Carbon Pricing and Investment*

James R. Brown†, Gustav Martinsson‡, Per Strömberg§, Christian Thomann¶

This version: October 1, 2026

Abstract

How does carbon pricing affect investment in brown firms? During the period 2000–2019, the effective cost of emitting carbon rose by about 400 percent for Swedish manufacturing firms. Despite lower operating margins, high-emission firms significantly increased both total capital investment and the share of investment dedicated to abatement. The response is concentrated among firms with strong internal financial capacity. We find no comparable investment increase in lower-emitting firms or in high-emission industries outside of Sweden. Our results show that pricing CO_2 emissions at a sufficiently high level can incentivize brown firms to make green investments.

Keywords: Carbon pricing, Climate policy, Investment, Environmental taxes
JEL codes: Q53, Q54, G31

---

*We would like to thank Marina Kumlin for help with the data. The paper has greatly benefited from comments by Pat Akey, Emmanuelle Auriol, Scott Barrett, Robert Engle, Ken French, Kenneth Gillingham, Luigi Guiso, Jarrad Harford, Oliver Hart, Geoffrey Heal, Peter Iliev, Matthew Kotchen, Claudio Michelacci, Matthew Serfling, Kelly Shue, Peter Tufano and seminar participants at Bank of Italy, Dartmouth, EIEF, Frankfurt School of Finance and Management, HEC Paris, IFN, IFN Sigtuna Conference, Imperial College, Jönköping University, Konjunkturinstitutet, NBER Climate Finance Conference, NBER The Economics of Decarbonizing Industrial Production Conference, National Institute of Economic Research, Smokey Mountain Finance Conference, the Swedish House of Finance, the 2026 Swiss Society for Financial Market Research conference, University of Amsterdam, and University of Lausanne. We are grateful for financial support from FORMAS, Marcus and Marianne Wallenberg Research Foundation, Nasdaq Nordic Foundation, and Jan Wallanders and Tom Hedelius Foundation. This research was partly undertaken when Per Strömberg was the BP Centennial Professor of Finance at the London School of Economics. Jiayu Zhang provided excellent research assistance.

†Texas A&M University, Mays Business School, Department of Finance, jrbrown@tamu.edu
‡Stockholm University, SHoF & HOSS, gustav.martinsson@sbs.su.se
§Stockholm School of Economics, CEPR, ECGI, SHoF, & HOSS, per.stromberg@hhs.se
¶Royal Institute of Technology, SHoF, & HOSS, christian.thomann@hhs.se

1 Introduction

A central economic question in the green transition is how emissions-intensive firms reallocate capital when environmental externalities are priced. Because the existing stock of carbon-intensive capital implies high future emissions, meaningful decarbonization ultimately requires the most emissions-intensive firms to replace that capital with cleaner technology (e.g., Davis et al., 2010, Tong et al., 2019).

Pricing emissions reduces the profitability of emitters, which should lead high-emitting firms to contract productive capacity (Nordhaus, 1992, 2019) and/or upgrade to greener technology (e.g., Hicks, 1932, Newell et al., 1999, Acemoglu et al., 2016, Aghion et al., 2016). But real-world policies may not work as predicted. Higher carbon prices may discourage new investment, induce relocation to areas with weaker regulation, or encourage asset divestitures or transfers to less accountable owners that reduce measured emissions without real abatement (e.g., Akey and Appel, 2021, Bartram et al., 2022, Duchin et al., 2025, Hartzmark and Shue, 2026). Whether higher carbon prices actually drive emissions-intensive firms to upgrade their capital stock is therefore an empirical question.

We study the investment response to carbon prices using micro-data on Swedish manufacturing firms over the period 2000 to 2019. Sweden provides an ideal empirical setting, as the marginal cost of emitting carbon for Swedish manufacturing firms increased by about 400 percent over this period. The increase was particularly pronounced after 2014, reaching levels comparable to standard estimates of the social cost of carbon (e.g., Nordhaus, 2019).[1]

Figure 1 shows how carbon pricing and manufacturing investment evolve in Sweden between 2000 and 2019. Following the sharp increase in the effective carbon price after 2014, capital investment in the dirtiest manufacturing industries (top decile of carbon intensity) increases by more than 83 percent, compared to 16 percent in the rest of manufacturing. As a result, the share of annual total manufacturing investment accounted for by the highest-emitting industries increases by approximately 32 percent between 2000 and 2019. These patterns suggest that higher carbon prices spur new capital investment in brown firms.

We formalize this relationship by estimating how firm-level investment responds to changes in the cost of carbon emissions. The richness of the data allows us to

[1] Sweden's carbon tax rate is consistently among the highest in the world (second highest as of 2025, see World Bank, 2025). However, these levels are sharply lower than recent estimates of the social cost of carbon reported in Moore et al. (2024) and Bilal and Känzig (2026).

measure the firm-specific marginal cost of emissions and to estimate highly saturated specifications including firm and four-digit industry-by-year fixed effects. We first show that carbon pricing significantly reduced operating margins in high-emitting firms, consistent with limited pass-through of carbon costs to output prices (Ganapati et al., 2020). Despite lower operating margins, we find a positive and statistically significant elasticity of investment with respect to the marginal cost of emitting carbon. In high-emission firms, a 10 percent increase in the marginal cost of carbon emissions is associated with a 1.7–3.0 percent increase in capital investment, while the effect is statistically indistinguishable from zero for low-emission firms.

To isolate green investment, we use detailed data on environmental investment expenditures, available for a subset of firms. Green investment responds even more strongly to carbon pricing: in the highest-emission firms, a 10 percent increase in the marginal cost of carbon emissions is associated with a 7 percent increase in abatement investment. High-emission firms also increase the share of abatement investment to total capital expenditures. These findings indicate that higher carbon prices induce capital reallocation toward cleaner technologies.

Next, we exploit the sharp increase in Swedish carbon prices after 2014 as a quasi-experimental shock and estimate difference-in-differences specifications comparing firms in the top decile of emissions intensity to other manufacturing firms. There are two advantages of this approach: i) we are not restricted to studying the sub-set of manufacturing firms with consistently available emissions data, and ii) we do not need to estimate the firm-specific marginal cost of emissions, which is potentially endogenous to firm investment and production decisions. We find a significant differential increase in capital expenditures among high-emitting firms in the post-2014 period, again consistent with the aggregate evidence in Figure 1.

We then investigate how high-emitting firms fund this investment. When sorting firms by internal and external financing capacity prior to the carbon price increase, we find that the investment response is driven by high-emission firms with more internal financial resources. Following the carbon price increase, these firms reduce dividend payouts by a similar magnitude to the observed increase in capital expenditures. We find similar patterns when sorting firms by ex ante internal cash flow instead of dividends. In contrast, we do not observe systematic differences in investment responses based on proxies for access to external finance, such as credit ratings. These findings highlight the central role of internal finance for green capital upgrading.

To address the concern that the Swedish carbon price increase may have coincided

with a broader investment boom in high-emission industries, we assemble industry-level investment data for four-digit manufacturing industries across European Union member states. We find no comparable increase in investment in high-emission industries outside Sweden during the post-2014 period, consistent with the interpretation that the observed investment response was driven by the increase in Swedish carbon prices, rather than broader underlying trends in demand or technology.

Our focus on capital investment differentiates us from most previous studies on the effects of carbon pricing (e.g., Martin et al., 2014, Dechezleprêtre et al., 2023, Rafaty et al., 2025, Akey et al., 2025). Most closely related to this paper, Martinsson et al. (2024) estimate emissions to carbon pricing elasticities for Swedish manufacturing firms over 1990–2015. They report a significantly lower carbon pricing elasticity for the high-emitting industries compared to the lower-emitting industries, where emissions likely are easier/cheaper to abate. In contrast, this paper documents a significantly *higher* investment response among high-emitting firms following the sharp post-2014 increase in carbon prices. This implies that it takes time for green capital investments to result in actual emission reductions in the highest-polluting sectors.

A handful of previous studies relate carbon pricing to firm-level investment, with contradictory results.[2] While Jacob and Zerwer (2024) document a negative investment response to the introduction of carbon taxes in France and Ireland, Colmer et al. (2025) find a positive response in Phase 2 of the EU ETS, and Bolton et al. (2026) report no investment effect in Phase 3 (possibly reflecting anticipatory adjustment). One reason for these inconclusive results could be that the level of carbon pricing was relatively low and (in the case of ETS) volatile. When switching technologies requires large fixed costs, firms may delay adjustment until carbon prices become sufficiently high and credible (Dixit and Pindyck, 1994, Cooper and Haltiwanger, 2006). Our setting enables us to study the investment response to a more sustained and material increase in carbon prices. Importantly, the strong investment response to carbon pricing is only present in the highest-emitting industries, which account for

[2] A related literature studies how environmental taxes and regulations affect the development and adoption of cleaner technologies, typically measured through R&D spending or patenting activity. This work shows that higher energy and fuel prices can induce clean innovation (Newell et al., 1999, Popp, 2002, Aghion et al., 2016), that higher sulfur oxide taxes encourage high-pollution firms to increase R&D and technological absorptive capacity (Brown et al., 2022), and that the EU ETS spurred low-carbon patenting among regulated firms (Calel and Dechezleprêtre, 2016). In contrast, we focus on physical capital upgrading, an essential mechanism through which carbon pricing can drive the transition to a low-carbon economy (e.g., Tong et al., 2019).

the vast majority of manufacturing emissions.[3] In this way, our study responds to recent calls for broad-scale, ex post empirical evidence on industrial decarbonization to complement a largely model-based literature (Gillingham et al., 2025).

We also find that the investment response to carbon pricing in high-emission sectors is confined to firms with strong internal cash flows, who cut dividend payouts to fund new capital. This result is in line with research showing the importance of financial constraints for green investment, including Lanteri and Rampini (2025), Fang et al. (2025), Bustamante and Zucchi (2024), Döttling and Rola-Janicka (2025), Biais et al. (2026), Bartram et al. (2022) and Xu and Kim (2022). In particular, our evidence complements Hartzmark and Shue (2026), who show that the high cost of capital of 'brown' firms impedes their ability to reduce emissions. Our finding that green investment relies on access to internal funds is consistent with a high cost of external capital for brown firms.

We also contribute to the literature comparing green finance to carbon pricing. Pedersen (2026) develops a unified model showing that green finance can replicate the effects of an optimal carbon tax only if increases in the cost of capital for carbon-intensive firms are sufficiently high. Oehmke and Opp (2025) show that socially responsible funds achieve real impact only when they invest in high-emission firms and accept a financial loss — without such engagement, carbon taxes remain the only effective tool to induce clean production.[4] Recent empirical work also suggests that market pressures from green investors may lead to counterproductive increases in the cost of capital for brown firms (Hartzmark and Shue, 2026, Kacperczyk and Peydró, 2026) or greenwashing through asset divestiture (Duchin et al., 2025). In contrast, we show that sufficiently high carbon prices can induce the capital reallocation required for decarbonization.

Finally, our work relates to the broader macroeconomic literature on the optimal design and aggregate effects of carbon pricing (e.g., Nordhaus, 1992, Golosov et al., 2014). These models hinge on how firms adjust capital in response to carbon emission costs. We provide micro-level evidence on this adjustment margin, showing that

[3]Many empirical studies on the impact of environmental regulation suffer from aggregation bias (e.g., Ederington et al., 2005, Levinson and Taylor, 2008), wherein the consequences of environmental policy are under-stated, because the costs of the policy are small for the average firm, even though they are large for the subset of firms that are most highly affected. The high concentration of carbon emissions to a relatively small number of firms is also documented in Pastor et al. (2026).

[4]Relatedly, Oehmke and Opp (2026) explain how green capital requirements may be complementary to carbon taxes by removing the stranded asset risk that may otherwise undermine a government's willingness to impose carbon pricing.

sufficiently high local carbon taxes can induce meaningful investment responses in emissions-intensive firms—consistent with recent work highlighting conditions under which subnational carbon pricing can be effective (e.g., Conte et al., 2026, Bilal and Känzig, 2025). Furthermore, while Känzig (2025) emphasizes the distributional consequences of carbon pricing across households, our findings highlight heterogeneity across firms: investment responses are concentrated among cash-rich, high-emission firms with the internal resources to finance capital upgrading.

2 Institutional Setting

2.1 Carbon pricing in Sweden

Sweden introduced a carbon tax in 1991, levied per ton of carbon dioxide (CO_2) emissions from fossil fuel use. Over time, effective carbon tax rates increased substantially, making Sweden one of the highest carbon-pricing jurisdictions globally (World Bank, 2025). A central institutional feature of carbon pricing in Sweden is the phase-out of carbon tax exemptions for manufacturing firms (NACE 10–33). Many energy-intensive manufacturing industries initially received reduced tax rates to mitigate competitiveness concerns. The overwhelming majority of the exemption removal occurs after 2014 (see Figure B.1), which raised effective marginal carbon costs for manufacturing firms by about 250 percent over a short period.

In the firm-level analysis, the main explanatory variable is $C_{i,t}$, the marginal cost of emitting one additional unit of CO_2 for firm i in period t, scaled by output (PPI-deflated sales). The marginal cost differs from the average cost for two reasons. First, as just explained, in the early part of the sample period, tax exemptions reduced the carbon emission tax for emissions above a threshold. Second, some Swedish manufacturing firms have installations (plants) regulated under the EU Emission Trading System, where EU ETS prices differ from the Swedish carbon tax. For firms that have some installations in the EU ETS and some subject to Swedish carbon tax, our main measure of $C_{i,t}$ uses the marginal cost from the installation that accounts for the largest fraction of the firm's emissions. In robustness tests, we report similar results where $C_{i,t}$ is the sales- or asset-weighted marginal emission cost across the firm's installations (again, scaled by output).

Figure 2 shows Swedish carbon prices converted to U.S. dollars per ton and compares the average price across manufacturing firms in our sample with three

different estimates of the social cost of carbon (SCC) from Nordhaus (2019): i) the DICE optimal (blue short dashed line, lowest), ii) price needed to limit global warming to under 2°C (blue medium dashed line, middle), and iii) the price required to stay below 1.5°C (blue long dashed line, highest). The figure shows that the post-2014 increase moves Swedish carbon pricing into a range comparable to leading estimates of socially optimal carbon prices. Figure 2 also shows that EU ETS prices remain below Swedish carbon tax levels for most of the sample, with the sharp rise in EUA prices occurring after our study period.

2.2 Measuring investment

A central empirical challenge in studying carbon pricing and capital reallocation is measuring investment that is specifically directed toward reducing emissions. Our primary measure of climate mitigation investment comes from the annual Environmental Protection Expenditure Survey conducted by Statistics Sweden, which follows the Classification of Environmental Protection Activities (CEPA) framework developed by Eurostat (European Parliament and Council, 2011). CEPA distinguishes between two broad categories of environmental capital expenditure: end-of-pipe investments, which treat pollution after it is generated (e.g., filters or scrubbers); and integrated or prevention investments, which reduce emissions by modifying the production process itself. Our abatement investment variable, which we denote *Abate Inv*, includes both categories, scaled by sales.

Critically, for prevention investments, surveyed firms are instructed to report only the *incremental* cost of the cleaner alternative relative to a conventional investment that would otherwise have been made. The full replacement cost of the cleaner equipment is therefore not captured. This has a direct implication for how we interpret our abatement investment estimates. Because prevention expenditures reflect only the marginal environmental premium rather than the full cost of the cleaner asset, *Abate Inv* understates the true investment attributable to climate mitigation purposes.

A concrete example illustrates this measurement issue. In September 2019, Swedish paper company SCA – operating in a D10 industry (NACE 1712) – announced a large investment in a new kraftliner mill in Obbola, Umeå (Figure B.2). Of the total investment of SEK 7.5 billion (approx. USD 800 million), spread over multiple years, approximately SEK 1 billion was explicitly classified as environmental improvements. These earmarked investments included the elimination of roughly 8,000 cubic meters

of annual oil consumption and upgrading the water treatment facility, with the goal of making SCA's industrial processes 97 percent fossil-free. Under CEPA reporting conventions, SCA would report only the SEK 1 billion additional cost of choosing the cleaner configuration as an environmental investment. The remaining SEK 6.5 billion investment, which is also necessary for switching to near-fossil-free production, is classified as regular capital expenditures. Thus, in the data, SCA would display only a modest abatement investment compared to their total capital expenditures.[5]

Because of this ambiguity in measurement, we use two complementary investment variables in the empirical analysis. Total capital expenditure (*Inv*) captures the full investment response of firms to higher carbon prices. Abatement investment (*Abate Inv*) isolates the directional reallocation toward emissions-reducing capital, but almost certainly understates its magnitude.

3 Data and Descriptive Evidence

3.1 Sample construction

We construct the main sample by combining five administrative datasets. The primary source is the annual capital investment survey conducted by Statistics Sweden, covering 2000–2019. We merge these data with: (i) firm- and plant-level CO_2 emissions from the Swedish Environmental Protection Agency (SEPA); (ii) abatement investment data from the Environmental Protection Expenditure Survey (Statistics Sweden)and (iii) firm balance sheet and income statement data from the Serrano dataset. Appendix A.1 provides detailed descriptions of each source. Firm-level observations are consolidated to the corporate group level.

The baseline sample – defined as the intersection of capital investment, CO_2 emissions, and firm financial statement data – contains around 10,000 firm-year observations over 2000–2019. Abatement investment data are available from 2002 onward and cover a smaller set of firms, resulting in approximately 3,000 observations.[6]

[5] In appendix A.2 we provide additional investment examples from other D10 industries during the post-2014 period, further illustrating the limitations of abatement investment as a measure of climate-motivated capital expenditures. Moreover, focusing solely on investment explicitly labeled "abatement investment" likely understates the marginal environmental effect of new investment because new capital is generally more energy-efficient and less polluting than existing capital, irrespective of whether is explicitly labeled "abatement" (e.g., Xepapadeas and de Zeeuw, 1999).

[6] We run investment in logs in section 4 which excludes zeros from the investment variables. This has little impact on the capital investment observation count as almost all firms in the investment

3.2 Industry-level emissions intensity

Manufacturing carbon emissions are highly concentrated in a small number of subsectors (Martinsson et al., 2024). We classify firms based on four-digit NACE industry-level emissions intensity, defined as aggregate CO_2 emissions divided by four-digit PPI-deflated sales in 2000. We rank 4-digit manufacturing subsectors based on this measure and sort them into emissions-intensity deciles, from highest (*D10*) to lowest (D1).[7] Because most manufacturing firms in our sample are exporters, revenues are sensitive to fluctuations in world market prices and exchange rates. Using PPI-deflated sales mitigates this concern, ensuring that the emissions-to-sales ratio approximates emissions per unit of output rather than reflecting variation in output prices. We then group industry deciles into three groups: low (*D1–D4*), mid (*D5–D9*), and high (*D10*) emission-intensity sectors.

Table 1 documents substantial heterogeneity in emissions across deciles. In 2000–2002, *D10* industries account for 83 percent of manufacturing emissions; by 2017–2019, this share rises to 89 percent. In contrast, *D10* industries account for 22.5% of aggregate output at the beginning of the time period, and 17.4% in 2017–2019. Thus, brown industries account disproportionate share of emissions compared to output.

Panel A of Table 1 reports time-series changes in emissions intensity. In 2000–2002, emissions intensity in *D10* industries is 28 times higher than in *D1–D4* and 8 times higher than in *D5–D9*. For *D10* industries, emission intensity falls from 0.0235 to 0.0152 between 2000–2002 and 2017–2019 (a 35 percent decline). Emissions intensity declines even more in lower-emission industries, making emissions increasingly concentrated in *D10* over time. By the end of the sample, emissions intensity in *D10* is 82 (15) times that of *D1–D4* (*D5–D9*).

Figure 3a, Figure 3b, and Figure 3c illustrate these dynamics. Emissions intensity declines steadily in lower-emission industries throughout the sample (72 percent lower in 2019 relative to 2000). High-emission industries experience reductions prior to the financial crisis (approximately 30 percent), but little additional decline thereafter; emissions intensity in *D10* is largely flat after 2012–2013.

Panels B and C of Table 1 relate the emissions-intensity classification to alternative industry characteristics used in the literature. In the absence of direct measures

survey invest every year. However, the abatement investment observation count includes many zeros which we address below.

[7]Based on emission-intensity for the year 2000, 18 industries are classified in *D10*; 14 of these are also in *D10* based 1990 data (Martinsson et al., 2024). Results are robust to the baseline year used.

of marginal abatement costs (Gillingham and Stock, 2018), we examine pollution abatement costs and expenditures (PACE; see e.g., Becker, 2005) and asset mobility (e.g., Ederington et al., 2005). We focus on air pollution abatement costs, which are the relevant abatement expenditures for carbon emissions. High PACE is defined as the aggregate four-digit industry PACE divided by output in 2002 (the first year of the Swedish PACE survey) being above median across all 4-digit industries. Similarly, we classify industries with above-median levels of fixed to total assets in 2000 (the first year of the sample period) as low mobility. Table 1, Panel B shows that all *D10* industries fall in the high PACE group, and 61 percent are characterized by both high PACE and low mobility. Panel C shows that 93 percent of *D10* industries are included on the EU carbon leakage list, primarily due to high emissions intensity.[8] Using U.S. PACE data yields similar classifications. Overall, the emissions-intensity deciles align closely with alternative measures of abatement costs and exposure to climate regulation.

3.3 Firm-level characteristics

Table 2 reports summary statistics for the full sample (Panel A), firms in the high emitting industries (D10; Panel B), and firms in the less emitting industries (deciles 1–9; Panel C). On average, capital expenditures exceed explicitly classified abatement investment across firms. Relative to lower-emission firms, *D10* firms are larger and invest more, both in total capital and in abatement. They rely less on long-term credit, and experience slower sales growth. EBIT margins and cash flows are similar across high- and low-emission industries.

3.4 Carbon prices and aggregate investment

The main takeaway from this paper is captured in Figure 1, which plots aggregate capital investment-to-sales ratios (three-year moving averages) for the manufacturing sector (black dashed line), firms in high (D10, black solid line), and low emitting industries (D1–D9, grey dashed line). The figure also shows the marginal carbon price that manufacturing firms faced during this period (grey dotted line, right axis).

[8] European Commission (2009) includes the initial carbon leakage list. Firms in a given four digit industry can be considered at risk of carbon leakage if it has i) high costs of carbon pricing (i.e., industries with high emission intensity ("Emission"), ii) high level of international competition (i.e., high levels of trade outside of the EU ("Trade only") or, iii) being exposed to both of these factors.

Carbon prices remain relatively stable during 2000–2010 (approximately 0.22–0.25 SEK per kilogram CO_2), increase modestly in 2011–2014 (to roughly 0.35), and rise sharply after 2014 (to approximately 1.15 SEK per kilogram), representing an increase of about 250 percent between 2014 and 2019. During the period of relatively low and stable carbon prices (2000–2014), investment-to-sales ratios decline across manufacturing, with similar trends for high- and low-emission firms; and the investment ratio falls by 23 percent for manufacturing overall (16 percent for high emitting firms and 27 percent for low emitting firms).

After 2014, investment trends diverge. The investment-to-sales ratio increases by 83 percent for high-emitting firms (from approximately 0.03 to 0.05), compared to a 16 percent increase for lower-emission industries (from 0.021 to 0.024). Figure B.3 presents normalized investment-to-sales ratios (indexed to 100 in 2000–2002). Investment declines similarly across groups through 2014 (approximately 35 percent for both high- and low-emission industries). After 2014, investment rises by 55 percent in high emitting industries and by 10 percent in low emitting industries. Over the full sample, investment-to-sales declines by 25 percent in lower-emission industries but increases by 22 percent in high emitting industries.

These trends are reflected in the composition of aggregate manufacturing capital expenditure. The share of investment accounted for by high emitting industries increases from approximately 25 percent to 33 percent over the sample period (Figure 4a). In real terms, aggregate capital expenditures increase by SEK 12 billion over the period, of which high emitting industries account for roughly SEK 7 billion (Figure 4b). Finally, Figure 4c relates investment to internal finance. For high emitting firms, the investment-to-cash-flow ratio increases from 0.325 to 0.500 over the sample period. In contrast, the ratio declines for lower-emission industries. We next turn to formal regression analysis of these patterns.

4 Carbon Pricing and Firm Investment

4.1 Baseline specification

To estimate the sensitivity of investment to carbon pricing, we run the following specification:

$$\ln(\text{Inv}_{i,t}) = \alpha + \sum_{s=0}^{q} \beta_s \ln(C_{i,t-s}) + \gamma X_{i,t-1} + \eta_i + \eta_{j,t} + \epsilon_{i,t}. \quad (1)$$

The dependent variable, $\text{Inv}_{i,t}$, is capital expenditure divided by sales for firm i in year t.[9] The variable $C_{i,t}$ denotes firm-specific carbon emissions cost intensity, defined as the firm's marginal cost of emitting CO_2 multiplied by total emissions and scaled by PPI-deflated sales. We note that because $C_{i,t}$ includes contemporaneous firm emissions, and successful abatement investment mechanically reduces emissions, this construction likely introduces a downward bias in the estimated elasticity: firms that invest and immediately reduce emissions will show a decrease in $C_{i,t}$ alongside an increase in investment, potentially attenuating the positive relationship. The elasticity estimates reported in this section should therefore be interpreted as conservative lower bounds on the true investment response. The difference-in-differences design in section 5, which relies on the shock to carbon prices following the regulatory phase-out of carbon tax exemptions, does not depend on contemporaneous emissions outcomes and arguably provides the cleaner identification. In some specifications we include lagged values of $C_{i,t}$ to allow for delayed responses to changes in carbon pricing.

Firm fixed effects η_i absorb time-invariant heterogeneity across firms. Industry-by-year fixed effects $\eta_{j,t}$ control for shocks common to firms within the same four-digit industry in a given year, including industry-specific demand and investment trends unrelated to carbon pricing. The vector $X_{i,t-1}$ includes lagged firm-level controls: cash flow to assets, log total assets, long-term debt to assets, and PPI-adjusted sales growth.

The estimates of β_s reflect the average sensitivity of investment to changes in the marginal cost of carbon. A negative β would indicate that higher carbon pricing reduces total investment declines, consistent with reduced profitability causing a contraction in productive capacity. A positive β, on the other hand, would indicate that carbon pricing increases total investment, as expected if higher emission costs increase the relative return to investing in lower-emitting capital. Alternatively, these effects may cancel out on average and/or across firms with different production

[9] Firms reporting zero capital expenditure in a given year are excluded from the log-specification, which therefore identifies the investment response on the intensive margin among firms with positive investment. This restriction has minimal impact on the main results: the share of zero-investment firm-year observations in the manufacturing sample is small.

technologies, resulting in a β estimate of zero.

Finally, our linear specification should be viewed as a "local" estimate of the sensitivity of investment to carbon pricing. Strictly speaking, a positive β would imply (unrealistically) that investment increases monotonically at the same rate with the carbon tax level, regardless of the magnitude. Rather, we view the estimates of β as being valid in the range of tax rates that we observe in our sample.

4.2 Carbon pricing and operating margins

Before turning to investment, we examine the extent to which carbon pricing affects firm profitability. The greater the market power of a firm, the larger will be its ability to pass on a carbon tax to customers through higher prices, mitigating the effect of carbon pricing on investment. consistent with incomplete pass-through. However, exports make up about 70% of manufacturing value added in Sweden, and over 80% in high emitting sectors such as basic metals, chemicals and paper and paper products (Flam, 2021). In competitive world markets, we would expect the ability of Swedish firms to pass through carbon tax costs to be very limited.

In Table 3 we report estimates of Equation 1 with operating margins (EBIT divided by sales) as the dependent variable. Because EBIT can be negative, operating margins are normalized to lie between zero and one before being log-transformed. Column 1 shows a statistically significant negative association between carbon pricing and operating margins in the full sample. Given substantial heterogeneity in emissions intensity across industries, we next estimate the specification separately for low-, medium-, and high-emission industries. For firms in low- and medium emitting industries (columns 2 and 3), the estimated coefficients are similar in magnitude to the full-sample estimate, though less precisely estimated. In contrast, column 4 shows that the coefficient estimate for high emitting (D10) firms is nearly three times larger and highly statistically significant.

These results highlight two points. First, the profitability impact of carbon pricing varies systematically with emissions intensity. Second, the negative impact on operating margins for high-emission firms is consistent with incomplete pass-through of carbon emission costs.

4.3 Carbon pricing and capital investment

Table 4 reports estimates of Equation 1. Columns 1–4 include only the contemporaneous carbon emission cost term ($s = 0$), while columns 5–7 incorporate up to three lags. In Column 1, which includes only year fixed effects, the estimated coefficent on the marginal cost of carbon term is 0.108. Adding firm fixed effects, four-digit industry-by-year fixed effects, and firm-level controls reduces the coefficient estimate to 0.055 (column 4). This estimate implies that a 10 percent increase in carbon prices is associated with a 0.6 percent increase in investment. Columns 5–7 allow for delayed responses. The contemporaneous effect remains positive and statistically significant. When three lags are included (column 7), the cumulative elasticity is 0.123, approximately 60 percent larger than the contemporaneous estimate.

Table B.2 reports robustness checks. Alternative constructions of firm-level marginal carbon emission cost intensity —using sales- or asset-weighted plant measures — yield similar results (columns 1–2). The baseline elasticity is also similar if we scaling investment and carbon emission cost by total assets (column 3), or control for lagged investment ratios (columns 4–5).

4.4 Heterogeneous effects

Next, we estimate Equation 1 separately by emissions-intensity group. Table 5 reports results for firms in *D1–D4* (columns 1–2), *D5–D9* (columns 3–4), and *D10* (columns 5–6). Because deciles are based on beginning-of-sample-period emission intensities, differences across groups are not driven by endogenous sorting.

For low- and medium-emission industries, the estimated elasticities are small and statistically indistinguishable from zero. In contrast, the response is economically large and precisely estimated for the high-emitting firms in *D10*. The contemporaneous elasticity is 0.168 (column 5). Allowing for lags increases the cumulative elasticity to 0.309 (column 6), consistent with delayed adjustment.[10] Thus, in the sub-sample of *D10* firms, a 10% increase in the marginal cost of carbon is associated with a 3% increase in capital investment.

Table 6 examines heterogeneity with respect to alternative measures of industry carbon tax exposure. The first measure is based on *ex ante* costs of reducing CO_2

[10]Including the lagged cost terms changes the regression sample. For comparability, in Table B.3 we report results with only the contemporaneous marginal cost term in smaller sample (even numbered columns in Table 5).

emissions, using data on air pollution abatement costs and expenditure (PACE; see Becker, 2005). The second measure captures the *ex ante* mobility of a firm's assets (Ederington et al., 2005). The largest investment response is for firms in high PACE and low mobility sectors – i.e., firms that face high abatement costs and are less able to avoid carbon taxes by moving production. We find similar results when we separate firms by whether their sub-sector is included on the EU "carbon leakage list" (European Commission, 2009).

Finally, we explore the intersection between emission-intensity and these alternative measures of carbon cost exposure. Table 7 shows that the strongest effects occur in firms that are both high-emitting (*D10*) and operate in high-abatement-cost industries. In contrast, firms in hard-to-abate or leakage-exposed industries that are not also high-emitting have small and statistically insignificant elasticities. These findings highlight the importance of focusing on emissions-intensive sectors to evaluate the effects of carbon pricing.

4.5 Abatement and the composition of investment

So far we have considered the effect of carbon pricing on total investment. Since not all investment is necessarily driven by reducing emissions, however, this can be considered an upper bound of green investment. For a subset of firms, we observe incremental capital expenditures on air emissions treatment and air emissions prevention equipment from the annual Environmental Protection Expenditure Survey conducted by Statistics Sweden starting in 2002 (see subsection A.1 for details). As we explained in subsection 2.2, this expenditure is defined as the incremental investment cost due to abatement measures, and can therefore be considered a lower bound on green investment.

We scale the incremental abatement investment variable by sales and denote it as *Abate Inv.* First, using the abatement sample, we re-estimate the baseline specification with total capital investment as the dependent variable. As reported in Table B.4, the investment-to-carbon-price elasticity in this subsample is 0.157, compared to 0.055 in the full manufacturing sample. This difference likely reflects the composition of the abatement survey, which oversamples D10 firms.

We present results in Table 8. Panel A runs OLS regressions in a log-log specification, analogous to Table 4. Since abatement investment is zero for a large fraction of surveyed firm-years, however, this analysis only covers the intensive margin

response to carbon pricing. Panel B shows results without logging the dependent variable estimated using Poisson Pseudo-Maximum Likelihood (PPML), as proposed by Cohn et al. (2022), which also captures the extensive margin response.[11] Columns 1–3 of Table 8 report estimates using *Abate Inv* as the dependent variable. For the full manufacturing sample, the elasticity of abatement investment with respect to carbon pricing is 0.468 (0.418) in the log-log (PPML) specification. Notably, the elasticity is small and insignificantly different from zero for firms in low emitting industries, but 0.700 (0.517) for firms in high emitting industries. In columns 4 and 5 we examine abatement capital spending divided by total capital expenditures (logged in Panel A and using PPML in Panel B). In high-emitting firms, the share of incremental environmental abatement investment-to-total capital expenditures increases sharply with higher carbon prices. This finding suggests that the investment response we document reflects investment in cleaner capital rather than purely scale expansion. Finally, columns 6 and 7 decomposes abatement investment into spending designated to the treatment of existing pollution and the prevention of future of pollution. A reason for making this distinction is abatement of CO_2 emissions is not about filtering out or cleaning up emissions (*Treatment*), but rather about changing to a lower-emitting production technology (*Prevent*). As expected, the majority of abatement investment appears to focus on the prevention of future pollution.

5 Quasi-experimental Evidence

5.1 Event regressions

We exploit the sharp increase in effective carbon prices beginning in 2015 as a quasi-experimental shock. Specifically, we estimate how the difference in capital investment between high-emitting firms and other manufacturing firms changes after the policy change. This event-based design complements the elasticity estimates by isolating discrete shifts in the carbon pricing regime. While this approach does not provide elasticity estimates, it has a number of other advantages: it bypasses the challenges associated with measuring the firm-specific marginal cost of carbon emissions (which are potentially endogenous to firm investment and production

[11] Alternatively, we have run specifications using the inverse hyperbolic sine transformation, with qualitatively similar results. Also, in Table B.5 we include specifications with the full lag structure of carbon prices.

decisions), it does not impose a strict log-linear functional form, and it allows us to expand the sample beyond firms for which plant-level emissions data are available.

Specifically, we estimate the following difference-in-differences specifications (with and without fixed-effects):

$$Inv_{i,t} = \sigma + \omega \cdot D10\ firm_i + \kappa \cdot Post_t + \phi(D10\ firm_i \cdot Post_t) + \epsilon_{i,t} \tag{2}$$

$$Inv_{i,t} = \sigma + \phi(D10\ firm_i \cdot Post_t) + \eta_i + \eta_t + \epsilon_{i,t} \tag{3}$$

D10 firm equals one if the firm operates in a top-decile emissions-intensity industry. *Post* equals one for years 2015–2019 and zero for 2010–2014. η_i and η_t are firm and year fixed-effects, respectively. Identification relies on the assumption that, absent the post-2014 carbon price increase, investment trends in *D10* and other manufacturing industries would have evolved similarly. Pre-2015 investment trends are comparable across groups, consistent with this assumption (Figure 1). The coefficient of interest, ϕ, captures the differential change in investment for *D10* firms in the post period.

We report estimates for the full manufacturing sample in the first three columns of Table 9. In column 1, without fixed effects, both *D10 firm* and *Post* enter positively, indicating that high-emission firms invest at higher rates on average and that investment increases economy-wide after 2015. Most importantly, the interaction term is positive and statistically significant, indicating a differential post-2015 investment increase among *D10* firms. The point estimate indicates that the yearly investment-to-sales ratio increases by 0.012 for D10 relative to firms in lower-emitting industries (compared to an overall sample mean of 0.028).

Including firm fixed-effects as in Equation 3 absorbs time-invariant differences in investment levels across industries, while year fixed-effects absorb aggregate investment shocks common to all firms. Because year fixed-effects capture macroeconomic conditions, the identifying variation arises from differential changes across emissions-intensity groups in the same year. The interaction coefficient is identical to before and statistically significant when these controls are included (columns 2 and 3). Robustness checks reported in Table B.7 confirm that the results are similar when collapsing the data to one pre- and one post-period observation per firm, and when restricting the sample to firms with emissions data.

5.2 Internal finance and investment

We also use the event-study framework to investigate the sensitivity of the green investment response to financial constraints. We first focus on the extent to which firms have access to internal cash flow (as opposed to having to rely on external funding). Our preferred proxy is *Div Firm*, an indicator equal to one if the firm paid dividends in the pre-period 2010-2014. We augment Equation 3 with interactions between *Div Firm*, *D10 firm*, and *Post*. The interaction *D10 firm* $\cdot$ *Post* now captures the response of high emitting firms that did not distribute dividends prior to 2015. The results in column 4 of Table 9 show that the differential post-2015 investment response is entirely driven by *D10* firms that paid dividends prior to the policy change, with a coefficient of 0.020 on the *Div Firm* $\cdot$ *D10 firm* $\cdot$ *Post* interaction term. The investment response for high-emitting firms that did not pay dividends is close to zero and statistically insignificant.

To further explore the financing mechanism, we examine whether dividend-paying *D10* firms reduce payouts to help finance the post-2014 increase in investment. Using dividend payments scaled by cash flow as the dependent variable, columns 5–8 show that high-emitting firms who paid dividends in the pre-period reduce dividend payouts sharply in the post-period. The reduction in dividend payouts is economically large, indicating that internal cash flow is the primary way firms fund their new capital spending.[12] Table B.6 reports descriptive statistics that corroborate this pattern: between 2010–2014 and 2015–2019 there is a sharp differential increase in investment and a corresponding reduction in dividends among dividend-paying firms in *D10*.

Table B.7 shows results for alternative measures of financial capacity. First, we construct pre-period averages (2010–2014) of cash flow to assets and sort firms by whether they are above or below the median, with similar results. We also examine proxies to capture variation in access to external finance, including credit ratings and long-term debt ratios. In contrast to the internal finance measures, proxies for external financing capacity are not associated with a differential post-2015 investment in *D10* industries. This suggests that green investment relies on high-emitting firms having access to internal funds. A potential explanation could be that brown firms have a higher cost of external capital, as documented by Hartzmark and Shue (2026). Consistent with this, Kacperczyk and Peydró (2026) show that climate commitments

[12] On average, in *D10* firms dividend payouts to cash flow decline by 0.282 in the post period (from 0.346 to 0.064) and capital investment relative to cash flow increases by 0.164 (0.347 to 0.511).

cause banks to reduce lending to high-emitting firms, in turn leading to lower leverage and lower investment in these firms.

Finally, we examine the extent to which high-emitting firms are more likely to exit the market in response to the increase in carbon pricing. The results, shown in Appendix Tables B.8 and B.9, do not indicate any relative increase in exit rates among *D10* firms following the carbon price increase.

Overall, the event-study evidence suggests that the post-2014 increase in carbon pricing triggered a differential investment responses in high-emitting firms, and that this response was financed primarily through reductions in dividend payouts.

5.3 Cross-country evidence

A concern with the results so far is that the increase in investment in high-polluting, Swedish firms may simply reflect broader industry trends, such as global shifts in technology or demand conditions. To address this possibility, we construct a country-by-industry panel using four-digit manufacturing data from Eurostat and compare investment patterns in Sweden to other EU countries. Specifically, we focus on the following triple-difference specifications:

$$Inv_{cj,t} = \sigma + \zeta \cdot Sweden + \omega \cdot D10 + \kappa \cdot Post + \phi(Sweden \cdot D10 \cdot Post) + \epsilon_{cj,t}. \quad (4)$$

$$Inv_{cj,t} = \sigma + \phi(Sweden \cdot D10 \cdot Post) + \eta_{jt} + \eta_{cj} + \eta_{ct} + \epsilon_{cj,t}. \quad (5)$$

$Inv_{cj,t}$ is capital investment for country-industry cj at time t. Country-industry fixed effects (η_{cj}) absorb time-invariant differences across country-industry pairs; industry-year fixed effects (η_{jt}) absorb common industry-wide shocks across Europe; and country-year fixed effects (η_{ct}) absorb macro-conditions specific to each country. The ϕ term then captures the differential investment response of high-emission industries in Sweden in the 2015–2019 period.

As a preliminary comparison, Table B.10 reports average capital expenditure-to-sales ratios across 2010–2014 and 2015–2019 for Sweden and the rest of the EU. High emitting Swedish industries increase investment intensity by 0.016 in the post period, while cleaner Swedish industries show little change, consistent with the firm-level evidence. In contrast, high-emitting industries in the EU (excl. Sweden) show only modest investment increases. The pattern is similar if we restrict the sample to EU15 countries or exclude all of the Nordic countries.

Table 10 reports estimates of Equation 4 (the specification without any fixed effects). Column 1 shows higher investment intensities for high-emitting industries in the 2010–2014 period and a general increase in manufacturing investment in the post period across EU countries. However, in high-emitting industries outside Sweden, there is no differential increase in investment in the post-2015 period, compared to the triple-interaction for Swedish high-emitting industries in the post-period which is positive and statistically significant. Column 5 shows the same result when estimating Equation 5 with country-year, industry-year, and industry-country fixed effects.

Notably, the magnitude of the triple-difference estimate closely matches the corresponding firm-level estimates reported in column 3 of Table 9. Taken together, these results are consistent with the interpretation that the post-2014 increase in Swedish carbon prices, rather than broader European trends, drove the observed investment response among high-emission industries.

6 Conclusion

Using detailed firm-level data from Swedish manufacturing over two decades, we show that large increases in carbon pricing are associated with higher capital investment of firms in the highest-emitting industries. However, the investment response is only found among high-emitting firms with sufficient internal financial capacity; these firms reduce dividend payouts and reinvest internal cash flow into cleaner capital.

Thus, pricing CO_2 emissions can incentivize brown firms to make green investments. The evidence does not support the view that carbon pricing primarily leads to disinvestment or relocation. Instead, when prices rise to economically meaningful levels, firms undertake lumpy capital adjustments and expand abatement investment. These patterns are not driven by broader European trends in high-emission industries. Overall, our results show that carbon pricing can function as a capital reallocation mechanism, steering private investment toward emissions-reducing technologies through standard market incentives.

While we believe Swedish manufacturing provides an ideal experimental setting, it also raises some questions regarding external validity.

First, because Sweden is a small, export-oriented economy, manufacturing firms have a limited ability to shift carbon costs into higher output prices (see e.g., Martinsson et al., 2024). Firms that cannot pass on emission costs to customers should face stronger pressure to invest in emission-reducing capital.

Second, Sweden has an unusually high carbon price compared to other countries. After 2014, the effective marginal cost of emitting carbon faced by Swedish manufacturers reached the range of standard social cost of carbon estimates and stood well above contemporaneous EU ETS allowance prices. While this is useful for identification, our elasticities may not extrapolate to lower-price regimes. In addition, the broad political agreement on carbon pricing in Sweden during our sample period may have further encouraged firms to invest by reducing uncertainty about future policy (Biais and Landier, 2026).

Third, Sweden has a relatively high supply of cheap, non-fossil energy (Eurostat, 2026). As a result, the ability of brown manufacturing firms to reduce emissions through adopting green technology may be higher in Sweden than other countries, increasing the investment response to carbon pricing.

Finally, we want to highlight what we believe are promising avenues for future research. First, given the caveats on external validity just mentioned, there is a need for additional studies that investigate the effect of climate policy on green investment in other settings and different institutional environments. Second, given the lag between capital expenditures and actual production, and the fact that most of the investment response occurs towards the end of our sample period, we are not able to trace out the effects of green investment on subsequent carbon emissions; nor its full implications for productivity. With access to a longer time series, future work can hopefully provide more comprehensive evaluation of the ultimate effectiveness of carbon pricing on decarbonization and economic efficiency.

References

Acemoglu, D., Akcigit, U., Hanley, D., and Kerr, W. (2016). Transition to clean technology. *Journal of Political Economy*, 124(1):52–104.

Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R., and Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy*, 124(1):1–51.

Akey, P. and Appel, I. (2021). The limits of limited liability: Evidence from industrial pollution. *The Journal of Finance*, 76(1):5–55.

Akey, P., Appel, I., Bellon, A., and Klausmann, J. (2025). Do carbon markets undermine private climate initiatives? *SSRN-4938460*.

Bartram, S. M., Hou, K., and Kim, S. (2022). Real effects of climate policy: Financial constraints and spillovers. *Journal of Financial Economics*, 143(2):668–696.

Becker, R. (2005). Air pollution abatement costs under the Clean Air Act: Evidence from the PACE survey. *Journal of Environmental Economics and Management*, 50:144–169.

Biais, B., Hombert, J., Schmidt, D., and Weill, P.-O. (2026). Cap and trade with imperfect hedging. *Working Paper*.

Biais, B. and Landier, A. (2026). Emission caps and investment in green technologies. *The Review of Financial Studies*, page hhag060.

Bilal, A. and Känzig, D. R. (2025). Does unilateral decarbonization pay for itself? In *AEA Papers and Proceedings*, volume 115, pages 369–373. American Economic Association 2014 Broadway, Suite 305, Nashville, TN 37203.

Bilal, A. and Känzig, D. R. (2026). The macroeconomic impact of climate change: Global versus local temperature. *The Quarterly Journal of Economics*, page qjag011.

BillerudKorsnäs (2016). BillerudKorsnäs makes strategic investment in Gruvön. Press release, December 12, 2016, BillerudKorsnäs.

Bolton, P., Lam, A., and Muûls, M. (2026). Do carbon prices affect stock prices? *Journal of Financial Research*, 49(2):631–665.

Borealis (2015). Borealis further upgrades cracker operations in Stenungsund, Sweden. Press release, July 1, 2015, Borealis.

Brown, J. R., Martinsson, G., and Thomann, C. (2022). Can environmental policy encourage technical change? Emissions taxes and R&D investment in polluting firms. *The Review of financial studies*, 35(10):4518–4560.

Bustamante, C. and Zucchi, F. (2024). Financially constrained carbon management. Working paper, University of Maryland.

Calel, R. and Dechezleprêtre, A. (2016). Environmental policy and directed technological change: evidence from the european carbon market. *Review of Economics and Statistics*, 98(1):173–191.

Cohn, J. B., Liu, Z., and Wardlaw, M. I. (2022). Count (and count-like) data in finance. *Journal of financial economics*, 146(2):529–551.

Colmer, J., Martin, R., Muûls, M., and Wagner, U. J. (2025). Does pricing carbon mitigate climate change? firm-level evidence from the european union emissions trading system. *Review of Economic Studies*, 92(3):1625–1660.

Conte, B., Desmet, K., and Rossi-Hansberg, E. (2026). On the geographic implications of carbon taxes. *The Economic Journal*, 136(677):1547–1581.

Cooper, R. W. and Haltiwanger, J. C. (2006). On the nature of capital adjustment costs. *The Review of Economic Studies*, 73(3):611–633.

Davis, S. J., Caldeira, K., and Matthews, H. D. (2010). Future CO_2 emissions and climate change from existing energy infrastructure. *Science*, 329(5997):1330–1333.

Dechezleprêtre, A., Nachtigall, D., and Venmans, F. (2023). The joint impact of the European Union Emissions Trading System on carbon emissions and economic performance. *Journal of Environmental Economics and Management*, 118:102758.

Dixit, A. K. and Pindyck, R. S. (1994). *Investment under uncertainty*. Princeton university press.

Döttling, R. and Rola-Janicka, M. (2025). Too levered for Pigou? Carbon pricing, financial constraints, and leverage regulation. *Journal of Financial Economics*, 172:104105.

Duchin, R., Gao, J., and Xu, Q. (2025). Sustainability or greenwashing: Evidence from the asset market for industrial pollution. *The Journal of Finance*, 80(2):699–754.

Ederington, J., Levinson, A., and Minier, J. (2005). Footloose and pollution-free. *Review of Economics and Statistics*, 87(1):92–99.

European Commission (2009). Determining, pursuant to directive 2003/87/ec of the European Parliament and of the council, a list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010D0002&from=EN.

European Parliament and Council (2011). Regulation (EU) no 691/2011 of the European Parliament and of the Council on European environmental economic accounts.

Eurostat (2026). Electricity prices components for non-household consumers – annual data (from 2007 onwards). Online data code: nrg_pc_205_c; last updated 19 May 2026.

Fang, M., Hsu, P.-H., and Tsou, C.-Y. (2025). Financial frictions and pollution abatement over the life cycle of firms. *Available at SSRN 4390975*.

Flam, H. (2021). Den internationella handelns betydelse för sverige. https://www.svensktnaringsliv.se/sakomraden/internationell-handel/den-internationella-handelns-betydelse-for-sverige_1177364.html.

Ganapati, S., Shapiro, J. S., and Walker, R. (2020). Energy cost pass-through in us manufacturing: Estimates and implications for carbon taxes. *American Economic Journal: Applied Economics*, 12(2):303–342.

Gillingham, K. and Stock, J. H. (2018). The cost of reducing greenhouse gas emissions. *Journal of Economic Perspectives*, 32(4):53–72.

Gillingham, K. T., Barrage, L., Armitage, S., Burtraw, D., Colmer, J., de Preux, L., Hawkins-Pierot, J., Holt, C., Karplus, V. J., Löfgren, Å., Martin, R., Miller, N., Muûls, M., Osborne, M., Severnini, E., Shobe, W., Sileo, G., Smirnyagin, V., Stoerk, T., Tsyvinski, A., Wagner, K., Wagner, U. J., and Wu, X. (2025). New frontiers in research on industrial decarbonization. *Science*, 390(6771):338–340.

Golosov, M., Hassler, J., Krusell, P., and Tsyvinski, A. (2014). Optimal taxes on fossil fuel in general equilibrium. *Econometrica*, 82(1):41–88.

Hartzmark, S. M. and Shue, K. (2026). Counterproductive sustainable investing: The impact elasticity of brown and green firms. *The Journal of Finance*.

Hicks, J. R. (1932). *The Theory of Wages*. Macmillan, London.

Jacob, M. and Zerwer, K. L. (2024). Emission taxes and capital investments: The role of tax incidence. *The Accounting Review*, pages 1–32.

Kacperczyk, M. and Peydró, J.-L. (2026). Carbon emissions and the bank-lending channel. *The Review of Financial Studies*, page hhag078.

Känzig, D. R. (2025). The unequal economic consequences of carbon pricing. Technical report, National Bureau of Economic Research.

Lanteri, A. and Rampini, A. (2025). Financing the adoption of green technology. *NBER Working Paper*, 33545.

Levinson, A. and Taylor, M. S. (2008). Unmasking the pollution haven effect. *International economic review*, 49(1):223–254.

Martin, R., De Preux, L. B., and Wagner, U. J. (2014). The impact of a carbon tax on manufacturing: Evidence from microdata. *Journal of Public Economics*, 117:1–14.

Martinsson, G., Sajtos, L., Strömberg, P., and Thomann, C. (2024). The effect of carbon pricing on firm emissions: Evidence from the swedish co2 tax. *The Review of Financial Studies*, 37(6):1848–1886.

Moore, F. C., Drupp, M. A., Rising, J., Dietz, S., Rudik, I., and Wagner, G. (2024). Synthesis of evidence yields high social cost of carbon due to structural model variation and uncertainties. *Proceedings of the National Academy of Sciences*, 121(52):e2410733121.

Newell, R. G., Jaffe, A. B., and Stavins, R. N. (1999). The induced innovation hypothesis and energy-saving technological change. *Quarterly Journal of Economics*, 114(3):941–975.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review*, 109(6):1991–2014.

Nordhaus, W. D. (1992). An optimal transition path for controlling greenhouse gases. *Science*, 258(5086):1315–1319.

Oehmke, M. and Opp, M. M. (2025). A theory of socially responsible investment. *Review of Economic Studies*, 92(2):1193–1225.

Oehmke, M. and Opp, M. M. (2026). Green capital requirements: Prudential regulation, credit allocation, and climate policy. *Journal of Finance*.

Pastor, L., Stambaugh, R., and Taylor, L. (2026). Carbon burden. Nber working paper no. w33110.

Pedersen, L. H. (2026). Carbon pricing versus green finance. *The Journal of Finance*.

Popp, D. (2002). Induced innovation and energy prices. *American economic review*, 92(1):160–180.

Rafaty, R., Dolphin, G., and Pretis, F. (2025). Carbon pricing and the elasticity of CO_2 emissions. *Energy Economics*, 144:108298.

SCA (2019). SCA invests in Obbola kraftliner mill. Press release, September 2, 2019, Svenska Cellulosa Aktiebolaget SCA.

SSAB (2018). HYBRIT's world-first pilot plant wins energy agency's backing. Press release, June 18, 2018, SSAB.

Tong, D., Zhang, Q., Zheng, Y., Caldeira, K., Shearer, C., Hong, C., Qin, Y., and Davis, S. J. (2019). Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target. *Nature*, 572(7769):373–377.

World Bank (2025). State and trends of carbon pricing 2025.

Xepapadeas, A. and de Zeeuw, A. (1999). Environmental policy and competitiveness: the porter hypothesis and the composition of capital. *Journal of Environmental Economics and Management*, 37(2):165–182.

Xu, Q. and Kim, T. (2022). Financial constraints and corporate environmental policies. *The Review of Financial Studies*, 35(2):576–635.

Figure 1: Investment and carbon prices in Swedish manufacturing

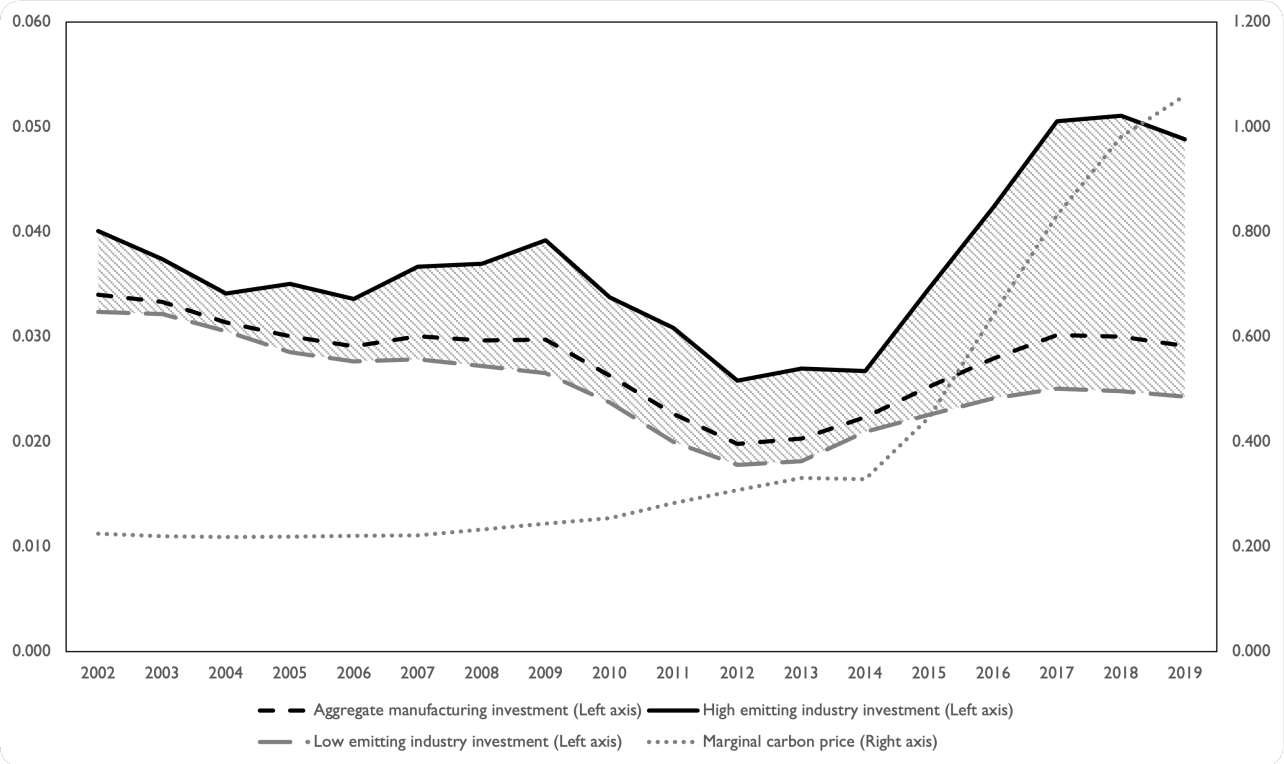


Figure 1 displays aggregate capital investment-to-sales ratios (left axis) for (i) all manufacturing firms (dashed black line), (ii) high-emitting industries (D10; solid black line), and (iii) low- and medium-emitting industries (D1–D9; dashed gray line). The dotted gray line shows the marginal carbon price (right axis), measured in constant 2020 SEK per kilogram of CO_2. The shaded area between the high- and low-emitting series highlights the gap in investment intensity between the two groups. High-emitting (D10) industries comprise firms in the four-digit industries in the top decile of carbon emissions to sales in 2000; low- and medium-emitting (D1–D9) industries comprise the remaining nine deciles. All series are three-year rolling averages (from t to $t-2$) over 2000–2019.

Figure 2: Swedish carbon prices and Social Cost of Carbon estimates

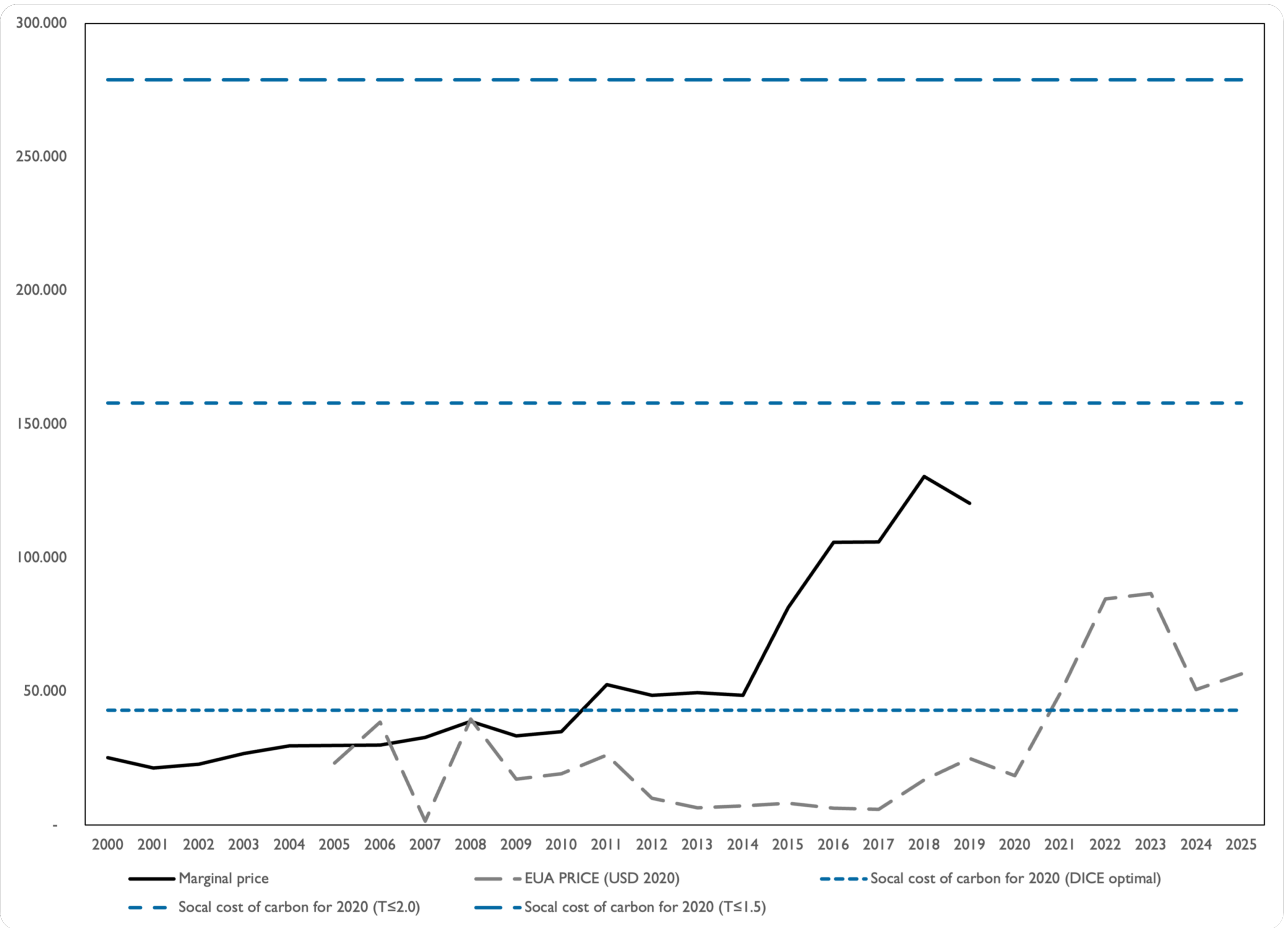
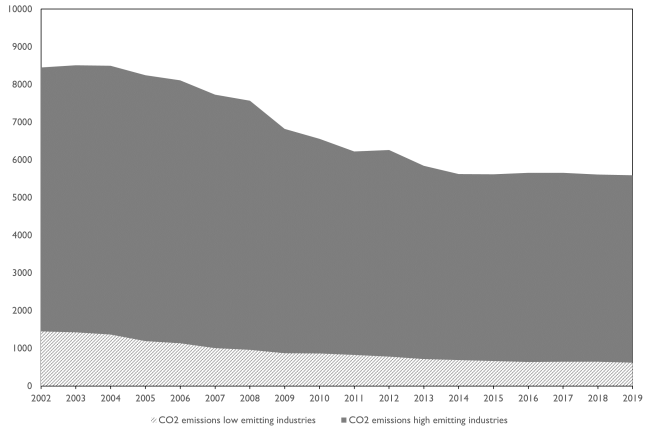


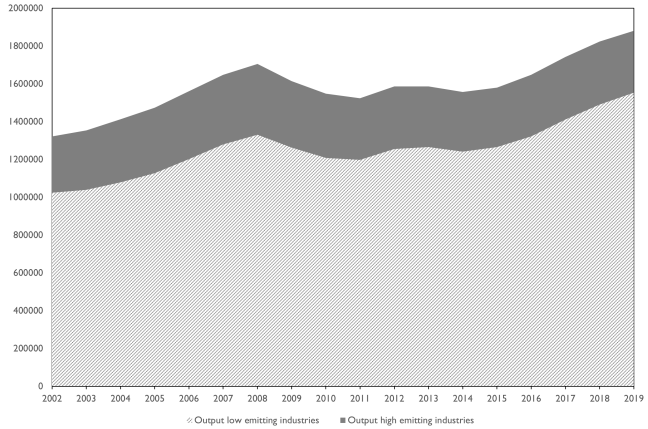
Figure 2 displays the marginal carbon price faced by firms in our sample (solid black line), converted to constant 2020 US dollars per ton of CO_2 and plotted through 2019. The gray dashed line shows the EU Emission Allowance (EUA) price, also in constant 2020 US dollars, plotted through 2025. The three horizontal blue dashed lines are estimates of the 2020 social cost of carbon (SCC) from Nordhaus (2019): the baseline optimal DICE estimate (short dashes, lowest), the SCC consistent with a 2°C-or-under target (medium dashes, middle), and the SCC consistent with a 1.5°C-or-under target (long dashes, highest)

Figure 3: Carbon emissions and output in Swedish manufacturing

(a) Aggregate carbon emissions (kt)



(b) Aggregate output (BSEK)



(c) Aggregate CO_2 to output (kg per SEK)

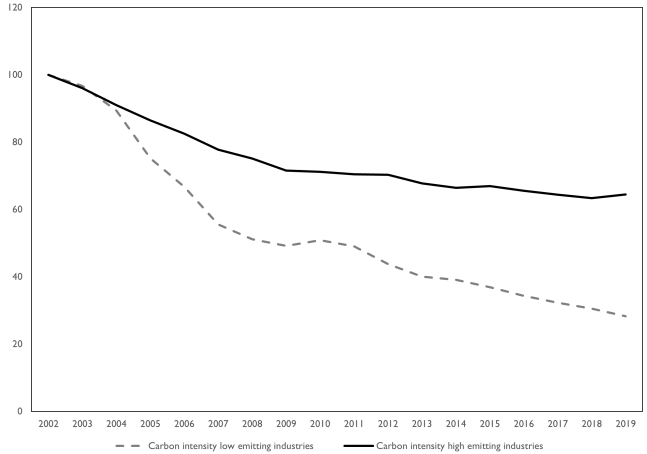


Figure 3 summarizes emissions and output for high- and low-emitting industries. Panels A and B are stacked area charts: Panel A shows aggregate carbon emissions (kilotons) and Panel B aggregate output (SEK billion), each split into high-emitting industries (D10; dark grey) and low-emitting industries (D1–D9; light grey), so that the total height equals the manufacturing aggregate. Panel C shows aggregate carbon intensity—emissions per unit of (PPI-deflated) output, in kg of CO_2 per SEK—indexed to 100 in 2002, for high-emitting (solid black line) and low-emitting (dashed grey line) industries. High-emitting (D10) industries comprise firms in the four-digit industries in the top decile of carbon emissions to sales in 2000; low-emitting (D1–D9) industries comprise the remaining nine deciles. All series are three-year rolling averages (from t to $t-2$) over 2000–2019

Figure 4: Investment shares and financing by emissions intensity groups

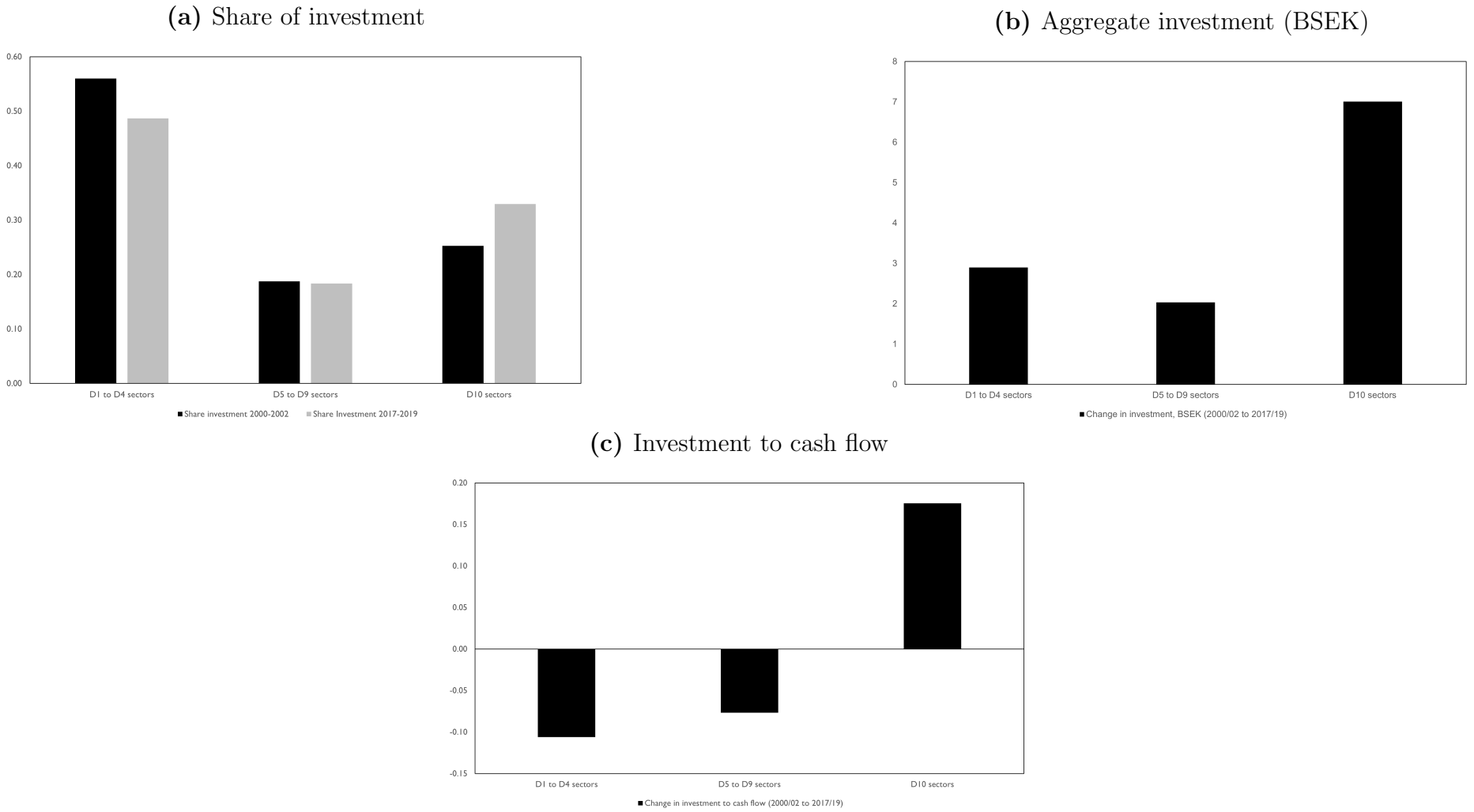


Figure 4 compares investment across emissions-intensity groups between the start and end of the sample period. Panel A shows the share of total manufacturing capital investment accounted for by eachgroup—D1–D4, D5–D9, and D10—in 2000–2002 (black bars) and 2017–2019 (grey bars). Panel B shows the change in aggregate real capital expenditures (SEK billion) by group between the 2000–2002 and 2017–2019 windows. Panel C shows the change in the investment-to-cash-flow ratio by group between the same two windows; the ratio rises for D10 and falls for the two lower-emitting groups. D1–D4 (D5–D9; D10) comprise firms in the four-digit industries in the bottom four deciles (fifth-to-ninth deciles; top decile) of carbon emissions to sales in 2000. All investment measures are three-year averages.

Table 1: Sorting the manufacturing sector in to emission decile groups

	ALL	D1–D4	D5–D9	D10
Panel A: Distribution of emissions, output and carbon intensity				
Share CO_2 2000–2002	1.000	0.076	0.095	0.828
Share CO_2 2017–2019	1.000	0.038	0.073	0.889
Share output 2000–2002	1.000	0.568	0.206	0.225
Share output 2017–2019	1.000	0.614	0.210	0.174
CO_2 to output 2000–2002	0.0064	0.0009	0.0030	0.0235
CO_2 to output 2017–2019	0.0030	0.0002	0.0010	0.0152
Panel B: Pollution abatement costs and mobility				
Low PACE	0.497	0.616	0.520	0.000
High PACE	0.503	0.384	0.480	1.000
Low Mobility	0.486	0.298	0.608	0.640
High Mobility	0.514	0.702	0.392	0.360
Low PACE & Low Mobility	0.146	0.106	0.221	0.000
Low PACE & High Mobility	0.351	0.506	0.305	0.000
High PACE & Low Mobility	0.337	0.174	0.410	0.613
High PACE & High Mobility	0.167	0.215	0.064	0.387
Panel C: EU leakage list and US based PACE measure				
Share firms on EU Carbon leakage list	0.484	0.545	0.334	0.930
On list for outside EU trade concern	0.371	0.540	0.287	0.117
On list for high emissions concern	0.113	0.005	0.048	0.813
Low PACE US	0.511	0.706	0.472	0.012
High PACE US	0.489	0.294	0.528	0.988

Table 1 reports statistics across emissions-intensity groupings. D1–D4 comprise firms in the four-digit industries in the bottom four deciles (bottom 40%) of carbon emissions to sales in 2000, D5–D9 the fifth-to-ninth deciles, and D10 the top decile; ALL is the full manufacturing sector. Panel A reports each group's share of aggregate CO_2 emissions and of aggregate output (PPI-deflated sales), and the ratio of aggregate emissions to output, averaged over 2000–2002 and 2017–2019. Panel B reports the share of firms in each group that fall in low (high) pollution abatement capital expenditure (PACE) industries—defined as below (above) the median four-digit-industry ratio of abatement investment to sales in the first year of abatement data (2002)—and in low (high) mobility industries—defined as above (below) the median four-digit-industry ratio of fixed assets to total assets in the first year of asset data (2000). The final four rows of Panel B report the share of firms in each PACE × mobility combination. Panel C reports the share of firms in industries on the European Union (EU) carbon leakage list (and, separately, on the list for trade concerns or for high-emission concerns), and, in the final two rows, the share of firms in low (high) PACE industries using US data, defined as below (above) the median four-digit-industry ratio of abatement expenditure to shipments from the 2005 US Environmental Protection Agency PACE survey.

Table 2: Summary statistics

	OBS	Mean	25th	Median	75th	St Dev
			Panel A: Full sample			
Inv	10,668	0.028	0.005	0.015	0.033	0.044
C	10,668	0.0011	0.0001	0.0003	0.0011	0.0021
Abate Inv	3,622	0.0006	0.0000	0.0000	0.0001	0.0019
Share Abate Inv	3,548	0.0267	0.0000	0.0000	0.0066	0.0928
EBIT	10,668	0.042	0.012	0.043	0.080	0.111
Cash flow	9,983	0.120	0.050	0.096	0.149	0.194
Total assets (BSEK)	10,668	3.209	0.057	0.202	0.873	18.100
Long term debt	10,668	0.145	0.000	0.064	0.230	0.198
Sales gwth	9,891	0.130	-0.060	0.020	0.116	0.758
			Panel B: Decile 10			
Inv	1,088	0.041***	0.011	0.024	0.047	0.054
C	1,088	0.0033***	0.0005	0.0019	0.0044	0.0039
Abate Inv	619	0.0016***	0.0000	0.0002	0.0013	0.0032
Share Abate Inv	614	0.0521***	0.0000	0.0066	0.0397	0.1180
EBIT	1,088	0.046	0.013	0.050	0.092	0.114
Cash flow	984	0.109	0.047	0.091	0.137	0.182
Total assets (BSEK)	1,088	9.188***	0.249	1.043	5.639	31.900
Long term debt	1,088	0.117	0.000	0.001	0.168	0.205
Sales gwth	974	0.098	-0.060	0.008	0.086	0.684
			Panel C: Decile 1–9			
Inv	9,580	0.027	0.005	0.014	0.031	0.042
C	9,580	0.0008	0.0000	0.0003	0.0008	0.0016
Abate Inv	3,003	0.0004	0.0000	0.0000	0.0000	0.0856
Share Abate Inv	2,934	0.0213	0.0000	0.0000	0.0027	0.0856
EBIT	9,580	0.042	0.011	0.042	0.079	0.110
Cash flow	8,999	0.121	0.050	0.096	0.151	0.195
Total assets (BSEK)	9,580	2.530	0.052	0.173	0.710	15.600
Long term debt	9,580	0.148***	0.000	0.073	0.234	0.197
Sales gwth	8,917	0.133***	-0.060	0.022	0.119	0.766

Table 2 reports summary statistics for the key variables across emissions-intensity groupings, with Panel A covering the full sample, Panel B decile 10 (D10), and Panel C deciles 1–9 (D1–D9); D10 (D1–D9) comprise firms in the four-digit industries in the top decile (bottom nine deciles) of carbon emissions to sales in 2000. The sample comprises Swedish manufacturing firms (NACE 1000–3300) with capital expenditure and CO_2 emissions data over 2000–2019, and all monetary values are in constant 2020 Swedish kronor (SEK). *Inv* is the capital expenditure to sales ratio. *C* is the marginal cost of emitting CO_2 (marginal cost × total CO_2 emissions) divided by sales. *Abate Inv* is air pollution abatement capital expenditure divided by sales. *Share Abate Inv* is air pollution abatement capital expenditure divided by total capital investment. *EBIT* is earnings before interest and taxes divided by sales. *Cash flow* is cash flow divided by total assets. *Total assets* is the book value of total assets (SEK billion). *Long term debt* is long-term bank debt divided by total assets. *Sales gwth* is the annual log change in PPI-adjusted sales. In Panels B and C, ***, **, and * indicate that the difference in means between D10 and D1–D9 is significant at the 1% , 5% , and 10% levels.

Table 3: Carbon pricing and operating margins

	(1)	(2)	(3)	(4)
	All	**D1–D4**	**D5–D9**	**D10**
$\ln(C_{i,t})$	-0.003***	-0.003*	-0.002*	-0.009***
	(0.001)	(0.002)	(0.001)	(0.003)
Firm fixed effects	Yes	Yes	Yes	Yes
Industry × Year effects	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes
Observations	6,234	2,483	3,071	680
Adjusted R^2	0.460	0.543	0.499	0.207

Table 3 reports OLS estimates of Equation 1. The dependent variable is $\ln(EBIT)_{i,t}$, where *EBIT* is the earnings-before-interest-and-taxes to sales ratio (rescaled to the unit interval) for firm i in year t. C is the cost of emitting CO_2 divided by sales for firm i in year t. The sample comprises Swedish manufacturing firms (NACE 1000–3300) with capital expenditure and CO_2 emissions data over 2000–2019. D1–D4 comprise firms in the four-digit industries in the bottom four deciles (bottom 40%) of carbon emissions to sales in 2000, D5–D9 the fifth-to-ninth deciles, and D10 the top decile; column 1 (All) pools all firms. All regressions include firm and four-digit-industry-by-year fixed effects and the firm controls $Cash\ flow_{i,t-1}$, $\ln(Total\ assets)_{i,t-1}$, $Long\ term\ debt_{i,t-1}$, and $Sales\ gwth_{i,t-1}$. Standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1% , 5% , and 10% levels.

Table 4: Carbon pricing and capital investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln(C_{i,t})$	0.108***	0.045***	0.059***	0.055**	0.077***	0.084***	0.073**
	(0.013)	(0.016)	(0.022)	(0.025)	(0.029)	(0.030)	(0.035)
$\ln(C_{i,t-1})$					-0.001	0.005	0.020
					(0.029)	(0.033)	(0.038)
$\ln(C_{i,t-2})$						0.019	0.028
						(0.028)	(0.031)
$\ln(C_{i,t-3})$							0.002
							(0.034)
Cash $\text{flow}_{i,t-1}$				0.510***	0.589***	1.286***	1.493***
				(0.188)	(0.234)	(0.382)	(0.376)
$\ln(\text{Total assets}_{i,t-1})$				0.017	0.030	-0.007	0.074
				(0.044)	(0.075)	(0.074)	(0.085)
Long term $\text{debt}_{i,t-1}$				-0.694***	-0.734***	-0.636***	-0.684***
				(0.198)	(0.210)	(0.218)	(0.244)
Sales $\text{gwth}_{i,t-1}$				-0.031	-0.056	-0.032	-0.182**
				(0.036)	(0.045)	(0.087)	(0.078)
$\sum \ln(C)$					0.076**	0.108***	0.123**
					(0.020)	(0.008)	(0.030)
Firm fixed effects	No	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	No	No	No	No	No
Industry × Year effects	No	No	Yes	Yes	Yes	Yes	Yes
Firm controls	No	No	No	Yes	Yes	Yes	Yes
Observations	9,839	9,043	7,869	6,242	5,477	4,681	3,653
Adjusted R^2	0.039	0.453	0.442	0.447	0.457	0.476	0.479

Table 4 reports OLS estimates of Equation 1. The dependent variable is $\ln(Inv)_{i,t}$, where *Inv* is the capital expenditure to sales ratio for firm i in year t. C is the cost of emitting CO_2 divided by sales for firm i in year t; columns 5–7 add up to three annual lags of $\ln(C)$. The sample comprises Swedish manufacturing firms (NACE 1000–3300) with capital expenditure and CO_2 emissions data over 2000–2019. Columns 2–7 include firm fixed effects; columns 1–2 include year fixed effects and columns 3–7 four-digit-industry-by-year fixed effects; columns 4–7 add the firm controls $Cash\ flow_{i,t-1}$, $\ln(Total\ assets)_{i,t-1}$, $Long\ term\ debt_{i,t-1}$, and $Sales\ gwth_{i,t-1}$. The row $\sum \ln(C)$ reports the sum of the contemporaneous and lagged $\ln(C)$ coefficients (the cumulative effect); its standard error and significance stars are from an F-test of their joint significance. Standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1% , 5% , and 10% levels.

Table 5: Carbon pricing and capital investment: Heterogeneity based on industry emissions-intensity

	(1)	(2)	(3)	(4)	(5)	(6)
	D1–D4		D5–D9		D10	
$\ln(C_{i,t})$	0.013	-0.025	0.051	0.090**	0.168***	0.207***
	(0.039)	(0.061)	(0.036)	(0.044)	(0.058)	(0.066)
$\ln(C_{i,t-1})$		-0.027		0.075		0.056
		(0.069)		(0.044)		(0.088)
$\ln(C_{i,t-2})$		0.105*		-0.070		0.094***
		(0.062)		(0.054)		(0.033)
$\ln(C_{i,t-3})$		0.057		-0.008		-0.048
		(0.050)		(0.053)		(0.082)
Cash $\text{flow}_{i,t-1}$	0.646**	2.011***	0.609**	1.500***	-0.118	1.044
	(0.277)	(0.744)	(0.263)	(0.483)	(0.537)	(0.831)
$\ln(\text{Total assets}_{i,t-1})$	-0.090	-0.157	0.077	0.214*	0.086	-0.054
	(0.077)	(0.217)	(0.053)	(0.113)	(0.149)	(0.190)
Long term $\text{debt}_{i,t-1}$	-0.751**	-1.038**	-0.673**	-0.345	-0.352	-0.359
	(0.320)	(0.504)	(0.300)	(0.360)	(0.460)	(0.525)
Sales $\text{gwth}_{i,t-1}$	-0.066	-0.053	-0.015	0.236*	-0.024	-0.216*
	(0.051)	(0.148)	(0.053)	(0.121)	(0.099)	(0.122)
$\sum \ln(C)$		0.110		0.087		0.309***
		(0.370)		(0.251)		(0.007)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,486	1,407	3,075	1,744	681	502
Adjusted R^2	0.405	0.444	0.449	0.463	0.467	0.510

Table 5 reports OLS estimates of Equation 1. The dependent variable is $\ln(Inv)_{i,t}$, where *Inv* is the capital expenditure to sales ratio for firm i in year t. C is the cost of emitting CO_2 divided by sales for firm i in year t; the even-numbered column within each group adds up to three annual lags of $\ln(C)$. Estimates are reported separately for D1–D4 (columns 1–2), D5–D9 (columns 3–4), and D10 (columns 5–6), where D1–D4 comprise firms in the four-digit industries in the bottom four deciles (bottom 40%) of carbon emissions to sales in 2000, D5–D9 the fifth-to-ninth deciles, and D10 the top decile. The sample comprises Swedish manufacturing firms (NACE 1000–3300) with capital expenditure and CO_2 emissions data over 2000–2019. All regressions include firm and four-digit-industry-by-year fixed effects and the firm controls $\textit{Cash flow}_{i,t-1}$, $\ln(\textit{Total assets})_{i,t-1}$, $\textit{Long term debt}_{i,t-1}$, and $\textit{Sales gwth}_{i,t-1}$. The row $\sum \ln(C)$ reports the sum of the contemporaneous and lagged $\ln(C)$ coefficients (the cumulative effect); its standard error and significance stars are from an F-test of their joint significance. Standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1% , 5% , and 10% levels..

Table 6: Carbon pricing and firm level capital investment: Other industry sorts

	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: PACE and Mobility					
	Low PACE	**High PACE**	**Low PACE**	**Low PACE**	**High PACE**	**High PACE**
			Low Mobility	**High Mobility**	**Low Mobility**	**High Mobility**
$\ln(C_{i,t})$	0.030	0.084**	0.046	0.031	0.098**	0.054
	(0.040)	(0.035)	(0.090)	(0.043)	(0.045)	(0.048)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,441	2,601	685	1,736	1,751	825
Adjusted R^2	0.468	0.401	0.544	0.417	0.399	0.414
	Panel B: EU leakage list and US PACE data					
	Leakage list		**Leakage list Yes**		**PACE US**	
	No	**Yes**	**Trade only**	**Emission**	**Low**	**High**
$\ln(C_{i,t})$	0.041	0.069*	0.052	0.098**	0.006	0.099***
	(0.034)	(0.035)	(0.050)	(0.043)	(0.034)	(0.035)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,349	2,893	2,175	718	3,142	2,905
Adjusted R^2	0.435	0.467	0.445	0.389	0.461	0.416

Table 6 reports OLS estimates of Equation 1. The dependent variable is $\ln(Inv)_{i,t}$, where *Inv* is the capital expenditure to sales ratio for firm i in year t, and C is the cost of emitting CO_2 divided by sales for firm i in year t. Panel A sorts firms by pollution abatement capital expenditure (PACE) and capital mobility: columns 1–2 report low- and high-PACE industries (below/above the median four-digit-industry ratio of abatement investment to sales in the first abatement-data year, 2002); column 3 low-PACE & low-mobility; column 4 low-PACE & high-mobility; column 5 high-PACE & low-mobility; and column 6 high-PACE & high-mobility, where low (high) mobility is above (below) the median four-digit-industry ratio of fixed assets to total assets (2000). Panel B sorts firms by EU carbon leakage status and by US abatement intensity: columns 1–2 report industries off and on the European Union (EU) carbon leakage list; columns 3–4 industries on the list for trade concerns and for high-emission concerns; and columns 5–6 low- and high-PACE industries defined using the median four-digit-industry ratio of abatement expenditure to shipments from the 2005 US Environmental Protection Agency PACE survey. The sample comprises Swedish manufacturing firms (NACE 1000–3300) with capital expenditure and CO_2 emissions data over 2000–2019. All regressions include firm and four-digit-industry-by-year fixed effects and the firm controls $Cash\ flow_{i,t-1}$, $\ln(Total\ assets)_{i,t-1}$, $Long\ term\ debt_{i,t-1}$, and $Sales\ gwth_{i,t-1}$. Standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1% , 5% , and 10% levels.

Table 7: Carbon pricing and capital investment: Other industry sorts and emissions-intensity deciles

	(1)	(2)	(3)	(4)	(5)	(6)
	PACE		Leakage list		PACE US	
	High	High	Yes	Yes	High	High
	D1–D9	D10	D1–D9	D10	D1–D9	D10
$\ln(C_{i,t})$	0.051	0.168***	0.011	0.176***	0.069	0.168***
	(0.041)	(0.060)	(0.039)	(0.057)	(0.042)	(0.058)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,973	628	2,256	637	2,224	681
Adjusted R^2	0.374	0.474	0.446	0.469	0.396	0.467

Table 7 reports OLS estimates of Equation 1. The dependent variable is $\ln(Inv)_{i,t}$, where Inv is the capital expenditure to sales ratio for firm i in year t, and C is the cost of emitting CO_2 divided by sales for firm i in year t. Each pair of columns restricts to a high-intensity sort and splits it by emissions decile: columns 1–2 use high-PACE industries (above the median four-digit-industry ratio of abatement investment to sales in 2002); columns 3–4 use industries on the European Union (EU) carbon leakage list; and columns 5–6 use high-PACE industries defined from the 2005 US Environmental Protection Agency PACE survey (abatement expenditure to shipments). Within each pair, results are for firms in D1–D9 industries (odd columns) and D10 industries (even columns), where D10 is the top decile and D1–D9 the bottom nine deciles of carbon emissions to sales in 2000. The sample comprises Swedish manufacturing firms (NACE 1000–3300) with capital expenditure and CO_2 emissions data over 2000–2019. All regressions include firm and four-digit-industry-by-year fixed effects and the firm controls $Cash\ flow_{i,t-1}$, $\ln(Total\ assets)_{i,t-1}$, $Long\ term\ debt_{i,t-1}$, and $Sales\ gwth_{i,t-1}$. Standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1% , 5% , and 10% levels.

Table 8: Carbon pricing and firm level abatement investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Air abate Inv			Abate rel to INV		Treatment	Prevent
	All	D1–D9	D10	D1–D9	D10	All	All
	Panel A: Estimates with OLS (Dependent variables in logs)						
$\ln(C_{i,t})$	0.468***	0.047	0.700***	-0.038	0.510**	0.211	0.691**
	(0.167)	(0.343)	(0.180)	(0.417)	(0.217)	(0.221)	(0.267)
Observations	420	197	233	197	223	242	207
Adjusted R^2	0.322	0.275	0.130	0.249	0.074	0.285	0.140
	Panel B: Estimates with Poisson Pseudo-Maximum Likelihood (Dependent variables not in logs)						
$\ln(C_{i,t})$	0.418***	0.222	0.517***	0.133	0.380**	0.226	1.079***
	(0.154)	(0.186)	(0.194)	(0.182)	(0.168)	(0.180)	(0.280)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	972	626	346	626	346	743	664
Pseudo R^2	0.159	0.190	0.109	0.375	0.205	0.141	0.178
Dropped due to zeros all years	1,544	1,461	82	1,461	82	1,920	2,063
Dropped due to fixed effects	508	430	79	430	79	361	297

Table 8 reports OLS estimates (Panel A) and Poisson Pseudo-Maximum Likelihood (PPML) estimates (Panel B) of Equation 1; dependent variables are in logs in Panel A and in levels in Panel B. The dependent variable is *Abate Inv* in columns 1–3 (air pollution abatement capital expenditure divided by sales), *Share Abate Inv* in columns 4–5 (abatement capital expenditure divided by total capital investment; shown under the heading "Abate rel to INV"), *Abate Inv: Treatment* in column 6 (abatement capital expenditure aimed at treating existing pollution), and *Abate Inv: Prevent* in column 7 (abatement capital expenditure aimed at preventing future pollution), each for firm i in year t. C is the cost of emitting CO_2 divided by sales for firm i in year t. Columns headed D1–D9 (D10) restrict to the bottom nine deciles (top decile) of carbon emissions to sales in 2000; columns headed ALL pool all firms. In Panel B, the bottom two rows report observations dropped because (i) the firm reports zeros in all years and (ii) of the fixed effects. The sample comprises Swedish manufacturing firms (NACE 1000–3300) with capital expenditure, abatement investment, and CO_2 emissions data over 2002–2019. All regressions include firm and four-digit-industry-by-year fixed effects and the firm controls $Cash\ flow_{i,t-1}$, $\ln(Total\ assets)_{i,t-1}$, $Long\ term\ debt_{i,t-1}$, and $Sales\ gwth_{i,t-1}$. Standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1% , 5% , and 10% levels.

Table 9: Carbon pricing and firm level investment and dividend payments: Event results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Inv				Div			
D10 Firm	0.010***				0.044			
	(0.004)				(0.064)			
Post	0.003***	0.001			0.049***	0.071***		
	(0.001)	(0.001)			(0.014)	(0.018)		
D10 Firm x *Post*	0.012**	0.012***	0.012***	0.000	-0.183**	-0.207**	-0.209**	0.014
	(0.005)	(0.005)	(0.005)	(0.004)	(0.077)	(0.087)	(0.087)	(0.059)
Post x *Div firm*				0.002				-0.038
				(0.002)				(0.033)
D10 Firm x *Post* x *Div firm*				0.020**				-0.351**
				(0.008)				(0.140)
Firm fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Year effects	No	No	Yes	Yes	No	No	Yes	Yes
Observations	8,597	8,108	8,108	7,404	8,596	8,108	8,108	7,404
Adjusted R^2	0.013	0.396	0.397	0.377	0.002	0.196	0.199	0.199

Table 9 reports OLS estimates of Equation 2 and Equation 3, with $Inv_{i,t}$ as the dependent variable in columns 1–4 and $Div_{i,t}$ in columns 5–8. *Inv* is the capital expenditure to sales ratio and *Div* the dividend-payment to cash-flow ratio, each for firm i in year t. *D10 Firm* equals one if the firm is in a decile-10 (top-emission) industry and zero otherwise; *Post* equals one for 2015–2019 and zero for 2010–2014; and *Div firm* equals one if the firm paid a dividend at any point in 2010–2014 and zero otherwise. The sample comprises Swedish manufacturing firms (NACE 1000–3300) with capital expenditure and CO_2 emissions data over 2010–2019. Columns 2–4 and 6–8 include firm fixed effects; columns 3–4 and 7–8 add year fixed effects. Standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1% , 5% , and 10% levels.

Table 10: Industry level investment across EU countries during, 2010–2019

	(1)	(2)	(3)	(4)	(5)
D10	0.010***				
	(0.002)				
Post	0.004**	0.003*			
	(0.002)	(0.001)			
D10 × Post	-0.002	-0.001	-0.001		
	(0.002)	(0.002)	(0.002)		
Sweden	-0.010***				
	(0.003)				
D10 × *Sweden*	0.004**				
	(0.002)				
Post × Sweden	-0.003*	-0.002	-0.002	-0.002	
	(0.002)	(0.001)	(0.001)	(0.002)	
D10 × *Post* × *Sweden*	0.010***	0.016***	0.016***	0.011***	0.012***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Country-industry effects	No	Yes	Yes	Yes	Yes
Year effects	No	No	Yes	No	No
Industry × year effects	No	No	No	Yes	Yes
Country × year effects	No	No	No	No	Yes
Observations	35,635	35,426	35,426	35,422	35,422
Adjusted R^2	0.010	0.405	0.405	0.409	0.422

Table 10 reports OLS estimates of a country-industry version of Equation 2 and Equation 3, estimated on four-digit manufacturing industries across European Union countries. The dependent variable is $Inv_{cj,t}$, the capital expenditure to sales ratio for country-industry cj in year t. *D10* equals one for decile-10 (top-emission) industries and zero otherwise; *Post* equals one for 2015–2019 and zero for 2010–2014; and *Sweden* equals one for Swedish country-industries and zero otherwise. The coefficient of interest is the triple interaction *D10* × post-2014 investment response of high-emitting industries in Sweden relative to the same industries elsewhere in the EU. Standard errors are clustered at the country level. ***, **, and * indicate significance at the 1% , 5% , and 10% levels.

A Appendix

A.1 Data and measurement

We build our sample data based on several sources. The study is based on administrative data on manufacturing Swedish limited liability companies (Swedish: Aktiebolag) from 1999 to 2020. The Swedish Companies Registration Office (SCRO) (Swedish: Bolagsverket) assigns each Swedish limited liability company an unique and permanent identifier entitled organization number. We link the data using the unique identifier by years. Due to privacy policy, all real identifiers related to micro objects are removed, the data is anonymized and handled by Statistics Sweden (SCB).

Firm-level financial data: First, we get accounting data of Swedish limited liability companies from Bisnode Serrano database. This database integrates financial information from balance sheets, income statements, bankruptcy records, as well as NACE Rev.2 industrial classifications from 1998 to 2020. All variables are converted into the respective calendar year. Since firms can switch industry during our research period, we take the latest 5-digit industrial classification codes (NACE Rev.2) to make it consistent across time.

We build a consolidated dataset at the group and year level by integrating the accounting variables within the same group. We merge accounting variables with corporate structure data from the knc file of serrano database. Each firm identity in a specific year is linked to a unique parent company identifier. In the absence of a group identity, we replace it with the firm's organization number and consider it as an independent entity. We establish coherent NACE Rev.2 for group using the classification of the subsidiary with the most sales or employees. If no entity provides NACE2007 information based on sales or employees, we choose the most recent one among the group. All required values are deflated by Consumer Price Index (CPI), and Swedish Producer Price Index (PPI) at four-digit NACE Rev.2 level with the base year of 2020. For a stand-alone firm, the consolidated figure will be its own value; for firms matched with corporate structure file, we aggregate figures of all subsidiaries within the same group.

General investments data: We have firm-level general investment data from the survey conducted by Statistics Sweden (SCB). This data contains information on implemented and planned general investments from 2000 to 2019, which is aligned with the European System of Accounts (ESA) framework. The investments are categorized into (a) buildings and facility, (b) machinery and equipment, and (c) housing for only real estate companies (NACE Rev.2 sector 68).

Environmental investments data: We obtain firm-level environmental expenditures from the survey conducted by Statistics Sweden (SCB), which adheres to EU Regulation[13] and utilizes the accounting system for environmental protection expenditure defined by Eurostat. This dataset consists of firms' environmental investment statistics from 2002 to 2019. The

[13]Regulation (EU) No 691/2011 of the European Parliament and of the Council of 6 July 2011 on European environmental economic accounts, https://eur-lex.europa.eu/eli/reg/2011/691/oj

survey includes all firms with 250 or more employees and a selection of firms with 50-249 employees. Surveyed firms are required by law to provide data to SCB (Lag (2001:99) om den officiella statistiken, 7 §). Accordingly on average, 88.5 percent of the surveyed firms in the years 2002-2019 complete the survey.[14]

Emission data: The data to calculate $C_{i,t}$ We acquire annual CO2 emissions at installation level from 1990 to 2021 from Environmental Protection Agency (SEPA). We also have CO_2 emissions and allowances at installation level from EU emissions trading system (EU ETS) since 2005. Below we describe our steps to process the emission data. First, we collect Swedish carbon tax rates and generate primary carbon tax payments by multiplying applicable tax rate with corresponding carbon emissions. We measure average cost and marginal cost incurred by firms when emitting an extra unit of CO2 using the summarized tax scheme and approach developed by Martinsson et al. (2024). In our research period, manufacturing sectors were subjected to the "0.8 percent rule" from 1997 to 2006, which indicated that firms paid carbon tax with a maximum of 0.8 percent of their sales, and 25 percent of the initial marginal tax rate was applied to the exceeding part of the payments. Subsequently, the exemption cap was raised from 0.8 percent to 1.2 percent during 2011 to 2014, and then was eliminated in 2015. While for high-emitting industries as cement and glass lime, the highest possible payment is 1.2 percent of sales until 2007, see Table 1 by Martinsson et al. (2024) for details. Second, for firms with installations also regulated under the European Union Emissions Trading Scheme (EU ETS) we collect information from the European Union Transaction Log (the official registry of EU ETS).

Finally, as SEPA only collects emissions on bigger installations from 2003 to 2006, we have relatively fewer observations during this period. We assume that the emission intensity within a firm between 2002 and 2007 is linear, we interpolate missing values if there are at least two observable emissions, i.e., neither missing or zero during this period. We further multiply the imputed emission intensity by deflated sales to scale the imputed emissions. Linear interpolation of a variable that may change non-linearly around capital investment events could introduce measurement error and attenuate estimated elasticities in the early part of the sample. However, our results are unchanged if we use only non-imputed emissions data.

Finally, We link data on general investments, environmental investments and accounting values for all manufacturing firms by organization numbers and years. Our sample data is from 1999 to 2020 and at unit of firm and year level.

Exits: Our main analysis uses consolidated firm groups: subsidiaries with ownership shares of at least 50 percent are aggregated to the top-mother level using a (scrambled) unique identifier. This consolidation allows us to measure firm size consistently, but changes in group

[14]The detailed information the survey, including lapse can be found here [in Swedish]: https://www.scb.se/hitta-statistik/statistik-efter-amne/miljo/miljoekonomi-och-hallbar-utveckling/miljoskyddskostnader/. An example of the web survey used for abatement investments in year 2019 can be found here [in Swedish] https://www.scb.se/contentassets/5c671de894c247a7aa6560cdb0b06e34/mi1302_staf_2019_ml_201014.pdf

ownership can mechanically generate apparent "exits" even when underlying operating entities continue.

To focus on actual exits rather than ownership reorganization, we therefore estimate exit patterns at the legal-firm level. We start from firms observed in the baseline year (2009) and included in the investment survey in that year. We define an exit in the post period (2015–2019) as either (i) the firm not being observed in any post-year or (ii) the firm being observed but reporting zero sales in all years of the post period.

Following Colmer et al. (2025), we define this exit indicator and test whether exit is systematically related to our key firm characteristics.

EU aggregates: In addition to the Swedish micro-data, we compare our empirical investigation to the European Union (EU) level. The country-level financial and investment data for 27 EU member states are obtained from Eurostat Structural Business Statistics (SBS) database. Following a significant legislative transition in the collection and reporting of European business statistics, the SBS framework was partitioned into two distinct datasets. Data prior to 2021 are sourced from *SBS - historical data* coded as *sbs_na_ind_r2* [15] while data from 2021 onwards are obtained from *SBS - Enterprise statistics on the whole business population* coded as *sbs_ovw_act*[16]. Our final dataset spans from 2008 to 2023 and encompasses all four-digit manufacturing industries categorized under NACE Rev.2 (Sector C). We focus on gross investments in machinery and equipment (variable name *Gross investment in machinery and equipment – million euro* coded as *V15150* from 2008 to 2020 and *Gross investment in machinery and equipment - million euro* coded as *GRSINV_MAC_MEUR* from 2021 to 2023). To scale our investment variable, we use sales/turnover (variable name *Turnover or gross premium written – million euro* coded as *V12110* from 2008 to 2020 and *Net turnover - million euro* coded as *NETTUR_MEUR* from 2021 to 2023).[17] Observations with missing values were excluded from the final sample. To maintain consistency with the primary firm-level analysis, we applied an identical decile-based classification methodology to this cross-country dataset.

A.2 Industry examples of climate-motivated capital investment

This appendix provides three illustrative examples of large capital investments in D10 industries during the post-2014 period. The cases span distinct four-digit sectors and reflect different forms of abatement investment discussed in the main text: integrated process investment, energy efficiency upgrading, and capital reallocation toward fundamentally new production technology.

[15] SBS database before 2021 on Eurostat: https://ec.europa.eu/eurostat/databrowser/view/sbs_na_ind_r2__custom_19374189/default/table

[16] SBS database after 2021 on Eurostat: https://ec.europa.eu/eurostat/databrowser/view/sbs_ovw_act/default/table

[17] In our final dataset, we use the variable name *gross investments in machinery and equipment* coded as *inv_mach_equipment_meur* and *turnover* coded as *turnover_meur*.

Paper and Paperboard (NACE 1712): BillerudKorsnäs, Gruvön Mill. In December 2016, BillerudKorsnäs approved an investment of SEK 5.7 billion—the largest in the company's history and one of the largest industrial investments in Sweden at the time—for the construction of a new board machine at its Gruvön production site in Värmland.[18] Construction ran from 2017 through 2018, with production starting in the first quarter of 2019; final investment costs rose to approximately SEK 6.8 billion. The new machine, with annual capacity of 550,000 tonnes, produces liquid packaging board, cartonboard, food service board, and kraftliner—renewable, fiber-based materials positioned explicitly as substitutes for fossil-based packaging. The investment also entailed a restructuring of the existing pulp mill and the gradual transfer of legacy paper production to other sites within the group.

Plastics in Primary Forms (NACE 2016): Borealis, Stenungsund Cracker Plant. In 2015, Borealis AB invested SEK 1.5 billion to upgrade four furnaces at its ethylene cracker plant in Stenungsund.[19] The stated purpose was to bring process safety and energy efficiency to the highest available standards, with the energy efficiency improvements reported to reduce the company's fossil carbon emissions by approximately 20,000 tonnes per year. This case exemplifies integrated or prevention investment: the primary capital expenditure serves a production purpose, with the incremental environmental benefit achievable only through the full equipment replacement. Under CEPA conventions, a firm making this investment would report only the marginal cost of the more energy-efficient configuration as abatement investment, while the bulk of the SEK 1.5 billion outlay would appear only in total capital expenditure.

Basic Iron and Steel (NACE 2410): SSAB, LKAB, and Vattenfall, HYBRIT Pilot Plant. In 2018, Swedish steelmaker SSAB, together with mining company LKAB and energy company Vattenfall, began construction of the world's first pilot plant for hydrogen-based, fossil-free steel production (HYBRIT) in Luleå.[20] Total expenditure for the pilot phase was approximately SEK 1.4 billion. The initiative originated in 2016—shortly after the sharp increase in effective carbon prices—as a joint feasibility study, and progressed to construction within two years. The technology replaces coking coal with green hydrogen in the iron ore reduction process, producing water vapor rather than carbon dioxide as a byproduct.

[18] See BillerudKorsnäs (2016).
[19] See Borealis (2015).
[20] See SSAB (2018).

A.3 Additional Tables and Figures

Figure B.1: Economy-wide vs Manufacturing Carbon Tax Rate 1990–2024

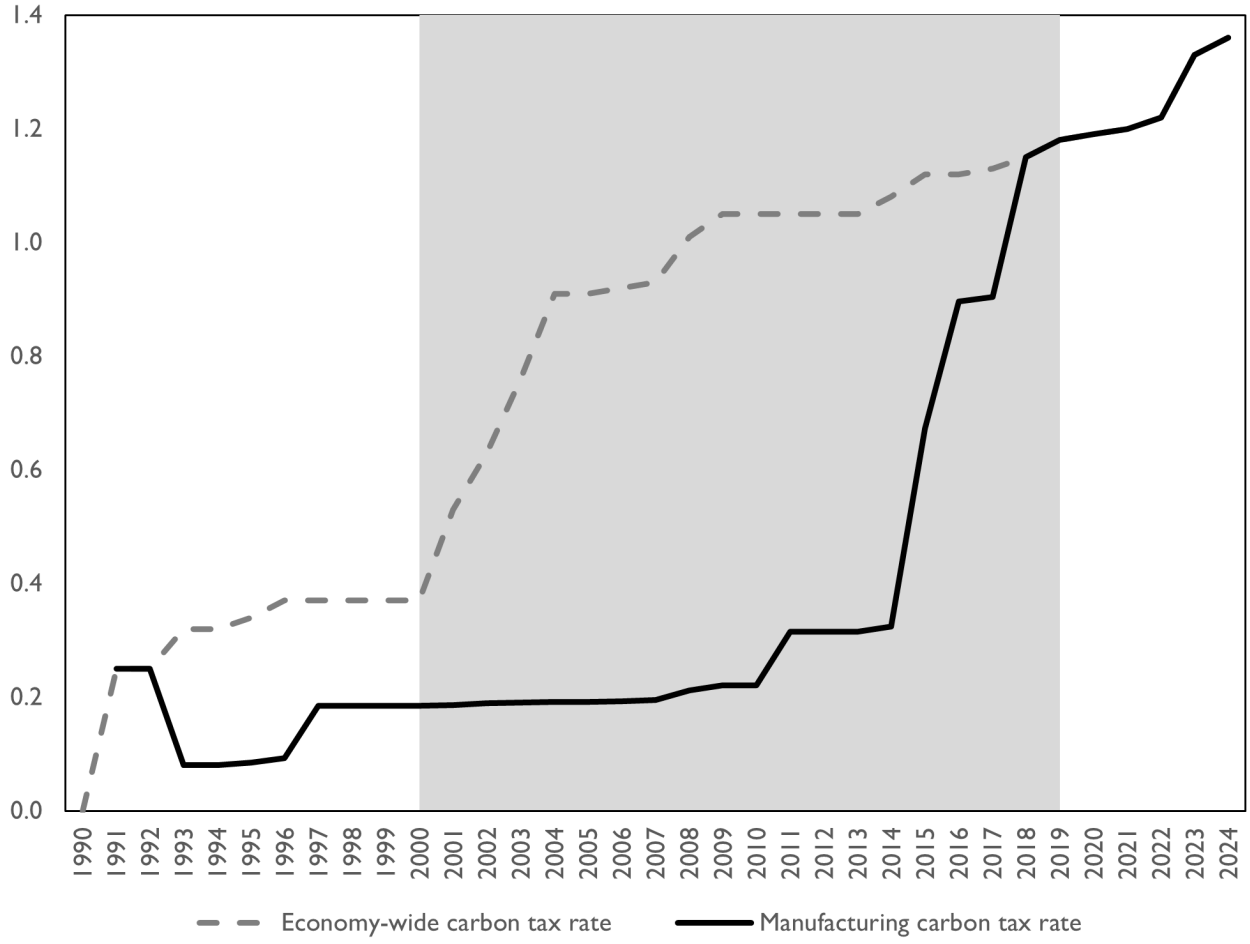


Figure B.1 displays Sweden's economy-wide carbon tax rate (grey dashed line) and the rate faced by the manufacturing sector after exemptions (black solid line), both in constant 2020 SEK per kilogram of CO_2, over 1990–2024. Manufacturing exemptions were fully phased out by 2018. The shaded band marks the 2000–2019 sample period used in the paper.

Figure B.2: SCA Press Release



MEDIA › PRESS RELEASES › SCA INVESTS IN OBBOLA KRAFTLINER MILL

SCA invests in Obbola kraftliner mill

PRESS RELEASE • 02/09/2019, 08:15 AM

SCA to build a new paper machine for the production of kraftliner at its Obbola paper mill in Umeå. The annual production in Obbola will increase from the current 450,000 tonnes of kraftliner to 725,000 tonnes to meet the growing demand for renewable packaging. The investment amount is SEK 7.5 billion.

SCA produces kraftliner – paper for transport packaging – at the paper mills in Obbola (Umeå) and Munksund (Piteå). SCA has today decided to invest to increase kraftliner capacity to 725,000 tonnes of kraftliner per year, an increase of 275,000 tonnes. The new paper machine will start operation in the first quarter of 2023.

The total investment amounts to SEK 7.5 billion over a five-year period. The investment replaces necessary reinvestments in Obbola of approximately SEK 2.5 billion. The investment will be mainly financed by operating cash flow, complemented by regular group financing acitivities.

In addition to the Obbola paper mill, SCA also produces kraftliner at Munksund paper mill in Piteå. Over the past twelve months SCA's kraftliner operations had an EBITDA margin of 35%. With a kraftliner trend price of EUR 600 per tonne, the investment is expected to generate an annual EBITDA improvement of approximately SEK 800-1,000 million after full ramp-up.

A profitable investment

Demand for paper based packaging is growing. This trend is being driven by a number of factors – increased e-commerce, a growing population and the ambition to reduce the use of plastic.
"This is a profitable investment in a growing segment," says CEO Ulf Larsson. "We expect the investment to be profitable already during the first year of operation and to contribute positively to the return on capital from our industrial operations."

"With the investment in Obbola we can meet the increased demand for sustainable packaging," says Mats Nordlander, President, Paper. "We have access to high-quality wood fiber from Norrland. We have efficient and reliable supply of wood and logistic operations. As a result of this investment in the markets's most advanced kraftliner machine with the best available technology, we will considerably improve the mill's competitiveness, cost position and product quality."

Full production during construction

The new paper machine is being constructed in a new building in line with the current paper machine. As a result the plant will be in full production during the entire construction period before switching over from the old machine to the new one ahead of the start up in 2023. The new plant's ramp-up to full capacity is expected to take three years.

The total investment amount of SEK 7.5 billion includes investments in environmental improvements of approximately SEK 1 billion, including a reduction in the need for oil by 8,000 cubic meters per year and improvements in the water treatment capacity. Following the investment, SCA's own industrial processes will be 97 per cent fossil-free.

Figure B.2 reproduces a September 2019 press release from SCA announcing a SEK 7.5 billion investment in a new kraftliner machine at its Obbola mill—an illustrative example of a high-emitting manufacturer undertaking a large capital investment financed mainly by internal cash flow, consistent with the paper's findings. Source: SCA (2019), https://www.sca.com/en/media/press-releases/2019/sca-invests-in-obbola-kraftliner-mill/ (accessed May 22, 2026)

Figure B.3: Capital investment in the manufacturing sector, with 2000–2002 as base years

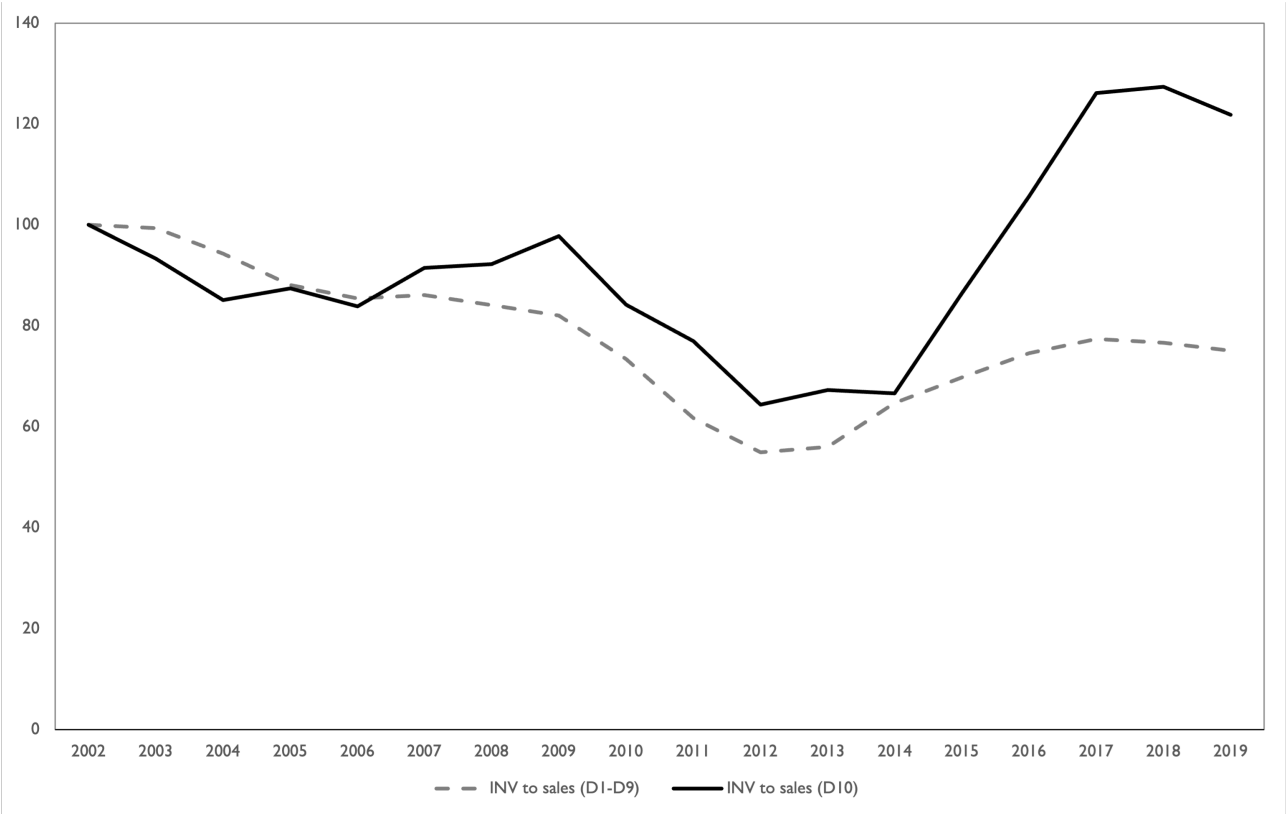


Figure B.3 displays the aggregate capital expenditure to sales ratio (a three-year rolling average, from t to $t-2$) for high-emitting industries (D10; solid black line) and low- and medium-emitting industries (D1–D9; dashed grey line), indexed to 100 in the 2000–2002 base period. D10 comprises firms in the four-digit industries in the top decile of carbon emissions to sales in 2000, and D1–D9 the remaining nine deciles. The series cover 2000–2019. This is the indexed counterpart to Figure 1.

Table B.1: Decile 10 industries

NACE	Four digit industries	Decile in 2000	Decile in 1990
1062	Starches and starch products	10	10
1081	Manufacture of sugar	10	10
1106	Manufacture of malt	10	10
1330	Finishing of textiles	10	10
1712	Manufacture of paper and paperboard	10	10
1920	Refined petroleum products	10	10
2013	Other inorganic basic chemicals	10	10
2016	Plastics in primary forms	10	10
2313	Manufacture of hollow glass	10	10
2351	Manufacture of cement	10	10
2352	Manufacture of lime and plaster	10	10
2362	Plaster products for construction purposes	10	10
2399	Other non-metallic mineral products n.e.c.	10	10
2410	Basic iron and steel and of ferro-alloys	10	10
1711	Manufacture of pulp	10	9
2014	Other organic basic chemicals	10	9
2341	Manuf of ceramic household articles	10	9
2370	Cutting, shaping and finishing of stone	10	7
1621	Veneer sheets and wood-based panels	8	10
2320	Manufacture of refractory products	9	10
2364	Manufacture of mortars	7	10

Table B.1 reports the four-digit NACE industries that make up decile 10 in 1990 and in 2000. Decile 10 is defined as four-digit industries that are in the 10th decile (top 10 percent) in terms of carbon emissions to output in 2000.

Table B.2: Some robustness

	(1)	(2)	(3)	(4)	(5)
		Inv	Inv Scaled TA	Inv	
$\ln(C_{i,t}$ - Sales weighted)	0.064***				
	(0.022)				
$\ln(C_{i,t}$ - Fixed assets weighted)		0.070***			
		(0.021)			
$\ln(C_{i,t}$ - Scaled by Total Assets)			0.093***		
			(0.027)		
$\ln(C_{i,t})$				0.055**	0.065***
				(0.026)	(0.011)
$\ln(Inv_{i,t-1})$				0.017	0.492***
				(0.025)	(0.020)
Firm fixed effects	Yes	Yes	Yes	Yes	No
Industry × Year effects	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes
Observations	6,242	6,154	6,243	5,161	5,664
Adjusted R^2	0.448	0.434	0.489	0.472	0.342

Table B.2 reports OLS estimates of Equation 1. $ln(Inv)_{i,t}$ is the dependent variable in columns 1–2 and 4–5, where *Inv* is the capital expenditure to sales ratio for firm i in year t. $ln(Inv\ Scaled\ TA)_{i,t}$ is the dependent variable in column 3, where *Inv Scaled TA* is the capital expenditure to total assets ratio for firm i in year t. *C - Sales weighted* and *C - Fixed assets weighted* is the unconsolidated firm sales and fixed assets weighted cost of emitting CO_2 divided by sales for firm i in year t respectively. *C - Scaled by TA* is the cost of emitting CO_2 divided by total assets for firm i in year t. The sample comprises Swedish manufacturing firms (NACE: 1000–3300) with capital expenditure and CO_2 emissions data during 2000–2019. All regressions include firm and four digit industry-year fixed effects and the following firm control variables: $Cash\ flow_{i,t-1}$, $ln(Total\ assets)_{i,t-1}$, $Long\ term\ debt_{i,t-1}$, and $Sales\ gwth_{i,t-1}$. The standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table B.3: Carbon pricing and firm level capital investment: Robustness deciles

	(1)	(2)	(3)
	D1–D4	**D5–D9**	**D10**
$\ln(C_{i,t})$	-0.009	0.109**	0.239***
	(0.067)	(0.042)	(0.057)
Firm fixed effects	Yes	Yes	Yes
Industry × Year effects	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes
Observations	1,407	1,744	502
Adjusted R^2	0.443	0.463	0.508

Table B.3 reports OLS estimates of Equation 1. $ln(Inv)_{i,t}$ is the dependent variable. *Inv* is the capital expenditure to sales ratio for firm i in year t. C is the cost of emitting CO_2 divided by sales for firm i in year t. The sample comprises Swedish manufacturing firms (NACE: 1000–3300) with capital expenditure and CO_2 emissions data during 2000–2019 and with firm-years in C in four consecutive years. D1–D4 include firms in the four-digit industries in the first to fourth deciles (bottom 40 percent) in terms of carbon emissions to output in 2000, D5–D9 represent firms in the fifth to ninth decile in terms of carbon emissions to output in 2000 and D10 the top decile. All regressions include firm and four digit industry-year fixed effects and the following firm control variables: $Cash\ flow_{i,t-1}$, $ln(Total\ assets)_{i,t-1}$, $Long\ term\ debt_{i,t-1}$, and $Sales\ gwth_{i,t-1}$. The standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table B.4: Carbon pricing and firm level capital investment: Abatement investment sub-sample

	(1)	(2)	(3)	(4)
$\ln(C_{i,t})$	0.124***	0.075***	0.148**	0.184***
	(0.021)	(0.025)	(0.065)	(0.066)
Firm fixed effects	No	Yes	Yes	Yes
Year fixed effects	Yes	Yes	No	No
Industry × Year effects	No	No	Yes	Yes
Firm controls	No	No	No	Yes
Observations	1,320	1,129	517	420
Adjusted R^2	0.062	0.496	0.489	0.462

Table B.4 reports OLS estimates of Equation 1. $ln(Inv)_{i,t}$ is the dependent variable. *Inv* is the capital expenditure to sales ratio for firm i in year t. C is the cost of emitting CO_2 divided by sales for firm i in year t. The sample comprises Swedish manufacturing firms (NACE: 1000–3300) with capital expenditure, abatement investment and CO_2 emissions data during 2002–2019. Regressions in columns 2–4 include firm fixed effects. Regressions in columns 1–2 include year fixed effects and columns 3–4 include four digit industry-year fixed effects. Regression in column 4 includes the following firm control variables: $Cash\ flow_{i,t-1}$, $ln(Total\ assets)_{i,t-1}$, $Long\ term\ debt_{i,t-1}$, and $Sales\ gwth_{i,t-1}$. The standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table B.5: Carbon pricing and firm level abatement investment: Baseline lagged specification

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(C_{i,t})$	0.289***	0.155***	0.342***	0.468***	0.281	0.266	0.498**	0.609**
	(0.035)	(0.050)	(0.148)	(0.167)	(0.186)	(0.197)	(0.200)	(0.256)
$\ln(C_{i,t-1})$					0.226	0.186	0.066	-0.117
					(0.157)	(0.174)	(0.173)	(0.169)
$\ln(C_{i,t-2})$						0.078	0.019	0.171
						(0.180)	(0.163)	(0.184)
$\ln(C_{i,t-3})$							0.127	0.267
							(0.187)	(0.255)
Cash $\text{flow}_{i,t-1}$				-0.805	-0.286	-0.183	0.324	3.002
				(1.118)	(1.096)	(1.856)	(2.405)	(3.675)
$\ln(\text{Total assets}_{i,t-1})$				0.042	0.790	0.840	0.468	0.407
				(0.272)	(0.499)	(0.518)	(0.514)	(0.556)
Long term $\text{debt}_{i,t-1}$				-0.150	0.090	0.097	1.395	1.735
				(1.009)	(0.896)	(0.921)	(0.885)	(1.330)
Sales $\text{gwth}_{i,t-1}$				0.071	0.019	0.324	0.477	0.527
				(0.239)	(0.237)	(0.374)	(0.371)	(0.430)
$\sum \ln(C)$					0.507***	0.530***	0.710**	0.931**
					(0.005)	(0.010)	(0.020)	(0.037)
Firm fixed effects	No	Yes	Yes	Yes	Yes		Yes	Yes
Year fixed effects	Yes	Yes	No	No	No	No	No	No
Industry x Year effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	No	No	No	Yes	Yes	Yes	Yes	Yes
Observations	1,320	1,129	517	420	402	382	317	183
Adjusted R^2	0.093	0.413	0.376	0.322	0.339	0.325	0.324	0.000

Table B.5 reports OLS estimates of Equation 1. $ln(Inv)_{i,t}$ is the dependent variable. *Abate inv* is the abatement capital expenditure to sales ratio for firm i in year t. C is the cost of emitting CO_2 divided by sales for firm i in year t. The sample comprises Swedish manufacturing firms (NACE: 1000–3300) with capital expenditure and CO_2 emissions data during 2002–2019. The sample in column 8 only includes the firms in the four-digit industries in the top decile in terms of carbon emissions to output in 2000. Regressions in columns 2–8 include firm fixed effects. Regressions in columns 1–2 include year fixed effects and columns 3–7 include four digit industry-year fixed effects. Regressions in columns 4–8 include the following firm control variables: $Cash\ flow_{i,t-1}$, $ln(Total\ assets)_{i,t-1}$, $Long\ term\ debt_{i,t-1}$, and $Sales\ gwth_{i,t-1}$. The standard errors are clustered at the firm level. $\sum \Delta\ln(C)$ present an F-test of joint significance. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table B.6: Investment and dividend before and after the event

	2010–2014	2015–2019	Diff periods	Diff-in-diff	Triple Diff
Panel A: Investment spending					
Div firm (D10)	0.032	0.051	0.019		
No div firm (D10)	0.031	0.029	-0.002		
Diff Groups (D10)	0.001	0.022		0.021	
Div firm (D1–D9)	0.022	0.025	0.003		
No div firm (D1–D9)	0.021	0.022	0.001		
Diff groups (D1–D9)	0.001	0.003		0.002	
Triple Diff					0.019
Panel B: Dividend to cash flow					
Div firm (D10)	0.346	0.064	-0.282		
No div firm (D10)	0.000	0.108	0.108		
Diff Groups (D10)	0.346	-0.044		-0.390	
Div firm (D1–D9)	0.281	0.314	0.033		
No div firm (D1–D9)	0.000	0.109	0.109		
Diff groups (D1–D9)	0.281	0.205		-0.076	
Triple Diff					-0.314

Table B.6 report summary statistics for *Inv* (investment to sales) in panel A and *Div* dividend payments to cash flow in panel B. *Div firm* (*No div firm*) is an indicator variable taking on the value one (zero) if the firm paid dividend in 2010–2014. D1–D9 (D10) include firms in the four-digit industries in the lowest nine (highest) deciles in terms of carbon emissions to sales in 2000. Values are expressed as averages for *Inv* (*Div*) in the first two columns in panel A (B). The table also reports difference in periods and groups as well as differences-in-differences within D1–D9 and D10 groups respectively across dividend paying status and triple differences to compare across firms in different decile groups.

Table B.7: Carbon pricing and firm level capital investment: event results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Collapsed	**Firm-years with emissions data**			**FM: Cash flow**			**FM: Credit ratings**			**FM: Long term debt**		
D10 Firm	0.004	0.012***			0.009**			0.010*			0.012**		
	(0.004)	(0.004)			(0.004)			(0.005)			(0.005)		
Post	0.000	0.004***	0.002*		0.003*	0.000		0.001	0.000		0.004**	0.001	
	(0.001)	(0.001)	(0.001)		(0.002)	(0.002)		(0.001)	(0.002)		(0.001)	(0.001)	
D10 Firm × Post	0.011**	0.012**	0.012**	0.012**	0.005	0.006	0.006	0.012**	0.015**	0.015**	0.009	0.014**	0.014**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
FM					0.008***			0.004***			0.001		
					(0.002)			(0.002)			(0.002)		
D10 Firm × *FM*					0.005			0.000			-0.005		
					(0.007)			(0.002)			(0.007)		
Post × *FM*					0.001	0.001	0.001	0.004*	0.003	0.003	-0.001	-0.001	-0.001
					(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
D10 Firm × *Post* × *FM*					0.011	0.017*	0.017*	-0.008	-0.005	-0.005	-0.002	-0.007	-0.007
					(0.009)	(0.010)	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Firm fixed effects	No	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Year effects	No	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Observations	2,144	5,594	5,096	5,096	7,309	7,026	7,026	7,309	7,309	7,026	7,309	7,026	7,026
Adjusted R^2	0.007	0.023	0.444	0.444	0.025	0.384	0.384	0.017	0.383	0.383	0.012	0.383	0.383

Table B.7 reports OLS estimates of Equation 2 with $Inv_{i,t}$ as the dependent variable. *Inv* is the capital expenditure to sales ratio for firm i in year t. *D10 Firm* is an indicator variable taking on the value one (zero) if the firm is (not) in a decile 10 industry. *Post* is an indicator variable taking on the value one (zero) for years 2015–2019 (2010–2014). *FM* (Finance Measure) is an indicator variable taking on the value one (zero) if the firm's average cash flow to assets in 2010–2014 is above (below) the median among decile 10 firms (or decile 1–9 firms) in columns 5–7, in terms of credit ratings in columns 8–10, and long term debt (bank plus bond debt) to assets in columns 11–13. The sample comprises Swedish manufacturing firms (NACE: 1000–3300) with capital expenditure and CO_2 emissions data during 2010–2019. The sample in column 1 is two observations per firm, one pre (averaged over 2010–2014) and one post (average over 2015–2019). The sample in columns 2–4 conditions the firm to have emissions data as in the baseline specification. Regressions in columns 3–4, 6–7, 9–10, and 12–13 include firm fixed effects. Regressions in columns 4, 7, 10 and 13 include year fixed effects. The standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table B.8: Number of firm exits

	All firms			Dividend firms			No dividend firms		
	# Firms	# Exits	Exit rate	# Firms	# Exits	Exit rate	# Firms	# Exits	Exit rate
All deciles	1,213	43	0.035	608	4	0.007	605	39	0.064
D1–D9	1,123	40	0.036	567	4	0.007	556	36	0.065
D10	90	3	0.033	41	0	0.000	49	3	0.061

Table B.8 reports number of exits across deciles and firms. A firm is considered to exit if it exists in 2010–2014 but does not show up in 2015–2019. *D10 Firm* is an indicator variable taking on the value one (zero) if the firm is (not) in a decile 10 industry. *Div firm* is an indicator variable taking on the value one (zero) if the firm paid dividend in the period 2010–2014 and zero otherwise.

Table B.9: Carbon pricing and firm exit

	(1)	(2)	(3)
D10 Firm	-0.030	-0.006	0.019
	(0.264)	(0.020)	(0.021)
Div Firm		-0.069***	
		(0.016)	
Size control			-0.011***
			(0.004)
Observations	1,213	1,213	1,213
Log likelihood	-185.8	-168.7	-181.3
Pseudo R^2	0.000	0.092	0.025

Table B.9 reports average marginal effects from Probit versions of Equation 2. *Firm exit* is the dependent variable which takes on the value one if a firm exits and zero otherwise. A firm is considered to exit if it is observed in 2010–2014 but does not appear in any of the years from 2015–2019. *D10 Firm* is an indicator variable taking on the value one (zero) if the firm is (not) in a decile 10 industry. *Div firm* is an indicator variable taking on the value one (zero) if the firm paid dividend in the period 2010–2014 and zero otherwise. The sample comprises Swedish manufacturing firms (NACE: 1000–3300) with capital expenditure and CO_2 emissions data during 2010–2019. The standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table B.10: Capital investment to sales in Sweden vs Europe

	Decile 10 industries			Decile 1–9 industries			
	2010–2014	2015–2019	Diff Periods	2010–2014	2015–2019	Diff Periods	Diff-in-diff
Sweden	0.048	0.063	0.016	0.030	0.033	0.003	0.013
EU excl Sweden	0.024	0.027	0.002	0.026	0.026	0.000	0.002
EU 15 excl Sweden	0.024	0.025	0.002	0.024	0.022	-0.001	0.003
EU excl Nordics	0.024	0.026	0.002	0.026	0.026	0.000	0.002

Table B.10 reports average, aggregate capital investment to sales ratios for 2010–2014 and 2015–2019 for decile 10 and decile 1–9 industries respectively in Sweden compared to in the European Union (EU).