ante, whether uncoordinated climate policies lead firms to rewire supply chains away from suppliers exposed to climate transition risk remains an open empirical question. On the one hand, customers may have incentives to shift sourcing away from suppliers operating in regulated jurisdictions in order to reduce supply chain uncertainty arising from policy-induced disruptions, such as higher costs or declines in output, employment, and capital (Greenstone, 2002; Ryan, 2012). These disruptions can place regulated suppliers at a competitive disadvantage relative to unregulated peers.[1] On the other hand, incentives to rewire supply chains may be attenuated by high switching costs, such as those arising from search frictions or input specificity (Barrot and Sauvagnat, 2016; Bernard, Moxnes, and Saito, 2019), which increase sourcing stickiness. In addition, reputational considerations associated with carbon-intensive supply chains (Ramadorai and Zeni, 2024) or pressure from environmentally conscious stakeholders and consumers (Krueger, Sautner, and Starks, 2020; Aghion, Bénabou, Martin, and Roulet, 2023) may instead encourage firms to source from greener suppliers, including those subject to climate regulation.[2]

To address this question, in this paper we study how climate policies reshape supply chains. Specifically, we examine whether regulated suppliers are more likely to lose pre-

[1]For example, in its Securities and Exchange Commission (SEC) Form 10-K filings, Air Products and Chemicals Inc. notes that "Any legislation that limits or taxes greenhouse gas (GHG) emissions could impact the Company's growth, increase its operating costs, or reduce demand for certain of its products" (available at https://www.sec.gov/Archives/edgar/data/2969/000119312512476878/d409668d10k.htm).

[2]On the other hand, regulators often mitigate the impact of climate policies on firm competitiveness by granting exemptions to highly energy-intensive and trade-exposed sectors (Fowlie, Reguant, and Ryan, 2016).

existing customer relationships as customers reallocate sourcing toward suppliers in jurisdictions without comparable policies. We also quantify the real effects of these relationship losses by tracing subsequent changes in firms' financial outcomes and in the carbon footprint of their supply chains.

Our empirical setting is California's cap-and-trade program, often described as one of the largest multi-sector carbon markets in the world, implemented in 2013. The program puts a price on emissions for facilities that emit more than 25,000 metric tons of carbon dioxide equivalent (CO2e) per year. California provides a useful laboratory for studying supply-chain responses to uncoordinated climate policy for two reasons. First, no other U.S. state prices industrial greenhouse-gas (GHG) emissions in the same way over our sample period, generating within-country variation in regulatory exposure. Second, the program phases down free allowance allocation over time (from roughly 85% initially), increasing regulated firms' effective exposure to carbon costs. This feature helps capture supply-chain adjustments as customers anticipate and respond to a supplier's rising transition risk, potentially disrupting regulated suppliers' economic activity in California.[3]

We implement a difference-in-differences (DiD) design to study whether customer–supplier relationships are more likely to end when the supplier becomes subject to California's cap-and-trade program. We identify regulated suppliers (hereafter *treated suppliers*) by linking facility-level emissions data from the U.S. Environmental Protection Agency (EPA) to supplier–customer relationships from FactSet Revere. A supplier is treated if it has at least one California facility that reported annual emissions exceeding 25,000 metric tons of CO2e in 2010; treatment is based on pre-policy emissions to ensure that regulatory exposure is predetermined. Our control group consists of suppliers with at least one facility in California but with no California facility exceeding 25,000 metric tons of CO2e in 2010 (hereafter *control*

[3]This framework is consistent with mechanisms in which customers preemptively shift their sourcing in expectation of rising supply chain disruption risk (Ersahin et al., 2024).

suppliers).[4] By comparing treated and control suppliers operating within the same state, we account for confounders unrelated to the program, such as state-level trends in input costs or prices.

Our baseline specification includes customer × supplier-sector fixed effects, which compare relationships with treated and control suppliers within the same supplier sector for a given customer and absorb time-invariant demand-side determinants of relationship formation and termination. We therefore identify the effect of regulation from changes in the probability that a given customer terminates a relationship with a treated supplier relative to an otherwise comparable control supplier in the same sector.

We next examine mechanisms underlying supply-chain reconfiguration in response to climate transition risk. Consistent with relatively low allowance prices and generous free allowance allocation, treated suppliers do not exhibit an immediate increase in operating costs after program implementation relative to control suppliers. We nevertheless find evidence of operational disruption among treated suppliers: relative to controls, they generate lower revenues and downsize total assets, with declines in accounts receivable, inventories, tangible assets, and investment. Treated suppliers also reduce employment significantly. In sum, these findings are consistent with production disruptions and reduced economic activity at treated suppliers, which can trigger customers to reallocate sourcing away from these suppliers.

We also examine whether relationship reconfiguration is concentrated among customers with low switching costs, i.e., those that can source inputs more readily from alternative suppliers. This mechanism implies stronger effects when suppliers operate in more competitive industries, where customers can reduce exposure to climate transition risk by switching to other suppliers. Consistent with this prediction, the baseline effects are larger for suppliers in more competitive industries (low Herfindahl-Hirschman Index (HHI), low Lerner Index, and more direct competitors) and for suppliers producing standardized goods and

[4]For multi-plant firms in California to be included in the control group, all California facilities must emit less than 25,000 metric tons of CO2e in 2010.

with shorter relationship durations. Supplier-level declines in revenues, assets, investment, and employment, are also stronger when switching costs are lower.

Even if regulation disrupts suppliers' operations, customers may maintain relationships with regulated suppliers to limit supply chain emissions, particularly if they expect broader environmental regulation in the future. Consistent with this view, we find that customers headquartered in more environmentally progressive jurisdictions (i.e., states that voted Democratic in recent presidential elections) and customers that were more attentive to climate transition risk before the program, proxied by the climate change attention index of Sautner et al. (2023), are less likely to terminate relationships with suppliers subject to cap-and-trade.

Finally, we study the environmental implications of uncoordinated climate policy. We first compare the supply chain configuration of customers that rewire away from suppliers regulated under cap-and-trade with that of other customers in the same sector that do not rewire. We find that rewirers shift toward smaller suppliers with higher emissions intensity. We then assess the extent of carbon leakage associated with this reconfiguration by comparing the carbon footprint of newly formed supply chains with a counterfactual benchmark based on customers that maintain relationships with cap-and-trade suppliers. Following the program's introduction, newly rewired supply chains exhibit a higher carbon footprint than supply chains that continue to source from these suppliers. Together, these results suggest unintended environmental consequences of uncoordinated climate policies, consistent with the carbon-leakage mechanism discussed by Cosbey, Droege, Fischer, and Munnings (2019).

Our findings contribute to several strands of the literature. First, we add to the empirical literature on carbon leakage, which shows that regional differences in climate regulation can incentivize firms to shift emissions to jurisdictions without comparable policies (Benincasa, Kabas, and Ongena, 2022; Laeven and Popov, 2023; Duchin, Gao, and Xu, 2025; Ivanov, Kruttli, and Watugala, 2024). Closest to our setting, Ben-David et al. (2021) and Bartram et al. (2022) document within-firm reallocation of production toward unregulated locations in

response to carbon pricing.[5] We build on this literature by studying carbon leakage that operates through supply chains rather than within firm boundaries. Specifically, we document a novel carbon leakage channel in which customers reallocate sourcing away from suppliers exposed to climate transition risk. This mechanism arises when customers circumvent suppliers located in regulated jurisdictions and therefore may not be fully addressed by policy instruments such as cross-border carbon taxes.

Second, we contribute to the literature on shocks to production networks (Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi, 2012; Jiang, Rigobon, and Rigobon, 2021; Baldwin and Freeman, 2022; Acemoglu and Tahbaz-Salehi, 2024) by examining how cap-and-trade programs affect supplier–customer networks. Related studies analyze the effects of import tariffs and carbon taxes using production-network and input–output frameworks (Devulder and Lisack, 2020; Demir, Javorcik, Michalski, and Ors, 2024). We complement this work by adopting a micro-level approach based on observed supplier–customer relationships, which allows us to trace how heterogeneous climate policies reshape production networks. Our findings also relate to research on the diffusion of corporate social responsibility (CSR) and environmental, social, and governance (ESG) practices along supply chains (Schiller, 2018; Dai, Duan, Liang, and Ng, 2021a; Dai, Liang, and Ng, 2021b; Asgharian, Dzieliński, Hashemzadeh, and Liu, 2023; Bisetti, She, and Zaldokas, 2023; Hege, Li, and Zhang, 2023; Lu, Peng, Shin, and Yu, 2023; Homroy and Rauf, 2024).

Third, our paper relates to studies on climate risk and supply chains. Barrot and Sauvagnat (2016) show that supplier disruptions caused by natural disasters propagate downstream, particularly when inputs are specific. Carvalho, Nirei, Saito, and Tahbaz-Salehi (2021) document substantial downstream effects following the 2011 Great East Japan Earthquake, and Pankratz and Schiller (2023) find that suppliers experiencing higher heat exposure

[5]Related work shows that as the EU ETS tightened, French firms increased imports of carbon-intensive products from outside the EU ETS (Coster, di Giovanni, and Mejean, 2024), while Belgian firms exposed indirectly through their supply chains diversified their supplier base without significant real effects (Martin, Muûls, and Stoerk, 2024).

face a greater likelihood of customer relationship termination. In contrast to this work, we focus on climate transition risk induced by state-level climate policy. This setting allows us to study supply-chain reconfiguration driven by regulatory risk and to assess its environmental consequences using new supply-chain-level measures of carbon footprint. Unlike physical climate risks or ESG shocks, the climate transition risks we study have a more persistent impact on firms' production networks.

Finally, we contribute to the literature on the real effects of environmental regulation (Greenstone, 2002; Ryan, 2012; Bushnell, Chong, and Mansur, 2013; Chan, Li, and Zhang, 2013; Dechezleprêtre and Sato, 2017; De Jonghe, Mulier, and Schepens, 2020; Bolton, Lam, and Muûls, 2023; Martinsson, Sajtos, Strömberg, and Thomann, 2024). We show that carbon pricing not only affects firms' operations but also induces reconfiguration of production networks as customers respond to uncertainty stemming from heterogeneous climate policies.

2 Institutional background

2.1 The California cap-and-trade program

Economists widely view carbon pricing as an effective tool for reducing global carbon emissions. Accordingly, many jurisdictions have implemented carbon taxes or cap-and-trade systems to facilitate the transition to a low-carbon economy.

In line with this approach, California enacted Assembly Bill 32 in 2006, setting a target to reduce greenhouse gas (GHG) emissions to 1990 levels by 2020. The California cap-and-trade program was introduced in January 2013 as part of this commitment. During its initial phase, from 2013 to 2014, the program covered electricity generation (including imports) and industrial facilities emitting more than 25,000 metric tons of carbon dioxide equivalent (CO2e) annually. In 2015, the program was expanded to include petroleum and natural gas distributors.

Under California's cap-and-trade program, regulated facilities are required to surrender

emission allowances corresponding to their verified emissions. A portion of these allowances is allocated for free, while the remainder is auctioned quarterly and traded in an allowance market. The specific allocation of free allowances at the plant level is not publicly disclosed. However, according to the California Air Resources Board, between 2013 and 2017, free allowance allocation was designed to cover, on average, approximately 85% of the emissions of a representative industrial facility under the program.[6]

Importantly, compliance obligations are based on emissions produced in prior years. As a result, the economic effects of the program are expected to materialize with a lag following its implementation or subsequent amendments. In 2013, the average supplier subject to the policy emitted approximately 2.6 million metric tons of CO2e at its California facilities. The auction price of allowances was $10 per ton in 2013 and averaged approximately $12.50 per ton between 2013 and 2017.

2.2 Carbon leakage

The adoption of carbon policies, such as California's cap-and-trade program, reflects jurisdiction-specific economic, political, social, and environmental considerations. As a result, substantial heterogeneity exists in the design and implementation of climate policies across regions and countries. This uneven regulatory landscape, characterized by incomplete geographical coverage, creates incentives to shift emissions from jurisdictions with stringent carbon pricing to those with weaker or no carbon pricing—a phenomenon known as "carbon leakage".

The literature identifies several channels through which carbon leakage can occur (Cosbey et al., 2019). One such channel operates through supply chains. Uncoordinated climate action exposes suppliers subject to climate regulation to elevated climate transition risk, potentially placing them at a competitive disadvantage relative to unregulated competitors (Fowlie, Reguant, and Ryan, 2016). In response, downstream customers may reduce exposure

[6]These calculations assume constant output and emission efficiency (see https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/allowance-allocation).

to supply chain uncertainty by reallocating sourcing away from regulated suppliers.

We build on this literature by focusing on the supply-chain channel of carbon leakage in the context of uncoordinated climate action within the United States. If carbon pricing imposes production constraints or operational and financial costs on suppliers, customers may rewire their supply chains away from regulated jurisdictions to mitigate supply chain uncertainty (Ersahin, Giannetti, and Huang, 2024; Custodio, Ferreira, and Garcia-Appendini, 2023). Such constraints can arise from higher compliance and legal costs, investment in emissions mitigation, downsizing of economic activity (e.g., pausing production to avoid regulatory thresholds, relocating production to less productive facilities outside California, or divesting emissions-intensive assets), or reduced access to bank credit (Ivanov et al., 2024).

Consistent with these concerns, firms frequently cite climate regulation as a source of operational and supply-chain risk. For example, in its SEC Form 10-K filings, Campbell Soup Company notes that "Increased compliance costs and expenses due to the impacts of climate change and additional legal or regulatory requirements regarding climate change that are designed to reduce or mitigate the effects of carbon dioxide and other greenhouse gas emissions on the environment may cause disruptions in, or an increase in the costs associated with, the running of our manufacturing facilities and our business, as well as increase distribution and supply chain costs."[7]

Beyond direct compliance costs, decarbonization efforts may generate stranded assets and heightened uncertainty regarding future policy adoption. Such uncertainty was salient at the time of program adoption, as illustrated by the lawsuit *California Chamber of Commerce v. State Air Resources Board*, which sought to invalidate the cap-and-trade program and its allowance auctions.[8]

Regulatory authorities overseeing California's cap-and-trade program explicitly recognize

[7]https://www.sec.gov/Archives/edgar/data/16732/000001673223000109/cpb-20230730.htm).

[8]The California Supreme Court denied the petitions in 2017; see https://climatecasechart.com/case/california-chamber-of-commerce-v-california-air-resources-board/).

carbon leakage as a risk associated with uncoordinated climate policy. To mitigate leakage concerns, the program grants exemptions to certain energy-intensive and trade-exposed entities. Fowlie et al. (2016) estimate substantial leakage risks in international trade flows arising from incomplete climate policies affecting energy prices in California, particularly in energy-intensive industries. A related literature studies border carbon adjustment mechanisms designed to address competitive imbalances across jurisdictions with heterogeneous climate policies (Fowlie, Petersen, and Reguant, 2021).[9]

Building on this conceptual framework, we empirically examine how the introduction of California's cap-and-trade program affects supplier–customer relationships and assess whether supply-chain reconfiguration contributes to carbon leakage through changes in the carbon footprint of firms' supply chains.

3 Methodology and data

This section outlines our empirical strategy, describes the sample, and defines the variables.

3.1 Empirical strategy

Our primary objective is to test whether suppliers subject to California's cap-and-trade program are more likely to experience the termination of customer relationships than otherwise similar suppliers located in California but not subject to the program.

To isolate the effect of the cap-and-trade program on customer-supplier relationships, we exploit both the timing of the program's implementation and cross-sectional variation in regulatory exposure across suppliers. We implement a difference-in-differences (DiD) design that compares changes in the likelihood of relationship termination between treated and control suppliers before and after the program's introduction in 2013. Specifically, we estimate

[9]Other channels include the market channel, whereby reduced demand for fossil fuels in regulated jurisdictions lowers global prices and raises consumption elsewhere (e.g., Harstad, 2012); the income channel, through which carbon taxes affect relative prices and wages across regions; and the technology spillover channel, whereby higher carbon prices stimulate investment and innovation in low-carbon technologies.

the following linear probability model at the supplier–customer-year level, using a sample of suppliers with at least one facility in California:

$$Ending_{i,j,t+1} = \beta\, Treated_i \times Post_t + \gamma_1' X_{i,t} + \sigma_t + \mu_i + \eta_{j,s(i)} + \epsilon_{i,j,t}, \tag{1}$$

where $Ending_{i,j,t+1}$ is a dummy variable that takes the value of one if the relationship between supplier i and customer j observed in year t is no longer present in year $t+1$, and zero otherwise. To avoid mechanically capturing relationship terminations driven by firm exits, we exclude supplier-customer pairs that end in the same year that either firm exits the Compustat sample due to mergers and acquisitions, delistings, or bankruptcies.

$Treated_i$ is a dummy variable that takes the value of one for suppliers with at least one facility in California reporting annual emissions above 25,000 metric tons of CO2e at the start of the EPA emission disclosure regime in 2010, and zero for suppliers whose California facilities all reported emissions below this threshold. $Post_t$ is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise.

$X_{i,t}$ includes supplier-level controls: firm size (logarithm of total assets), profitability (return on assets, ROA, defined as EBITDA-to-assets ratio), leverage (total debt-to-assets ratio), Tobin's Q, and R&D stock (the ratio of cumulative past R&D expenditures to assets). These controls account for potential correlations between treatment status and firm characteristics, as well as between firm characteristics and relationship stability. Our baseline specification includes year fixed effects σ_t, supplier fixed effects μ_i, and customer $\times$supplier sector fixed effects $\eta_{j,s(i)}$. Standard errors are clustered at the supplier level.

We mitigate concerns about reverse causality by defining treatment status using emissions data from 2010, three years prior to the program's implementation. If pre-policy supply chain configurations were optimal, firms would have limited incentives to adjust relationships before the policy's introduction. This approach is conservative: if some treated suppliers reduced emissions below the regulatory threshold between 2010 and 2012, or if some control

suppliers crossed the threshold during this period, the resulting misclassification would bias our estimates toward zero.

Our coefficient of interest is β. With customer $\times$ supplier-sector fixed effects, β captures the differential change in termination probability between treated and control suppliers operating in the same sector and serving the same customer. In some specifications, we further include customer $\times$ year fixed effects, in which case β compares, within a given year, the same customer's propensity to terminate relationships with treated versus control suppliers. This design absorbs time-varying customer-specific demand shocks and strengthens the supply-side interpretation of the estimates.[10]

Accordingly, a positive estimate of β indicates that suppliers subject to the cap-and-trade program are more likely to lose customer relationships relative to comparable unregulated suppliers, consistent with the program placing treated suppliers at a competitive disadvantage. Our identification strategy relies on the parallel trends assumption—that, absent the policy, relationship termination probabilities for treated and control suppliers would have evolved similarly. We examine the validity of this assumption in Section 4.

3.2 Data sources and sample

To assess the effects of the California cap-and-trade program on supply chains, we combine four data sources: supplier-customer relationships and firm competitors from FactSet Revere, facility-level carbon emissions from the U.S. Environmental Protection Agency (EPA), firm-level financial data from Compustat, and establishment locations from the National Establishment Time Series (NETS).

We obtain information on supplier–customer relationships and competitors from FactSet Revere, which covers business relationships of publicly listed companies worldwide since 2003.

[10]This within-customer comparison parallels approaches in the banking literature that compare lenders serving the same borrower to identify the effects of bank-level shocks (Khwaja and Mian, 2008). Ivashina et al. (2022) and Paravisini et al. (2023) note that this approach assumes demand is not specific to individual banks. In our setting, this implies that customers' purchasing decisions are not specific to individual suppliers, which is more plausible when suppliers operate within the same industry.

FactSet Revere compiles these links and competitor information from sources such as SEC 10-K filings, investor presentations, and press releases.

We collect facility-level emissions data from the EPA's Greenhouse Gas Reporting Program (GHGRP). Since October 2009, the GHGRP has reported Scope 1 emissions for U.S. facilities emitting 25,000 tons or more of CO2e annually. These data are publicly available through the Facility Level Information on Greenhouse Gases Tool (FLIGHT). We manually merge facility-level emissions records to firms in FactSet Revere using EPA parent company names and, when parent names do not match, facility names.

We obtain firm-level financial variables and industry classifications for both customers and suppliers from Compustat North America and Compustat Global. We link Compustat to FactSet Revere using FactSet identifiers and PERMCO identifiers obtained through the Center for Research in Security Prices (CRSP).

Finally, we use the National Establishment Time-Series (NETS) database to verify whether suppliers operate establishments in California that emit less than 25,000 tons of CO2e in 2010. NETS provides comprehensive information on the location of U.S. establishments, as well as parent firm names and locations. We first retain California establishments from NETS and fuzzy-match them to EPA facility names to identify plants emitting above the 25,000-ton CO2e threshold. California establishments in NETS that do not appear in the EPA data are assumed to emit less than 25,000 tons of CO2e. We then use the NETS mapping between establishments and parent firms and manually match parent firms to Compustat North America and Global Fundamentals. Finally, we link each parent firm to FactSet Revere to classify suppliers as treated or control.

Our initial sample consists of a panel of 150,168 supplier–customer pair-year observations from FactSet Revere spanning 2010 to 2017. The sample includes U.S.-headquartered suppliers with at least one establishment in California and with financial information available in Compustat, and excludes supplier–customer pairs that end in the same year in which either

firm exits the Compustat sample. The sample period begins with the start of EPA emissions reporting and covers three years prior to the program's implementation in 2013 and four years thereafter. The final sample includes 1,458 unique suppliers and 13,538 unique customers, of which 57 suppliers have at least one California facility subject to the cap-and-trade program (treated suppliers). The treated suppliers are all U.S. firms and collectively have 2,054 unique customers. The remaining 1,401 suppliers are not subject to the program. Using FactSet Revere, we also identify the direct competitors of treated suppliers.

Figure 1 illustrates the structure of our data using the example of a treated firm, U.S. Steel, which owns a facility near San Francisco with emissions sufficient to be regulated under the cap-and-trade program. U.S. Steel and its direct competitors, such as Steel Dynamics, NUCOR, and AK Steel, supply Worthington Industries. In our preferred analysis, we compare the evolution of supplier-customer pairs involving a treated supplier (e.g., U.S. Steel-Worthington Industries) with pairs involving a competitor selling to the same customer (e.g., NUCOR-Worthington Industries).

3.3 Summary statistics

Table 1 presents summary statistics for the baseline sample. Panel A shows that, on average, about one in five supplier-customer relationships terminate each year (i.e., the annual termination probability is 21%). Table IA1 in the Internet Appendix compares our baseline sample to the broader sample of FactSet U.S. suppliers without plants in California in 2010. While suppliers with at least one plant in California in 2010 are larger (logarithm of total assets) and more profitable (EBITDA-to-total assets), they are comparable along other characteristics (leverage, Tobin's Q, and R&D stock), as indicated by standardized differences in means.

The maximum relationship duration in our sample is 15 years, and the average duration is 3.5 years. These durations suggest that our sample window, three years before the cap-

and-trade program's implementation and four years after, is sufficient to capture dynamic effects and persistence while limiting exposure to longer-horizon confounding changes. Table A1 in the Appendix provides definitions of all other variables used in our study.

4 Results

This section presents the difference-in-differences (DiD) results on supply-chain restructuring following the introduction of California's cap-and-trade program. We then discuss the identifying assumptions and report robustness tests.

4.1 Business relationship termination

Table 2 reports estimates of equation (1) using our baseline sample. Column (1) includes year, supplier, and customer × supplier-sector fixed effects. The coefficient on the interaction term *Treated* × *Post* is positive and statistically significant at the 1% level, indicating that suppliers subject to the cap-and-trade program are more likely to lose customer relationships than comparable unregulated suppliers. The point estimate implies that the program increases the probability of relationship termination by 11.4 percentage points. This effect is economically significant, corresponding to a 29% increase relative to the standard deviation of the termination probability (40%; see Table 1) and a 54% increase relative to the unconditional mean termination rate in the sample (21%).

One concern with the specification in column (1) is that time-varying supplier characteristics correlated with both regulatory exposure and relationship termination could drive the results. Column (2) addresses this concern by including supplier-level controls. The coefficient on *Treated* × *Post* remains similar in magnitude and statistically significant, consistent with the comparability of treated and control suppliers.

A related concern is that the results may reflect demand-side shocks affecting customers subject to the cap-and-trade program rather than suppliers' regulatory exposure. To address

this issue, column (3) excludes customers with California facilities emitting more than 25,000 tons of CO2e (i.e., treated customers). This restriction helps rule out the possibility that the estimated effect is driven by customers' direct exposure rather than suppliers' regulatory status. The estimated effect remains close to that in column (1), suggesting that the baseline results are not driven by customers' direct exposure to the policy.

To further address concerns that demand-driven shocks may drive our results, we estimate an alternative specification that includes customer $\times$ year fixed effects, which compares treated and control suppliers selling to the same customer within a given year. This approach has two drawbacks. First, it restricts the sample to customers with at least two suppliers in a given year, reducing the sample size by approximately 30%. Second, focusing on customers with multiple suppliers may bias the estimates upward if these customers can more easily discontinue relationships with treated suppliers due to pre-existing ties with alternative suppliers. Nonetheless, when we apply the specification in column (2) to this restricted sample (column (4)), the coefficient on $Treated \times Post$ is 0.10, statistically significant at the 1% level, and close to the estimate in column (1).

Including customer $\times$ year fixed effects may also attenuate the estimated effect. For example, terminating relationships with treated suppliers may be unnecessary for customers that can flexibly increase the (unobserved) quantity of inputs sourced from comparable alternative untreated suppliers within a given year. Column (5) reports results from the specification with customer $\times$ year fixed effects. The coefficient remains positive and statistically significant at the 10% level but is smaller than in column (4), at 0.038, which corresponds to a 10% increase relative to the standard deviation of the termination probability in the sample and a 18% increase relative to the mean. This attenuation is consistent with the idea that some customers substitute toward alternative suppliers without severing existing relationships.

Overall, our results indicate that the introduction of California's cap-and-trade program increases the likelihood of relationship termination along supply chains. The magnitude is

in line with prior evidence on climate-related disruptions to supplier–customer relationships. For example, Pankratz and Schiller (2023) estimate that suppliers exposed to more than expected heat days are 28% more likely to lose pre-existing customer relationships in the same year, relative to an unconditional termination probability of 27% in their sample. This similarity to prior estimates supports the external validity of our findings. The magnitude is also consistent with documented real responses to California's cap-and-trade program. Bartram et al. (2022) report a 42% increase in output shifting from plants in California to plants located in other states within the same firm. Ivanov et al. (2024) find that, following the program's implementation, banks shortened loan maturities by 12 months (40% of the mean), reduced loan commitments by 25–33% across specifications, and increased interest rates by 1.7 percentage points for private firms with substantial emissions in California.

4.2 Identifying assumption

In this section, we assess the identifying assumption underlying our empirical approach. Our design relies on the parallel trends assumption: absent the policy, regulated and unregulated firms would have exhibited similar outcome trajectories. Figure 2 reports dynamic DiD estimates around the introduction of the cap-and-trade program. The pre-policy coefficients are not statistically different from zero, indicating no differential trends in relationship termination between treated and control suppliers prior to implementation. After 2013, treated suppliers exhibit a higher probability of terminating pre-existing customer relationships: the estimated effect becomes statistically significant and remains stable at around 10 percentage points. These patterns support the parallel trends assumption and suggest that the effect emerges only after the policy is enacted, alleviating concerns about anticipatory adjustments.

4.3 Robustness and extensions

Our results thus far indicate that California's cap-and-trade program increases the likelihood that treated suppliers lose customer relationships relative to control suppliers. We next assess

robustness to alternative outcomes, samples, and specifications. These results are reported in the Internet Appendix.

Generalized difference-in-differences. If the cap-and-trade program drives the observed effects, we would expect the likelihood of terminating relationships with treated firms to be greater for suppliers with higher emission levels in California. Because treatment intensity is determined by emissions in California, and compliance costs increase with emissions, we test robustness by replacing the dummy variable $Treated_i$ in equation (1) with a continuous measure, $Treatment\ Intensity_i$. This measure equals a firm's total emissions in California above 25,000 tons of CO2e in 2010, scaled by total assets, and standardized by its standard deviation; control suppliers are assigned a value of zero. Table IA2 in the Internet Appendix reports positive and statistically significant coefficients for $Treatment\ Intensity \times Post$ across all specifications, indicating that the probability of relationship termination rises with emissions intensity.

Alternative standard error clustering. In our baseline specification, we cluster standard errors at the supplier level to account for the correlation of standard errors for a given supplier over time. This approach is motivated by the fact that treatment is assigned at the supplier level at the beginning of the sample period. However, we also perform robustness checks using standard errors clustered at the pair level, consistent with similar empirical strategies in the literature (e.g., Pankratz and Schiller, 2023). Column (1) of Table IA3 in the Internet Appendix indicates that our results remain robust to this alternative clustering approach, using the specification in column (1) of Table 2.

Alternative treatment dummy variable. In Table IA3, column (2), we present baseline results using an alternative method for allocating suppliers into treatment and control

groups. In this alternative approach, treated suppliers are defined as those with facilities in California emitting more than 25,000 tons of CO2e in 2012 (one year before the program's introduction) rather than in 2010, as in our baseline case. Although defining treatment based on emissions in the year immediately preceding the policy raises concerns about anticipatory effects, the baseline results remain robust under this alternative specification.

Within group of competitors. Table IA3, column (3), presents the baseline specification estimates on an alternative sample that matches each treated supplier with control suppliers drawn from its group of direct competitors (drawn from Facset Revere). This sample is larger for two reasons: first, it includes suppliers headquartered outside the United States; and second, it allows each competitor of a treated supplier to also be a competitor of other treated suppliers, which results in some competitors appearing multiple times in the sample. The effect of interest remains statistically significant in this alternative sample. This result confirms that our findings are robust to restricting the comparison to direct competitors.

Suppliers geographically concentrated in California. Table IA3, column (4), reports estimates of the baseline specification after excluding geographically diversified treated suppliers. We identify geographically diversified firms using the firm-level measure of geographic diversification in Bartram et al. (2022).[11] Suppliers geographically concentrated in California have limited scope to reduce exposure to the cap-and-trade program by shifting production out of state. Consistent with this interpretation, the estimated effect remains large: geographically concentrated treated suppliers experience a 10.6 percentage point greater increase in relationship termination relative to control suppliers. These results suggest that our findings are not driven solely by within-firm reallocation of production to facilities outside California.

[11] A firm is geographically diversified if, beyond producing emissions in its California plants, it also produces emissions elsewhere in the U.S., in its non-California plants.

Financially unconstrained suppliers. Table IA3, column (5), reports estimates of the baseline specification restricting the sample to relationships involving treated suppliers that are not financially constrained. We identify financially unconstrained firms by replicating the approach in Bartram et al. (2022): a firm is classified as financially constrained if it meets at least four of six constraint measures computed prior to the sample period (2003-2008), namely firm size, dividend payout, short- and long-term debt ratings, the Kaplan and Zingales, 1997 index, the Whited and Wu, 2006 index, and the Hadlock and Pierce, 2010 index. This restriction focuses on treated suppliers that are less likely to relocate economic activity outside California, consistent with prior evidence that within-firm carbon leakage is concentrated among financially constrained firms. If within-firm reallocation were the sole driver of our results, we would expect no effect in this subsample. Instead, the estimates remain economically and statistically significant, indicating that the baseline findings are robust among financially unconstrained treated suppliers.

Placebo test. Table IA3, column (6), reports a placebo test using an alternative treatment group. Suppliers are classified as placebo-treated if they are headquartered in California but have no California facilities emitting more than 25,000 tons of CO2e in 2010. This group includes, for example, technology firms headquartered in California such as HP Inc. and DSP Group. The estimates show no significant increase in relationship termination for placebo-treated suppliers after the introduction of the cap-and-trade program.[12]

Supply chain turnover. Throughout our analysis, we use a large and representative sample of supplier–customer relationships and focus on the extensive margin, namely relationship termination. As a robustness check, we replicate the analysis on a smaller sample of eco-

[12] Although these suppliers may be affected by cap-and-trade–induced changes in electricity prices at their headquarters, they do not directly face the climate transition risks associated with regulating large emitting facilities. As a result, their customers have weaker incentives to reconfigure supply chains away from these placebo-treated suppliers.

nomically significant relationships identified from SFAS 14 and 131 disclosures, which require publicly listed U.S. firms to report customers accounting for at least 10% of total sales. [13] Column (7) of Table IA3 examines the intensive margin by using the logarithm of supplier sales to each disclosed customer in a given year as the dependent variable. The estimates show that sales from treated suppliers decline more than sales from control suppliers after the introduction of the cap-and-trade program. These results indicate that the program affects not only relationship termination but also the intensity of ongoing supplier-customer relationships.

Conditional logit. Table IA3, column (8), reports the baseline specification estimated using a conditional logit model. This addresses concerns that the linear probability model may produce predicted probabilities outside the [0,1] interval. The specification includes year and customer $\times$ supplier-sector fixed effects but omits supplier fixed effects for computational tractability. The results are qualitatively similar to the baseline, with the coefficient of interest remaining positive and statistically significant.

Full U.S. sample. Table IA3, column (9), reports estimates of the baseline specification on an expanded sample of supplier-customer pairs that also includes U.S. suppliers without facilities in California in 2010. This specification mitigates concerns that our control group-suppliers with California facilities whose 2010 emissions were below 25,000 tons of CO2e—may not be representative of the typical U.S. supplier within the same sector. The results remain consistent with the baseline in both magnitude and statistical significance.

Business relationship initiation. We interpret our baseline results as evidence of supply-chain rewiring away from suppliers exposed to California's cap-and-trade program. However,

[13] This information is drawn from the Compustat Segment database and covers the period 2010-2017.

if treated suppliers simultaneously attract new customers, the results could reflect a reshuffling of their customer base rather than a broader reconfiguration of supply chains away from the cap-and-trade region. To assess this alternative explanation, we examine the likelihood that customers initiate new relationships with treated suppliers relative to other potential suppliers in the same sector in a given year. We implement a DiD design on an augmented sample that, for each baseline customer-year, includes all suppliers operating in the sector of any supplier with whom the customer maintains an active relationship in that year.

We estimate the following linear probability model:

$$Beginning_{i,j,t} = \beta\, Treated_i \times Post_t + \gamma_1' X_{i,t} + \sigma_t + \mu_i + \eta_{j,s(i)} + \epsilon_{i,j,t}, \tag{2}$$

where $Beginning_{i,j,t}$ is a dummy variable that takes the value of one if a relationship between supplier i and customer j is observed for the first time in year t , and zero otherwise (i.e., if a relationship between supplier i, in the same sector $s(i)$ as other existing suppliers of customer j is not observed in year t).

Table IA4 in the Internet Appendix shows that treated suppliers are not more likely to form new customer relationships after the program's introduction. If anything, treated suppliers are less likely to initiate new relationships following the policy. Taken together, these results reinforce our interpretation that supply chains are being rewired away from suppliers exposed to the risks associated with California's cap-and-trade program.

5 Mechanisms

We have shown that California's cap-and-trade program leads to supply-chain restructuring away from regulated suppliers. In this section, we provide evidence on the mechanisms through which climate transition risk drives this reorganization.

5.1 Economic performance

In this subsection, we extend the analysis by examining the economic performance of affected suppliers. We collapse our customer-supplier pair-year panel into a supplier-year panel and estimate the following regression equation:

$$Y_{i,t} = \beta \ \mathit{Treated}_i \times \mathit{Post}_t + \mu_i + \mu_{s(i),t} + \epsilon_{i,t}, \tag{3}$$

where $Y_{i,t}$ is the supplier's economic performance: revenues, total assets, account receivables, inventory, tangible assets (as proxied by PPE), investment (as proxied by CAPEX), and employment (proxied by number of employees). The regressions include supplier fixed effects (μ_i) and supplier industry $\times$ year ($\mu_{s(i),t}$) fixed effects.

Table 5 reports the effects of the cap-and-trade program on suppliers' real outcomes. Column (1) shows that, after the program's introduction, treated suppliers experience a statistically significant decline in revenues of 10.8% relative to comparable control suppliers. This drop in revenues is consistent with a meaningful contraction in treated suppliers' output or sales activity following the onset of regulatory exposure. Column (2) shows that treated suppliers also downsize, with total assets falling by 11.9%, indicating that the revenue contraction is accompanied by balance-sheet adjustments rather than reflecting a purely transitory shock.

Columns (3)-(6) shed light on the components of this downsizing. The decline in assets is driven by reductions in working-capital items and productive capacity: treated suppliers reduce accounts receivable and inventories, and they also cut tangible assets and investment (CAPEX). The magnitudes are particularly large for inventories and tangible assets (PPE), which fall by 18.4% and 17.4%, respectively. The pronounced decline in tangible assets is consistent with firms divesting pollution-intensive assets when facing environmental

pressures (Duchin et al., 2025).[14] Column (7) further shows that treated suppliers reduce employment by roughly 10%, reinforcing the interpretation that the program is associated with real adjustments in production inputs.

Taken together, the evidence indicates that carbon pricing exposure is followed by persistent reductions in sales, assets, investment, and employment at regulated suppliers, consistent with an erosion in their competitive position and their ability to reliably serve customers. This mechanism provides a natural link to the relationship-termination results: customers may reallocate sourcing away from treated suppliers in response to heightened supply risk and impaired operational performance.

To further corroborate the validity of our identifying assumption, we analyze the annual economic performance of suppliers in our sample from 2010 to 2017. Our identification strategy assumes that customers of treated suppliers did not reconfigure their supply chains in anticipation of the cap-and-trade program. Figure 3 shows that treated suppliers' revenues, total assets, account receivables, inventories, tangible assets, investment, and employment decline significantly only after 2013, indicating that customers did not reduce their economic activity with treated suppliers prior to the policy's implementation. This pattern reinforces our conclusion that the observed effects are not driven by anticipatory adjustments.

Importantly, these real adjustments do not appear to be driven by an immediate increase in operating costs. Consistent with the relatively low allowance prices and generous free allocation in the early years of the program, Figure 3 shows no significant differential change in cost of goods sold scaled by revenues (COGS/Revenues) for treated suppliers versus control suppliers around the policy's implementation. Together, these results suggest that the declines in revenues, assets, investment, and employment are unlikely to reflect direct cost pass-through from carbon pricing. Instead, they point to operational disruptions and

[14]Figure IA1 in the Internet Appendix shows no differential change in the investment rate (CAPEX/PPE) around implementation. Yet both PPE and CAPEX decline for treated suppliers, indicating a proportional scaling down of investment and capital. This pattern is consistent with balance-sheet contraction through asset divestitures, potentially of emissions-intensive capital, rather than a reduction in investment intensity.

heightened uncertainty associated with regulatory exposure, such as adjustments in production processes, asset reallocation, and expectations of future tightening, as key mechanisms affecting treated suppliers. These disruptions, rather than higher contemporaneous costs, provide a plausible explanation for why customers reallocate sourcing away from regulated suppliers in anticipation of increased supply risk.

Next, we examine whether the climate transition risk shock propagates downstream to customers indirectly exposed through their suppliers. If customers can reallocate sourcing away from regulated suppliers, they should be largely insulated from shock propagation. Moreover, because relationship terminations occur primarily when switching costs are low, we do not expect customers to incur sizable financial losses when switching suppliers after the program's introduction.

We collapse the customer-supplier pair-year panel into a customer-year panel, excluding customers directly affected by the cap-and-trade, and estimate the following regression equation:

$$Y_{j,t} = \beta \textit{Ex-Post Indirectly Treated}_j \times \textit{Post}_t + \eta_j + \eta_{s(j),t} + \epsilon_{j,t}, \tag{4}$$

where $Y_{j,t}$ is the customer's economic performance: revenues, total assets, account receivables, inventory, tangible assets, investment, and employment. $\textit{Ex-Post Indirectly Treated}_j$ is a dummy variable that takes the value of one if customer j has at least one treated supplier after the introduction of the program and zero otherwise. The regressions include customer fixed effects η_j and industry $\times$ year fixed effects $\eta_{s(j),t}$.

Tables IA6 present the results in terms of economic performance, respectively. Overall, these results do not point to a significant propagation of the effects of the cap-and-trade program to indirectly treated customers, in line with the selective rewiring effectively shielding customers from suppliers that might expose them to significant risks.

5.2 Competition and switching costs

When climate policies increase suppliers' exposure to climate transition risk, customers have an incentive to reduce supply-chain uncertainty by reallocating sourcing toward less-exposed suppliers. Whether customers do so depends on product-market competition and switching costs. Rewiring should therefore be more pronounced when affected suppliers operate in highly competitive industries and when input specificity is low, because customers can more easily identify and substitute toward alternative suppliers that are not subject to comparable climate policies. Conversely, when inputs are relationship-specific or supplier markets are concentrated, higher switching costs should make sourcing stickier and dampen relationship termination, even if regulation disrupts suppliers' operations.

To test this mechanism, we first examine heterogeneity in supply-chain reconfiguration across levels of product-market competition by re-estimating our baseline regression on competition-based subsamples. Panel A of Table 3 reports the results. Columns (1) and (2) split suppliers by whether their pre-treatment Herfindahl–Hirschman Index (HHI), computed at the three-digit SIC level, is above or below the median. Columns (3) and (4) split suppliers by the pre-treatment Lerner Index, computed as average net income over sales at the three-digit SIC level and capped between zero and one. Columns (5) and (6) split suppliers by whether the number of pre-treatment direct competitors in their matched competitor group is below or above the median. Across all competition measures, the coefficient on *Treated* $\times$ *Post* is economically and statistically significant for suppliers operating in more competitive industries, with larger effects in industries characterized by lower HHI, lower Lerner indices, and a greater number of competitors.

We next turn to input specificity, which provides an additional dimension of switching costs. When suppliers produce standardized inputs, where substitution is easier, customers should be more willing to terminate relationships in response to heightened climate transition risk. This effect should be especially pronounced in weaker ties, where customers are less

locked into existing relationships.

To assess the role of switching costs, we re-estimate equation (1) across subsamples defined by three supplier- and relationship-level characteristics: (1) standardized versus differentiated goods, based on the two-digit SIC classification of Giannetti, Burkart, and Ellingsen (2011); (2) above- versus below-median R&D stock-to-assets; and (3) relationship duration above versus below the sample median.

In line with this mechanism, Panel B of Table 3 shows that relationship terminations are concentrated among treated suppliers producing standardized goods (column (2)), treated suppliers with below-median RD stock (column (4))[15], and relationships with below-median duration (column (6)). These results suggest that customers are more likely to reconfigure sourcing when alternative suppliers are readily available and existing ties are less specific.

These results are complemented by Table IA5 in the Internet Appendix, which shows that the negative economic effects at treated suppliers are concentrated among producers of standardized rather than differentiated inputs, where customers can more readily substitute away from exposed suppliers.

Taken together, these findings highlight the central role of switching costs in shaping supply-chain responses to climate transition risk. Relationship terminations are concentrated in competitive industries and among suppliers producing standardized inputs and engaged in shorter-duration relationships. Overall, the evidence supports the view that low switching costs amplify cap-and-trade–induced supply-chain reconfiguration as customers adjust sourcing to reduce exposure to climate transition risk.

5.3 Climate transition risks awareness

We have shown that product-market competition and switching costs shape the restructuring of supply chains away from suppliers affected by the cap-and-trade program. We next examine whether customers' awareness of climate transition risks moderates this response.

[15] Approximately 50% of customers in our sample have at least one supplier producing a standardized good.

Customers that are more environmentally conscious or that anticipate future regulation of supply-chain emissions may have incentives to maintain relationships with affected suppliers in order to benefit from potential reductions in scope 3 emissions.

To test this hypothesis, we split customers based on the pre-treatment industry-level median of climate change attention, measured using the climate attention index of Sautner et al. (2023).[16] Table 4 reports estimates of equation (1) for customers in industries above and below this median. Columns (1) and (2) show that supply-chain restructuring is concentrated among customers in lower-attention industries, whereas customers in higher-attention industries are significantly less likely to terminate relationships with treated suppliers.

We further explore this mechanism using alternative proxies for customers' sensitivity to climate transition risk. In columns (3) and (4), we split customers by the political affiliation of their headquarters' state, classified as Democratic or Republican based on the 2016 presidential election. In columns (5) and (6), we split customers by whether their headquarters' state was a member of the U.S. Climate Alliance as of 2017. The results show that supply-chain rewiring is concentrated among customers headquartered in Republican states and in states that are not members of the U.S. Climate Alliance, both of which are typically associated with lower sensitivity to environmental issues.

Taken together, these findings indicate that customers with greater awareness of climate transition risks are less inclined to sever relationships with suppliers subject to the cap-and-trade program, consistent with an incentive to maintain cleaner supply chains in anticipation of future environmental regulation.

6 Environmental performance

This section examines the environmental implications of supply-chain rewiring following the introduction of California's cap-and-trade program, focusing on emissions along customers'

[16] This measure captures the frequency of climate change-related language in analyst–management earnings call discussions and is constructed at the firm–year level. Data are available at: `https://osf.io/fd6jq`.

supply chains.

We construct supply-chain-level emissions measures using facility-level data from the U.S. Environmental Protection Agency (EPA). For each supplier-year, we aggregate emissions across all U.S. facilities in the EPA database; the matched EPA–FactSet sample covers 501 suppliers from 2010 to 2017. We also compute supplier emissions intensity as total emissions scaled by total assets. Using direct supplier–customer links from FactSet Revere, we then construct customer-level measures for each year: the log of total supply-chain emissions (sum across suppliers), average supplier emissions, and average supplier emissions intensity (emissions over total assets).

These measures differ from commonly used inferred scope 3 emissions and avoid their well-documented measurement issues (Aswani, Raghunandan, and Rajgopal, 2024). Rather than relying on imputed upstream emissions, our approach captures the realized emissions footprint of customers' direct suppliers, allowing us to test whether customers that rewire away from treated suppliers select replacement suppliers with systematically different environmental performance.[17]

We next compare the environmental performance of customers' supply chains when they rewire away from suppliers subject to cap-and-trade to that of customers not indirectly exposed to the program through their suppliers. This analysis assesses whether indirectly exposed customers form new supplier relationships and how the environmental performance of their supply chains changes after the program's introduction.

We collapse the supplier-customer pair-year panel to a customer-year panel and estimate the following specification:

$$Y_{j,t} = \beta \textit{Ex-Ante Indirectly Treated}_j \times \textit{Post}_t + \eta_j + \eta_{s(j),t} + \epsilon_{j,t}, \tag{5}$$

where $Y_{j,t}$ captures characteristics of a customer's direct suppliers in year t: the number of

[17] In contrast, inferred upstream scope 3 emissions reported by data providers typically aggregate emissions across the entire supply chain and scale them by purchases from each supplier.

new relationships formed with control suppliers in the same two-digit SIC sector as previously treated suppliers, the average size of suppliers (log total assets), and three measures (self-constructed) of supply-chain environmental performance: the log of total emissions, the log of average emissions, and average emissions intensity. *Ex-Ante Indirectly Treated*$_j$ is a dummy that takes the value of one if customer j sources its inputs from at least one treated supplier prior to the program's introduction, and zero otherwise. The specification includes customer fixed effects η_j and sector $\times$ year fixed effects $\eta_{s(j),t}$.

Table 6 shows that indirectly treated customers actively rewire their supply chains following the policy. Column (1) indicates that these customers form new relationships with control suppliers in the same sector as their previously treated suppliers. Column (2) shows that the new suppliers are smaller, which mechanically leads to lower total and average emissions (columns (3) and (4)). However, column (5) shows that these suppliers exhibit higher emissions intensity. Taken together, these results suggest that customers substitute toward smaller but dirtier suppliers on an emissions-per-asset basis.

While informative, this comparison does not fully establish supply-chain carbon leakage, as it contrasts rewired customers with customers not indirectly exposed to the policy. To more directly assess whether rewiring worsens environmental outcomes relative to a counterfactual in which customers remain linked to treated suppliers, we estimate:

$$Y_{j,t} = \beta_1 \textit{Rewired}_{j,t} \times \textit{Post}_t + \beta_2 \textit{Rewired}_{j,t} + \eta_j + \eta_{s(j),t} + \epsilon_{j,t}, \tag{6}$$

where $Y_{j,t}$ is one of the three alternative measures of supply chain environmental performance. *Rewired*$_{j,t}$ is a dummy that takes the value of one if a customer j sources its inputs from a supply chain that is rewired away from the cap-and-trade in a given year (i.e., a customer sources from fewer treated suppliers than in the previous year), and zero otherwise. In an alternative specification, we replace this dummy with *Rewired Suppliers since 2010*, which captures the cumulative number of treated suppliers from which the customer has disengaged

since 2010. The specification again includes customer fixed effects and sector × year fixed effects.

The results show that rewired supply chains exhibit a higher carbon footprint than counterfactual supply chains that remain linked to treated suppliers. Columns (1), (3), and (5) indicate higher emissions across all three measures, and columns (2), (4), and (6) show that the deterioration in environmental performance increases with the extent of rewiring away from treated suppliers. These findings suggest that uncoordinated climate policy can induce supply-chain reconfiguration toward more emissions-intensive suppliers, consistent with a supply-chain channel of carbon leakage.

7 Conclusion

Many jurisdictions have adopted climate policies to curb firms' carbon emissions, yet these initiatives often remain uncoordinated across regions and countries. This paper shows that supply-chain rewiring is an important channel through which uncoordinated climate policy can generate carbon leakage.

Using a difference-in-differences design, we find that suppliers subject to California's cap-and-trade program are significantly more likely to lose pre-existing customer relationships than comparable unregulated suppliers, consistent with customers reallocating sourcing away from regulated firms. The effects are strongest among suppliers operating in more competitive industries, producing standardized inputs, investing less in R&D, and maintaining shorter-duration customer ties, where switching costs are lower. These suppliers also experience larger subsequent declines in revenues, assets, and employment, consistent with significant economic adjustments following the policy's introduction. Moreover, relationship terminations are more concentrated among customers headquartered in states with weaker environmental commitments, suggesting that downstream preferences and regulatory orientation shape the incidence of supply-chain adjustment. Taken together, these findings indicate

that uncoordinated climate policies can distort competitive conditions within production networks and shift economic activity toward less regulated regions.

We further show that supply-chain rewiring has adverse environmental consequences. Customers that rewire away from cap-and-trade–regulated suppliers shift toward smaller but more emissions-intensive suppliers, and newly rewired supply chains exhibit a higher carbon footprint than counterfactual supply chains that remain linked to regulated suppliers. These results underscore that carbon leakage can operate through supply-chain reallocation and can erode the intended environmental benefits of carbon pricing. More broadly, our findings highlight the importance of policy coordination and complementary instruments that address leakage along supply chains. While implementing a carbon border adjustment mechanism in the U.S. may pose practical and political challenges, our evidence points to its relevance in the broader debate on effective and coordinated climate action.

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Table 1: Summary Statistics

	Mean	Std. Dev.	Median	Minimum	Maximum	Obs.
Panel A: Pair-Year Data						
Ending	0.21	0.40	0.00	0.00	1.00	150,168
Treated	0.06	0.25	0.00	0.00	1.00	150,168
Supplier total assets (billion $)	39.01	92.38	4.24	0.01	531.86	149,864
Supplier ROA	0.10	0.12	0.12	-0.80	0.34	144,787
Supplier leverage	0.25	0.19	0.23	0.00	0.99	149,012
Supplier Tobin's Q	1.99	1.20	1.63	0.61	8.81	135,619
Supplier R&D stock	0.39	0.70	0.14	0.00	5.50	150,168
Relationship duration (years)	3.47	2.80	2.00	1.00	15.00	150,168
Panel B: Supplier-Year Data						
Treated	0.04	0.20	0.00	0.00	1.00	10,103
Revenues (billion $)	8.17	19.64	1.64	0.00	126.72	10,079
Total assets (billion $)	16.27	51.49	2.04	0.01	392.65	10,084
Receivables (billion $)	1.37	4.39	0.20	0.00	34.99	9,674
Inventory (billion $)	0.29	0.78	0.02	0.00	5.21	7,401
PPE (billion $)	2.48	6.71	0.26	0.00	45.19	9,805
CAPEX (billion $)	0.41	1.21	0.05	0.00	9.04	9,660
Employment	20.15	43.42	4.80	0.01	271.00	9,996
COGS/Revenues	0.75	0.90	0.65	0.06	7.98	8,199
Panel C: Customer-Year Data						
Ex-post indirectly treated	0.27	0.44	0.00	0.00	1.00	15,300
Revenues (billion $)	7.17	17.34	1.30	0.00	117.11	15,223
Total assets (billion $)	19.94	77.09	1.85	0.01	650.77	15,243
Receivables (billion $)	1.96	7.73	0.15	0.00	64.56	14,485
Inventory (billion $)	0.31	0.82	0.01	0.00	5.20	10,523
PPE (billion $)	2.82	8.32	0.25	0.00	62.00	14,966
CAPEX (billion $)	0.52	1.51	0.05	0.00	10.66	14,732
Employment	18.71	41.36	3.48	0.00	272.20	14,929
Ex-ante indirectly treated	0.23	0.42	0.00	0.00	1.00	33,344
# New suppliers	0.24	0.76	0.00	0.00	23.00	33,344
Average supplier size	64.28	144.42	8.17	0.03	717.24	18,775
Average supplier emissions (thousand tons CO2e)	7,304.33	14,014.39	915.05	2.28	70,806.12	8,677
Sum of suppliers' emissions (thousand tons CO2e)	4,758.54	14,108.55	0.00	0.00	82,342.83	18,790
Average supplier emission intensity	170.66	394.58	29.34	0.09	2,421.18	8,677
Rewired	0.14	0.35	0.00	0.00	1.00	2,509
# Rewired suppliers since 2010	-0.51	1.01	0.00	-7.00	3.00	2,509

This table presents the mean, standard deviation, median, minimum, maximum and number of observations for the main variables of interest. Panel A contains statistics for the entire sample of customer-supplier-year observations. This sample is obtained from merging FactSet Revere data on customer-supplier pairs, EPA data on facility-level emissions, and Compustat data on financial information about suppliers. Panels B and C contain statistics for supplier-year and customer-year observations in our base sample, respectively. The sample period is from 2010 to 2017. All continuous variables are winsorized at the 1 and 99% level. Refer to Table A1 in the Appendix for variable definitions.

Table 2: Probability of Termination and Cap-and-Trade Program: Baseline

	(1)	(2)	(3)	(4)	(5)
Treated × Post	0.114***	0.108***	0.112***	0.100***	0.038*
	(0.029)	(0.031)	(0.031)	(0.025)	(0.019)
Supplier total assets (log)		-0.015	-0.016	-0.019	-0.013
		(0.023)	(0.024)	(0.023)	(0.020)
Supplier ROA		-0.061	-0.066	-0.036	-0.030
		(0.070)	(0.072)	(0.060)	(0.059)
Supplier leverage		-0.023	-0.021	-0.013	-0.027
		(0.060)	(0.061)	(0.060)	(0.055)
Supplier Tobin Q		-0.001	-0.001	-0.003	-0.001
		(0.007)	(0.007)	(0.007)	(0.007)
Supplier R&D stock		-0.041*	-0.042*	-0.046***	-0.036**
		(0.024)	(0.025)	(0.016)	(0.015)
Excl. Treated Customer	No	No	Yes	No	No
Year FE	Yes	Yes	Yes	Yes	No
Supplier FE	Yes	Yes	Yes	Yes	Yes
Customer × Supplier Sector FE	Yes	Yes	Yes	Yes	Yes
Customer × Year FE	No	No	No	No	Yes
Obs.	150,168	130,347	125,412	101,713	101,713
R^2	0.248	0.257	0.259	0.246	0.488

This table presents difference-in-differences estimates of customer-supplier-level panel regressions using equation (1). The dependent variable *Ending* is a dummy variable that takes the value of one if the supplier-customer relationship ends in a given year, and zero if the relationship persists in both the current and previous year. *Treated* is a dummy variable that takes the value of one for suppliers that have at least one facility in California reporting emissions above 25,000 tons of CO2 equivalents in 2010; zero for suppliers that have at least one facility in California reporting emissions below 25,000 tons of CO2 equivalents in 2010. For suppliers with multiple facilities in California to be included in the control group, all of their plants must have emissions below the 25,000 tons of CO2 threshold in 2010. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. In column (3), customers that produce emissions above 25,000 tons of CO2e in California in 2010 are excluded. In column (4), the sample consists of supplier-customer pairs where the latter has business relationships with at least two suppliers every year. The sample consists of supplier-customer pair-year observations from FactSet Revere, with corresponding US supplier financial data sourced from Compustat, in the 2010-2017 period. Suppliers with no plants in California in 2010, as well as supplier-customer pairs that terminate their relationship when either firm exits the Compustat sample, are excluded from the sample. Robust standard errors adjusted for supplier-level clustering are reported in parentheses. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Table 3: Probability of Termination and Cap-and-Trade Program: Switching Costs

Panel A: Market Competition						
	(1)	(2)	(3)	(4)	(5)	(6)
	HHI		Lerner Index		Number of Competitors	
	High	Low	High	Low	Low	High
Treated × Post	0.082**	0.183***	0.097***	0.109**	-0.030	0.036**
	(0.034)	(0.060)	(0.036)	(0.043)	(0.034)	(0.018)
Year FE	Yes	Yes	Yes	Yes	No	No
Supplier FE	Yes	Yes	Yes	Yes	No	No
Customer × Supplier Sector FE	Yes	Yes	Yes	Yes	No	No
Year × Competitor group FE	No	No	No	No	Yes	Yes
Supplier × Competitor group FE	No	No	No	No	Yes	Yes
Customer × Competitor group FE	No	No	No	No	Yes	Yes
Obs.	71,918	77,584	67,964	81,634	101,539	119,872
R^2	0.267	0.243	0.260	0.249	0.511	0.259
Difference	-0.102**		-0.012***		-0.065**	
Panel B: Input Specificity						
	(1)	(2)	(3)	(4)	(5)	(6)
	Type of Good Sold		R&D Stock		Relationship Duration	
	Differentiated	Standardized	High	Low	High	Low
Treated × Post	0.083	0.129***	0.079	0.082***	0.047	0.061*
	(0.075)	(0.036)	(0.089)	(0.031)	(0.029)	(0.034)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Customer × Supplier sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Supplier FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	60,405	65,843	66,820	75,432	28,159	58,207
R^2	0.234	0.252	0.229	0.279	0.326	0.277
Difference	-0.046***		-0.004***		-0.014*	

This table presents difference-in-differences estimates of customer-supplier-level panel regressions using equation (1). The dependent variable *Ending* is a dummy variable that takes the value of one if the supplier-customer relationship ends in a given year, and zero if the relationship persists in both the current and previous year. *Treated* is a dummy variable that takes the value of one for suppliers that have at least one facility in California reporting emissions above 25,000 tons of CO2 equivalents in 2010; zero for suppliers that have at least one facility in California reporting emissions below 25,000 tons of CO2 equivalents in 2010. For suppliers with multiple facilities in California to be included in the control group, all of their plants must have emissions below the 25,000 tons of CO2 threshold in 2010. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. In columns (1) and (2), panel A, suppliers are in a sector with average pre-treatment SIC three-digit HHI above or below the median, respectively. In columns (3) and (4), suppliers are in SIC three-digit sectors with average pre-treatment Lerner Index above or below the median, respectively. In columns (5) and (6), suppliers have a mean pre-treatment number of matched competitors in their group below or above the median, respectively. In columns (1) and (2), panel B, suppliers produce differentiated or standardized inputs, respectively (according to the classification provided by Giannetti et al., 2011). In columns (3) and (4), suppliers have an average R&D over total assets throughout the pre-treatment period above or below the median, respectively. In columns (5) and (6), pairs have a pre-treatment length of relationship above or below the median. The sample consists of supplier-customer pair-year observations from FactSet Revere, with corresponding US supplier financial data sourced from Compustat, in the 2010-2017 period. Suppliers with no plants in California in 2010, as well as supplier-customer pairs that terminate their relationship when either firm exits the Compustat sample, are excluded from the sample. Statistical difference between estimated coefficients is reported at the bottom of the table. Robust standard errors reported in parentheses are adjusted for supplier-level clustering and for supplier-by-competitor group and competitor group level clustering in columns (5) and (6), panel A. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Table 4: Probability of Termination and Cap-and-Trade Program: Customers' Climate Transition Awareness

	(1)	(2)	(3)	(4)	(5)	(6)
	Climate Change Awareness		Political Party		U.S. Climate Alliance	
	High	Low	Democrat	Republican	Yes	No
Treated × Post	0.029	0.091***	-0.043	0.124***	-0.014	0.109***
	(0.028)	(0.029)	(0.033)	(0.035)	(0.031)	(0.035)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Supplier FE	Yes	Yes	Yes	Yes	Yes	Yes
Customer × Supplier sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	27,454	26,187	22,497	22,192	22,237	22,444
R^2	0.240	0.240	0.273	0.287	0.272	0.291
Difference	-0.061***		-0.168***		-0.123***	

This table presents difference-in-differences estimates of customer-supplier-level panel regressions using equation (1). The dependent variable *Ending* is a dummy variable that takes the value of one if the supplier-customer relationship ends in a given year, and zero if the relationship persists in both the current and previous year. *Treated* is a dummy variable that takes the value of one for suppliers that have at least one facility in California reporting emissions above 25,000 tons of CO2 equivalents in 2010; zero for suppliers that have at least one facility in California reporting emissions below 25,000 tons of CO2 equivalents in 2010. For suppliers with multiple facilities in California to be included in the control group, all of their plants must have emissions below the 25,000 tons of CO2 threshold in 2010. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. Columns (1) and (2) are based on customers with relatively high or low average pre-treatment attention to climate change relative to the median computed at the SIC two-digit and headquarters' country level. Columns (3) and (4) are based on customers with headquarters in democratic or republican states as per their 2016 elections, respectively. Columns (5) and (6) are based on the sub-sample of customers with headquarters in states members of the U.S. Climate Alliance and in the remaining states, respectively (according to the data and approach provided by von Meyerinck et al., 2021, members of the U.S. Climate Alliance at the onset of the coalition, in 2017, are California, Colorado, Connecticut, Delaware, Hawaii, Massachusetts, Minnesota, New York, North Carolina, Oregon, Rhode Island, Vermont, Virginia, and Washington; democrat states are California, Connecticut, Delaware, Hawaii, Illinois, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont, Washington). The sample consists of supplier-customer pair-year observations from FactSet Revere, with corresponding US supplier financial data sourced from Compustat, in the 2010-2017 period. Suppliers with no plants in California in 2010, as well as supplier-customer pairs that terminate their relationship when either firm exits the Compustat sample, are excluded from the sample. Statistical difference between estimated coefficients is reported at the bottom of the table. Robust standard errors adjusted for supplier-level clustering are reported in parentheses. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Table 5: Supplier's Economic Performance

	(1) Revenues (log)	(2) Total assets (log)	(3) Receivables (log)	(4) Inventory (log)	(5) PPE (log)	(6) CAPEX (log)	(7) Employment (log)
Treated × Post	-0.108**	-0.119**	-0.093	-0.184**	-0.174***	-0.140*	-0.100**
	(0.053)	(0.053)	(0.084)	(0.075)	(0.039)	(0.084)	(0.048)
Supplier FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Supplier Sector × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	9,857	9,908	9,353	5,143	9,571	9,223	9,804
R^2	0.982	0.984	0.972	0.973	0.979	0.960	0.984

This table presents difference-in-differences estimates of supplier-level panel regressions using equation (3). The dependent variables in columns (1)-(3) are the logarithm of revenues, total assets, account receivables, inventory, PPE, CAPEX and employees. *Treated* is a dummy variable that takes the value of one for suppliers that have at least one facility in California reporting emissions above 25,000 tons of CO2 equivalents in 2010; zero for suppliers that have at least one facility in California reporting emissions below 25,000 tons of CO2 equivalents in 2010. For suppliers with multiple facilities in California to be included in the control group, all of their plants must have emissions below the 25,000 tons of CO2 threshold in 2010. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. The sample consists of FactSet Revere US suppliers with financial information sourced from Compustat in the 2010-2017 period. Suppliers that have no plants in California in 2010 are excluded from the sample. Robust standard errors adjusted for supplier-level clustering are reported in parentheses. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Table 6: Supply Chain Effects of Cap-and-Trade Program

	(1) # New suppliers	(2) Average supplier size	(3) Sum of suppliers' emissions	(4) Average supplier emissions	(5) Average supplier emission intensity
Ex-ante indirectly treated × Post	0.140***	-0.272***	-0.388***	-0.330***	33.874**
	(0.039)	(0.073)	(0.117)	(0.109)	(15.860)
Customer FE	Yes	Yes	Yes	Yes	Yes
Customer Sector × Year FE	Yes	Yes	Yes	Yes	Yes
Obs.	10,320	6,860	3,499	3,499	3,534
R^2	0.484	0.868	0.883	0.898	0.890

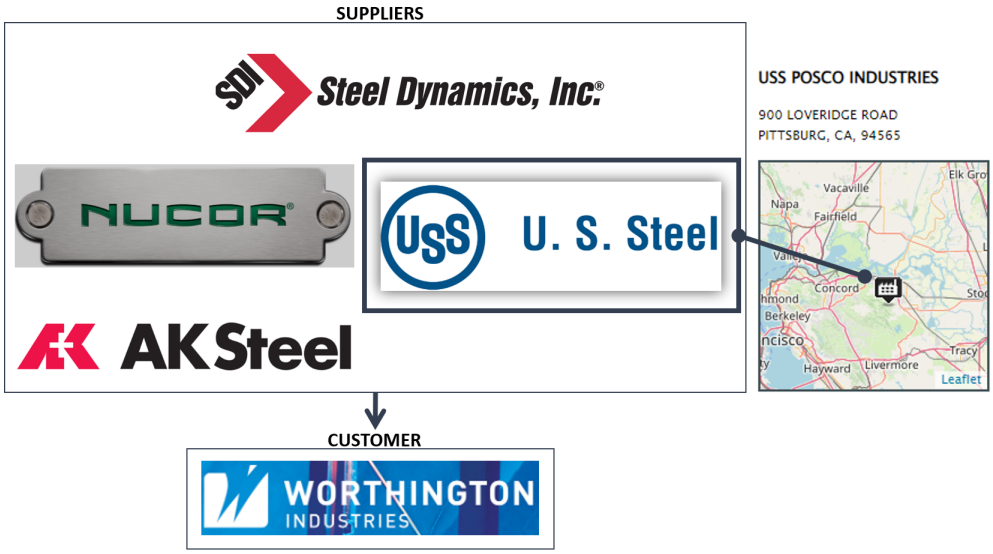
This table presents difference-in-differences estimates of customer-level panel regressions using equation (5). In column (1), the dependent variable is the number of new relationships a customer establishes in a given year with control suppliers in the same SIC 2-digit sector as its treated ones; in column (2), it is the natural logarithm of the average total assets of the suppliers of a customer in a given year; in column (3), it is the natural logarithm of the sum of the emissions of the suppliers of a customer in a given year; in column (4), it is the natural logarithm of the average emissions of the suppliers of a customer in a given year; in column (5), it is the average emission intensity of the suppliers of a customer in a given year. *Ex-Ante Indirectly Treated* is a dummy that takes the value of one if a customer sources its inputs from at least one treated supplier prior to the introduction of the cap-and-trade in a given year, and zero otherwise. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. The sample consists of FactSet Revere customers underlying our baseline analysis in Table 2. Robust standard errors adjusted for customer-level clustering are reported in parentheses. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Table 7: Environmental Effects of Cap-and-Trade Program

	(1)	(2)	(3)	(4)	(5)	(6)
	Sum of suppliers' emissions		Average supplier emissions		Average supplier emission intensity	
Rewired × Post	1.248***		0.942***		82.143*	
	(0.352)		(0.346)		(49.220)	
# Rewired suppliers since 2010 × Post		0.342**		0.269*		10.982
		(0.172)		(0.157)		(18.547)
Rewired	-2.047***		-1.455***		-84.997*	
	(0.333)		(0.332)		(43.327)	
# Rewired suppliers since 2010		-1.023***		-0.667***		-36.253*
		(0.171)		(0.157)		(20.849)
Customer FE	Yes	Yes	Yes	Yes	Yes	Yes
Customer Sector × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	1,877	1,262	1,877	1,262	1,880	1,269
R^2	0.866	0.821	0.884	0.810	0.836	0.821

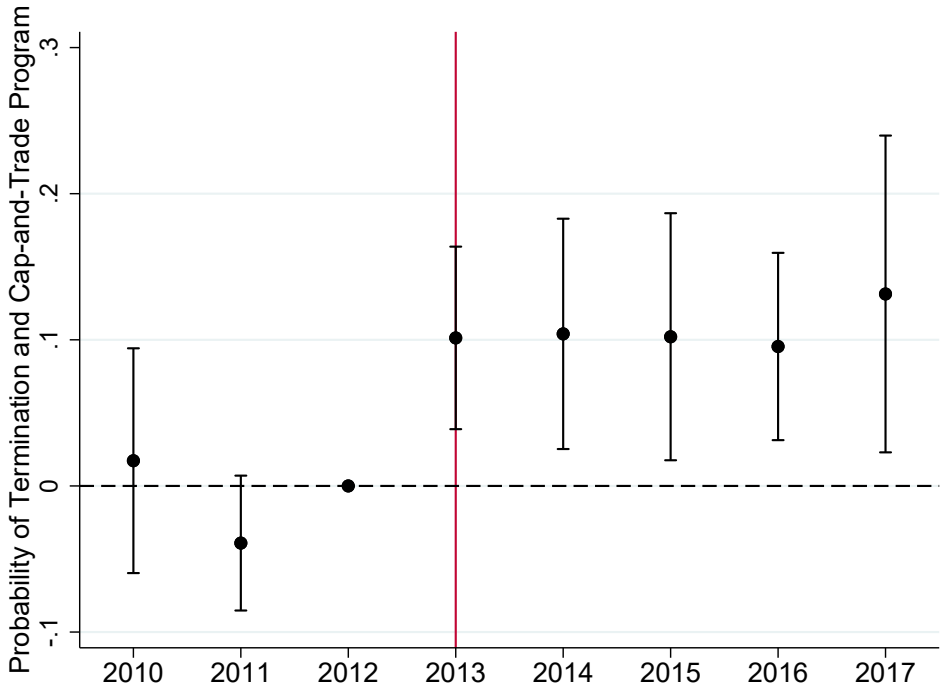
This table presents difference-in-differences estimates of customer-level panel regressions using equation (6). The dependent variable is the logarithm of the sum or average of U.S. supply chain emissions or the average U.S. supply chain emission intensity of a given customer j in year t. *Rewired* is a dummy that takes the value of one if a customer sources its inputs from a supply chain that is rewired away from the cap-and-trade in a given year (i.e., if that year, the customer has fewer treated suppliers than in the previous year), and zero otherwise. *# Rewired suppliers since 2010* is the cumulation of the number of treated suppliers the customer rewired away from in a given year since 2010. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. The sample consists of FactSet Revere customers sourcing from at least one US supplier linked to a plant in California in 2010 and with financial information sourced from Compustat. Robust standard errors adjusted for customer-level clustering are reported in parentheses. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Figure 1: Illustration of the Structure of the Data



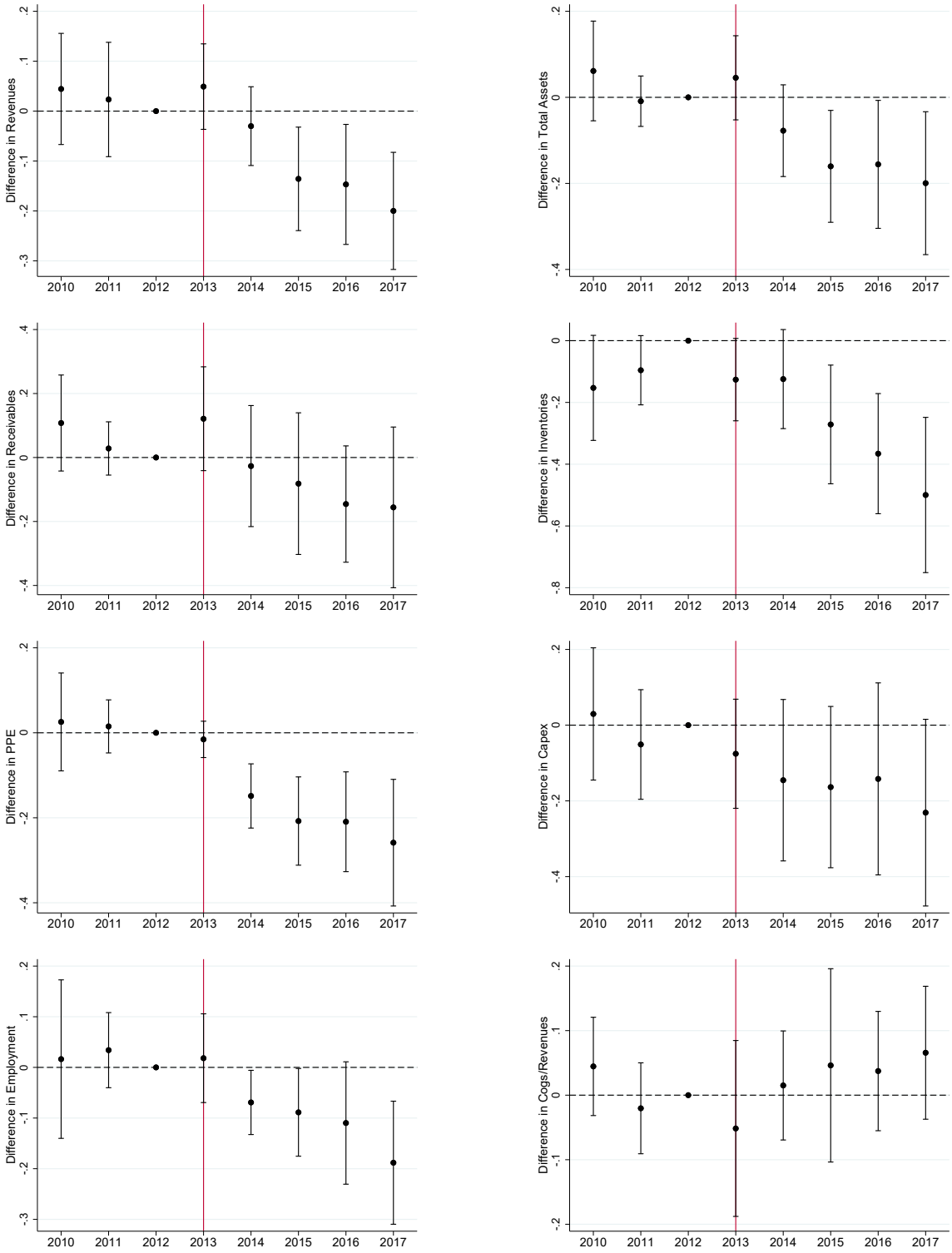
This figure illustrates the structure of the dataset through the example of the treated supplier U.S. Steel and its customer Worthington Industries. According to the EPA FLIGHT data, the U.S. Steel POSCO facility mapped close to San Francisco on the right-hand side of the figure produced sufficient emissions to be subject to the cap-and-trade. We map this facility to its owner, U.S. Steel. U.S. Steel is a supplier of Worthington Industries, visualized at the bottom of the figure, and a direct competitor of other suppliers of the same company (i.e., Steel Dynamics, NUCOR and AK Steel, visualized in the left-hand side of the figure). Our final dataset follows supplier-customer pairs such as U.S. Steel-Worthington Industries or NUCOR-Worthington Industries over time.

Figure 2: Probability of Termination around Cap-and-Trade Program



This figure shows the difference and 95% confidence intervals in the probability of termination of a business relationship between treated and control suppliers around the introduction of the Californian cap-and-trade program in 2013 using the specification in column (1) of Table 2. Treated suppliers are defined as firms with at least one facility in California reporting emissions exceeding 25,000 tons of CO2 equivalents in 2010. The sample consists of supplier-customer pair-year observations from FactSet Revere, with corresponding U.S. supplier financial data sourced from Compustat, in the 2010-2017 period. Suppliers with no plants in California in 2010, as well as supplier-customer pairs that terminate their relationship when either firm exits the Compustat sample, are excluded from the sample. Standard errors are adjusted for supplier-level clustering.

Figure 3: Difference in Suppliers' Economic Performance around Cap-and-Trade Program



This figure shows the difference and 95% confidence intervals in the economic performance between treated and control suppliers around the introduction of the Californian cap-and-trade program in 2013. The sample consists of FactSet Revere U.S. suppliers with financial information sourced from Compustat in the 2010-2017 period. Suppliers that have no plants in California in 2010 are excluded from the sample. Standard errors are adjusted for supplier-level clustering.

Appendix

Table A1: Variable Definitions

Variable	Definition
Ending	Dummy variable that takes the value one if the relationship between supplier i and customer j is not observed in year $t+1$, and zero if the relationship is observed in year t and continues into $t+1$ (FactSet Revere).
Beginning	Dummy variable that equals one hundred if a relationship between supplier i, in sector $s(i)$ and customer j is observed in year t but not in year $t-1$, and zero if a relationship between supplier in sector $s(i)$ and customer j is not observed in year t (FactSet Revere).
Treated	Dummy variable that takes the value of one if the supplier producing at least 25,000 tons of CO2e in one of its California facilities in 2010; zero for suppliers that have at least one facility in California reporting emissions below 25,000 tons of CO2 equivalents in 2010. (EPA, FactSet Revere, NETS).
Supplier total assets	Total assets in billion $ (Compustat (AT)).
Supplier ROA	Ratio of earnings before interest, taxes, depreciation, and amortization to total assets (Compustat EBITDA / AT).
Supplier leverage	Long-term debt plus debt in current liabilities, divided by total assets (Compustat (DLTT + DLC) / AT).
Supplier Tobin's Q	Tobin's Q (Compustat (AT + Market Value − BE) / AT where Market Value = CSHO × PRCC F).
Supplier R&D stock	Ratio of stock of research and development (R&D) computed as the sum of R&D expenses from 2005 to year t, assuming R&D expenditures are zero when the observation is missing, divided by total assets (Compustat $\sum_{t=2005}^{t} XRD$ / AT).
Supplier revenues	Total revenues in billion $ (Compustat REVT).
Supplier COGS/Revenues	Ratio of cost of goods sold to revenues (Compustat COGS / REVT).
Supplier receivables	Supplier receivables in levels (Compustat RECT).
Supplier inventory	Supplier inventories in levels (Compustat INVFG).
Supplier PPE	Supplier property, plant, and equipment in levels (Compustat PPE).
Supplier CAPEX	Supplier CAPEX in levels (Compustat CAPX).
Supplier employment	Supplier number of employees in levels (Compustat EMP).

(Continued)

Table A1: Variable Definitions - *Continued*

Variable	Definition
Ex-ante indirectly treated	Dummy variable that takes the value of one if the customer has at least one supplier before 2013 producing at least 25,000 tons of CO2e in its California facilities in 2010, and zero otherwise (EPA, FactSet Revere).
Ex-post indirectly treated	Dummy variable that takes the value of one if the customer has at least one supplier including and after 2013 producing at least 25,000 tons of CO2e in its California facilities in 2010, and zero otherwise (EPA, FactSet Revere).
Customer total assets	Total assets in billion $ (Compustat AT).
Customer ROA	Ratio of earnings before interest, taxes, depreciation, and amortization to total assets (Compustat EBITDA / AT).
Customer leverage	Long term debt plus debt in current liabilities, divided by total assets (Compustat (DLTT + DLC) / AT).
Customer revenues	Total revenues in billion $ (Compustat REVT).
Customer COGS/Revenues	Ratio of cost of goods sold to revenues (Compustat COGS / REVT).
Customer receivables	Customer receivables in levels (Compustat RECT).
Customer inventory	Customer inventories in levels (Compustat INVFG).
Customer PPE	Customer property, plant, and equipment in levels (Compustat PPE).
Customer CAPEX	Customer CAPEX in levels (Compustat CAPX).
Customer employment	Customer number of employees in levels (Compustat EMP).
# New suppliers	Number of new relationships a customer establishes in a given year with control suppliers in the same SIC 2-digit sector as its treated one (FactSet Revere).
Average supplier size	Average total assets of the suppliers of each customer (Compustat AT, FactSet Revere).
Sum of suppliers' emissions	Total U.S. emissions of the suppliers of each customer (EPA, FactSet Revere).
Average supplier emissions	Average U.S. emissions of the suppliers of each customer (EPA, FactSet Revere).
Average supplier emission intensity	Average U.S. emission intensity of the suppliers of each customer (EPA, FactSet Revere).
Rewired	Dummy variable that equals one if a customer j sources its inputs from a supply chain that is rewired away from the cap-and-trade in a given year (i.e., if that year, the customer has fewer treated suppliers than in the previous year), and zero otherwise (EPA, FactSet Revere).
# Rewired suppliers since 2010	Cumulative sum of the number of rewired suppliers of a given customer since 2010 up to each given year, divided by its total treated suppliers in 2010 (EPA, FactSet Revere).

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Table IA1: Sample Comparison

	Suppliers with no plants in California in 2010		Suppliers with plants in California in 2010		
	Mean	Std. Dev.	Mean	Std. Dev.	SDM
Total assets (log)	6.06	2.18	7.66	2.22	-0.72
ROA	-0.01	0.27	0.08	0.17	-0.42
Leverage	0.26	0.25	0.25	0.22	0.01
Tobin Q	2.24	1.84	1.98	1.32	0.16
R&D stock	0.52	1.15	0.38	0.85	0.13

This table presents the standardized difference between the means of the financial characteristics of the sample of US suppliers with at least one plant in California in 2010 and the sample of US suppliers having no plants in California in 2010 and being mapped into the FactSet supplier-customer database over the 2010-2017 interval.

Table IA2: Probability of Termination and Cap-and-Trade Program: Treatment Intensity

	(1)	(2)	(3)	(4)	(5)
Treatment intensity × Post	0.010***	0.008***	0.010***	0.009***	0.006**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Supplier total assets (log)		-0.032	-0.032	-0.034	-0.019
		(0.025)	(0.026)	(0.024)	(0.022)
Supplier ROA		-0.095	-0.100	-0.058	-0.036
		(0.070)	(0.072)	(0.058)	(0.059)
Supplier leverage		-0.036	-0.035	-0.026	-0.040
		(0.066)	(0.067)	(0.064)	(0.058)
Supplier Tobin Q		-0.001	-0.001	-0.004	-0.002
		(0.007)	(0.006)	(0.007)	(0.007)
Supplier R&D stock		-0.054**	-0.055**	-0.054***	-0.034**
		(0.025)	(0.025)	(0.016)	(0.014)
Excl. Treated customer	No	No	Yes	No	No
Year FE	Yes	Yes	Yes	Yes	No
Supplier FE	Yes	Yes	Yes	Yes	Yes
Customer × Year FE	No	No	No	No	Yes
Customer × Supplier Sector FE	Yes	Yes	Yes	Yes	Yes
Obs.	132,557	116,058	111,635	88,927	88,927
R^2	0.242	0.249	0.251	0.237	0.488

This table presents difference-in-differences estimates of customer-supplier-level panel regressions using equation (1). The dependent variable *Ending* is a dummy variable that takes the value of one if the supplier-customer relationship ends in a given year, and zero if the relationship persists in both the current and previous year. *Treatment Intensity* is the ratio of each supplier's California emissions in 2010 and its total assets. This value is then standardized by its standard deviation. *Treated* is a dummy variable that takes the value of one for suppliers that have at least one facility in California reporting emissions above 25,000 tons of CO2 equivalents in 2010; zero for suppliers that have at least one facility in California reporting emissions below 25,000 tons of CO2 equivalents in 2010. For suppliers with multiple facilities in California to be included in the control group, all of their plants must have emissions below the 25,000 tons of CO2 threshold in 2010. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. In column (3), customers who report emissions above 25,000 tons of CO2e in California in 2010 are excluded. The sample consists of supplier-customer pair-year observations from FactSet Revere, with corresponding US supplier financial data sourced from Compustat, in the 2010-2017 period. Suppliers with no plants in California in 2010, as well as supplier-customer pairs that terminate their relationship when either firm exits the Compustat sample, are excluded from the sample. Robust standard errors adjusted for supplier-level clustering are reported in parentheses. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Table IA3: Probability of Termination and Cap-and-Trade Program: Robustness

	(1) Cluster by Pair	(2) Treated Supplier 2012	(3) Within Competitors group	(4) Geographically Concentrated	(5) Financially Unconstrained	(6) Placebo California HQ	(7) Segments Sample Sales (log)	(8) Conditional Logit	(9) Entire U.S. Sample
Treated × Post	0.114***		0.029*	0.106**	0.090***		-0.112*	1.487***	0.112***
	(0.013)		(0.017)	(0.046)	(0.033)		(0.062)	(0.133)	(0.028)
Treated 2012 × Post		0.124***							
		(0.031)							
HQ California × Post						-0.026			
						(0.023)			
Treated								-1.242***	
								(0.138)	
Year FE	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Customer × Supplier sector FE	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Supplier FE	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Year × Competitor group FE	No	No	Yes	No	No	No	No	No	No
Customer × Competitor group FE	No	No	Yes	No	No	No	No	No	No
Supplier × Competitor group FE	No	No	Yes	No	No	No	No	No	No
Obs.	150,168	150,168	228,634	144,734	55,750	140,344	17,672	79,062	263,106
R^2	0.248	0.248	0.383	0.248	0.250	0.247	0.939		0.239

This table presents difference-in-differences estimates of customer-supplier-level panel regressions using equation (1). *Treated* takes the value of one for suppliers that have at least one facility in California reporting emissions above 25,000 tons of CO2 equivalents in 2010; zero for suppliers that have at least one facility in California reporting emissions below 25,000 tons of CO2 equivalents in 2010. For suppliers with multiple facilities in California to be included in the control group, all of their plants must have emissions below the 25,000 tons of CO2 threshold in 2010. *Post* takes the value of one in 2013 and subsequent years, and zero otherwise. Where not specified, the dependent variable is *Ending* (it takes the value of one if the supplier-customer relationship ends in a given year, and zero if it persists) and the sample consists of supplier-customer pair-year observations from FactSet Revere, with corresponding US supplier financial data sourced from Compustat, in the 2010-2017 period. Suppliers with no plants in California in 2010, as well as supplier-customer pairs that terminate their relationship when either firm exits the Compustat sample, are excluded from the sample. In column (1), standard errors are clustered at the pair level. In column (2), the treatment is allocated according to firms' 2012 emissions in their Californian facilities. In column (3), each treated supplier is compared to a control supplier within its group of direct competitors. In column (4), treated suppliers are not geographically diversified. In column (5), treated suppliers are financially unconstrained, using the composite financial constraint indicator proposed by Bartram et al. (2022). In column (6), the placebo group consists of non-treated firms headquartered in California. Column (7) is based on the Compustat Segment sample. The dependent variable in column (7) is the logarithm of the sales between the pair in a given year. In column (8), the model is a conditional logit with bootstrapped standard errors using the sample underlying column (1), Table 2. In column (9), the baseline sample is expanded to include control suppliers headquartered in the U.S. that do not have plants in California in 2010. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Table IA4: Probability of Starting New Relationship and Cap-and-Trade Program

	(1)	(2)	(3)	(4)	(5)
Treated × Post	-0.136**	-0.119*	-0.116*	-0.119*	-0.017
	(0.060)	(0.063)	(0.063)	(0.063)	(0.038)
Supplier total assets (log)		0.052***	0.052***	0.052***	0.025***
		(0.016)	(0.015)	(0.016)	(0.009)
Supplier ROA		-0.041	-0.044	-0.041	-0.012
		(0.028)	(0.027)	(0.028)	(0.018)
Supplier leverage		-0.010	-0.008	-0.010	-0.014
		(0.036)	(0.036)	(0.036)	(0.021)
Supplier Tobin Q		0.006*	0.006*	0.006*	0.004**
		(0.003)	(0.003)	(0.003)	(0.002)
Supplier R&D stock		0.055***	0.055***	0.055***	0.029***
		(0.010)	(0.010)	(0.010)	(0.007)
Excl. Treated Customer	No	No	Yes	No	No
Supplier FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	No
Customer × Supplier Sector FE	Yes	Yes	Yes	Yes	Yes
Customer × Year FE	No	No	No	No	Yes
Obs.	50,681,088	43,600,235	42,591,960	43,600,182	43,600,182
R^2	0.007	0.007	0.008	0.007	0.011

This table presents difference-in-differences estimates of customer-supplier-level panel regressions using equation (2). The dependent variable *Beginning* is a dummy variable that takes the value of one hundred if the supplier-customer relationship starts in a given year, and zero if the relationship is not observed in FactSet (for ease of readability, due to the relatively small unconditional probability of starting a new relationship in this sample, equal to 0.09% with a standard deviation of 3.08, the dependent variable is multiplied by 100). *Treated* is a dummy variable that takes the value of one for suppliers that have at least one facility in California reporting emissions above 25,000 tons of CO2 equivalents in 2010; zero for suppliers that have at least one facility in California reporting emissions below 25,000 tons of CO2 equivalents in 2010. For suppliers with multiple facilities in California to be included in the control group, all of their plants must have emissions below the 25,000 tons of CO2 threshold in 2010. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. In column (3), customers that produce emissions above 25,000 tons of CO2e in California in 2010 are excluded. The sample consists of new or possible supplier-customer pair-year observations from FactSet Revere, where corresponding supplier financial data sourced from Compustat is available in the 2010-2017 period. Suppliers with no plants in California, as well as supplier-customer pairs that terminate their relationship when either firm exits the Compustat sample, are excluded from the sample. Robust standard errors adjusted for supplier-level clustering are reported in parentheses. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Table IA5: Supplier's Economic Performance

	(1) Revenues (log)	(2) Total assets (log)	(3) Receivables (log)	(4) Inventory (log)	(5) PPE (log)	(6) CAPEX (log)	(7) Employment (log)
Treated × Post	-0.144***	-0.213***	-0.245***	-0.242***	-0.179***	-0.257**	-0.148***
	(0.039)	(0.041)	(0.044)	(0.076)	(0.044)	(0.103)	(0.055)
Specialized × Treated × Post	0.057	0.187**	0.225*	0.221	0.041	0.311**	0.074
	(0.092)	(0.076)	(0.132)	(0.169)	(0.088)	(0.145)	(0.096)
Supplier FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Supplier Sector × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	8,098	8,143	7,976	4,949	8,110	8,025	8,059
R^2	0.982	0.983	0.970	0.972	0.979	0.959	0.983

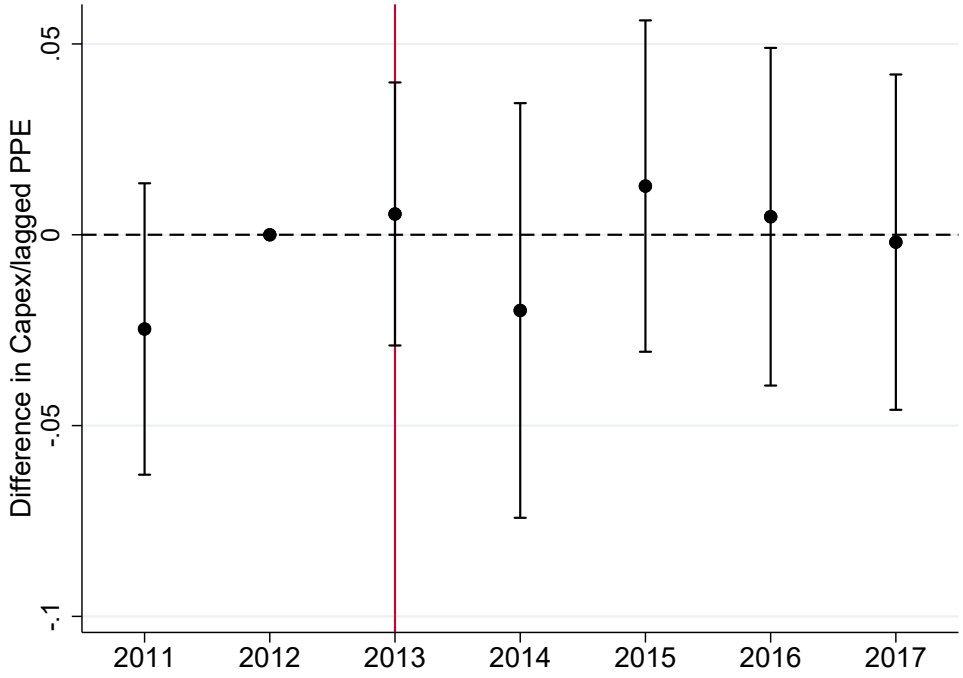
This table presents difference-in-differences estimates of supplier-level panel regressions using equation (3). The dependent variables are the logarithm of revenues, total assets, account receivables, inventory, PPE, CAPEX, employees. *Treated* is a dummy variable that takes the value of one for suppliers that have at least one facility in California reporting emissions above 25,000 tons of CO2 equivalents in 2010; zero for suppliers that have at least one facility in California reporting emissions below 25,000 tons of CO2 equivalents in 2010. For suppliers with multiple facilities in California to be included in the control group, all of their plants must have emissions below the 25,000 tons of CO2 threshold in 2010. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. *Differentiated* is a dummy variable that takes the value of one for suppliers in industries that produce differentiated goods, and zero otherwise (according to the classification provided by Giannetti et al., 2011). The sample consists of FactSet Revere US suppliers with financial information sourced from Compustat in the 2010-2017 period. Suppliers that have no plants in California in 2010 are excluded from the sample. Robust standard errors adjusted for supplier-level clustering are reported in parentheses. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Table IA6: Customer's Economic Performance

	(1) Revenues (log)	(2) Total assets (log)	(3) Receivables (log)	(4) Inventory (log)	(5) PPE (log)	(6) CAPEX (log)	(7) Employment (log)
Ex-post indirectly treated × Post	-0.018	-0.016	-0.045	-0.045	0.057	0.038	-0.025
	(0.032)	(0.027)	(0.037)	(0.052)	(0.037)	(0.047)	(0.031)
Customer FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Customer Sector × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	14,423	14,702	13,542	6,464	14,232	13,585	14,111
R^2	0.979	0.984	0.973	0.974	0.980	0.959	0.986

This table presents difference-in-differences estimates of customer-level panel regressions using equation (4). The dependent variables are the logarithm of revenues, total assets, account receivables, inventory, PPE, CAPEX, and employees. *Ex-Post Indirectly Treated* is a dummy variable that takes the value of one for customers who have at least one treated supplier after the introduction of the cap-and-trade program. *Post* is a dummy variable that takes the value of one in 2013 and subsequent years, and zero otherwise. The sample consists of FactSet Revere customers sourcing from at least one US supplier linked to a plant in California in 2010 and with financial information sourced from Compustat. Customers directly affected by the California cap-and-trade program are excluded from the sample. Robust standard errors adjusted for customer-level clustering are reported in parentheses. Refer to Table A1 in the Appendix for variable definitions. * $p<.10$; ** $p<.05$; *** $p<.01$.

Figure IA1: Difference in Suppliers' Investment Rate around Cap-and-Trade Program



This figure shows the difference and 95% confidence intervals in the investment rate between treated and control suppliers around the introduction of the Californian cap-and-trade program in 2013. The sample consists of FactSet Revere U.S. suppliers with financial information sourced from Compustat in the 2010-2017 period. Suppliers that have no plants in California in 2010 are excluded from the sample. Standard errors are adjusted for supplier-level clustering.