EU-ETS carbon pricing affect on Nordic and Swedish firms & emissions

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May 13, 2025

Abstract

This study investigates the impact of European Union Emissions Trading System (EU-ETS) carbon pricing on firm-level emissions behavior and financial performance in Sweden and the broader Nordic region between 2015 and 2023. Using firm-level panel data and fixed-effects regressions, the analysis reveals that higher carbon prices are significantly associated with reductions in both absolute emissions and emissions intensity, indicating that firms are responding to the cost signal by cutting emissions. At the same time, carbon pricing is found to negatively affect financial outcomes, including returns and Sharpe ratios, suggesting that firms face short-term financial headwinds in adapting to decarbonization policies. These effects persist even after controlling for firm size, profitability, leverage, environmental innovation, and regulatory exposure. While the findings confirm that carbon pricing is effective in driving environmental improvements, they also underscore transitional costs for firms, particularly in financial markets where carbon risk appears to be priced in. The results highlight the importance of policy stability, technological innovation, and investor awareness in managing the trade-offs between environmental and economic objectives. This research contributes to the growing literature on climate finance by empirically linking carbon pricing to both emissions performance and market-based financial indicators at the firm level.

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Abbreviations

EU-ETS	European Union Emissions Trading System
CBAM	Carbon Border Adjustment Mechanism
ESG	Environmental, Social, and Governance
CO2	Carbon dioxide
CO2e	CO2 Equivalent Emissions
GHG	Greenhouse Gases
ROE	Return on Equity
D/E	Debt-to-equity
COVID-19	Coronavirus disease 2019
RnD	Research and Development
ISIN	International Securities Identification Number

1 Introduction

1.1 Background & motivation

Understanding how the carbon price in the EU-ETS affects companies and their emissions is essential for assessing both economic and environmental consequences. The EU-ETS, as the world's first and largest carbon market, plays a crucial role in shaping corporate behavior by imposing financial costs on carbon emissions, incentivizing emission reductions, and driving investment in low-carbon technologies. Companies, particularly those in energy-intensive industries, are directly impacted by fluctuations in carbon prices, which can influence their competitiveness, operational costs, and overall sustainability strategies (Bolton & Kacperczyk, 2023; Ivanov et al., 2023).

Sweden, known for its ambitious climate policies (Bolton & Kacperczyk, 2023) and commitment to reducing greenhouse gas emissions, is part of the EU-ETS, which means that firms operating within covered sectors must purchase allowances to offset their emissions. The price of these allowances, determined by market mechanisms and regulatory decisions, dictates the cost burden on companies. A rising carbon price increases expenses for businesses with high emissions, compelling them to adopt cleaner technologies or seek operational efficiencies to reduce their carbon footprint. Conversely, a lower carbon price may weaken the incentive to invest in decarbonization, potentially delaying progress toward the long-term climate targets (Bolton & Kacperczyk, 2021; Zhang, 2025).

This thesis shows that there is a significant relationship between higher carbon prices and lower emissions both in the Nordic and Swedish scope. The emissions are lower in both a total measure and intensity-wise. That implies that EU-ETS plays an important role in journey of fighting climate changes (Sautner et al., 2023).

One of the primary industries affected by the EU-ETS is the manufacturing sector, particularly steel, cement, and chemical production. These industries have historically been reliant on fossil fuels, making them significant carbon emitters. A high carbon price adds financial pressure on these businesses, as they must either pay for their emissions or transition to greener alternatives, such as electrification, carbon capture, or renewable energy sources. While this can be seen as a challenge, it also represents an opportunity to drive innovation and to stay relevant in the race of sustainability (Banerjee et al., 2025; Brown et al., 2022).

The power generation sector is another key area where carbon pricing exerts considerable influence. Sweden's electricity production is already largely decarbonized, with a mix of hydropower, nuclear, and wind energy dominating the grid. However, some industrial processes still rely on fossil-based energy sources, particularly in district heating and backup power generation. A high carbon price discourages the use of fossil fuels, reinforcing the transition to fully renewable energy systems. This transition is critical for achieving the goal of net-zero emissions by 2045 (Bartram et al., 2022; Naturvårdsverket, 2025).

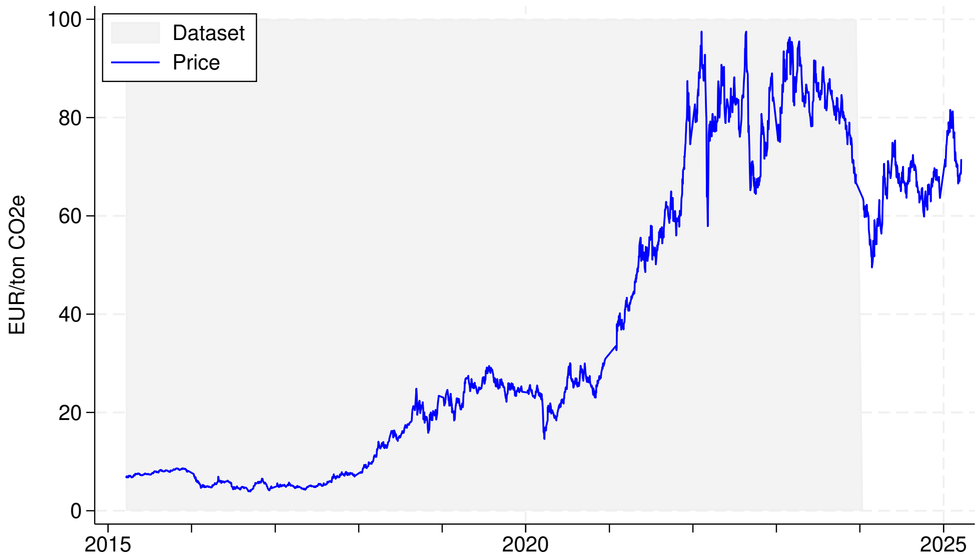

Figure 1.1: Carbon price

Another aspect to consider is the effect of carbon pricing on corporate financial planning and investment decisions. Companies must account for the cost of emissions in their long-term strategies, evaluating whether to invest in low-carbon technologies or continue purchasing allowances. As carbon prices rise, the economic rationale for green investment strengthens, pushing businesses toward sustainable solutions (Pástor et al., 2021, 2022). Since 2021 the carbon price has been substantially higher, see Figure 1.1. The volatility of carbon prices, however, introduces uncertainty, making it essential for firms to incorporate flexible strategies that can adapt to regulatory changes and market fluctuations. This thesis shows that high carbon prices impact, at least in the short term, the financial performance at the firm level (Hsu et al., 2023; Ivanov et al., 2023).

The role of carbon leakage is also an important consideration. If domestic companies face higher carbon costs than competitors in regions with less stringent regulations, they might struggle to remain competitive in global markets (Zhang, 2025). In some cases, firms may consider shifting production to countries with weaker climate policies, undermining the effectiveness of the EU-ETS. To address this risk, mechanisms such as the Carbon Border Adjustment Mechanism (CBAM) are being introduced to level the playing field and ensure that imported goods reflect a fair carbon price.

Furthermore, carbon pricing influences consumer behavior and market dynamics. As companies pass on the costs of emissions to consumers through higher prices for goods and services, demand may shift toward more sustainable alternatives. This shift can create opportunities for companies that invest early in green technologies and eco-friendly products, giving them a competitive edge in the transition to a low-carbon economy. Consumer awareness of carbon pricing may also drive businesses to adopt transparent reporting practices, enhancing corporate sustainability efforts and fostering trust in environmentally responsible brands (Bolton & Kacperczyk, 2021; Feldhütter et al., 2024).

From a policy perspective, the government plays a vital role in ensuring that carbon pricing supports national climate goals without causing excessive economic hardship. Policymakers must balance the need for ambitious climate action with maintaining industrial competitiveness. This may involve complementary policies such as subsidies for green innovation, tax incentives for renewable energy adoption, or support for workforce reskilling in affected industries (Bartram et al., 2022; Brown et al., 2022). Additionally, revenue generated from carbon pricing can be reinvested into climate-friendly initiatives, further accelerating the decarbonization efforts (Martinsson et al., 2024).

The financial sector also interacts with carbon pricing in meaningful ways. Banks, investors, and asset managers consider carbon pricing when assessing the risks and opportunities associated with corporate investments. As Environmental, Social, and Governance (ESG) considerations become increasingly important, firms with high exposure to carbon pricing risks may face higher financing costs or reduced access to capital (Ivanov et al., 2023). This dynamic encourages companies to proactively reduce their emissions to attract investment and maintain financial stability in a changing regulatory landscape (Hsu et al., 2023; Sautner et al., 2023).

Ultimately, understanding the impact of carbon pricing in the EU-ETS on companies is crucial for aligning business strategies with climate objectives. Companies that anticipate and adapt to carbon price trends will be better positioned to thrive in a low-carbon future, while those that fail to address emissions costs may struggle to remain competitive. The interplay between regulation, market forces, and technological innovation underscores the importance of integrating carbon pricing considerations into corporate decision-making (Choi et al., 2020; Pástor et al., 2021). By doing so, businesses can contribute to both economic resilience and environmental sustainability, reinforcing a leadership in the global climate transition.

1.2 Research gap & contribution

Although there is extensive research evaluating the overall effectiveness of the EU-ETS, much of the existing work tends to focus on the system's aggregate impacts across the European Union or on major industrialized countries like Germany, France, and Italy. Studies often analyze emission reductions, allowance price fluctuations, and overall economic effects at the EU or sectoral level, but there is relatively little detailed, firm-level analysis within smaller yet highly climate-ambitious economies (Bolton & Kacperczyk, 2023; Busch et al., 2022; Zhang, 2025). There is especially a lack of in depth research on how firms operating in cleaner energy contexts or with existing strong climate commitments adapt their operations, investments, and financial strategies in response to carbon pricing (Krueger et al., 2020; Sautner et al., 2023).

This leaves several important gaps. First, it is unclear how the EU-ETS operates in economies where renewable energy penetration is high, industrial emissions are relatively low, and climate policies are already stringent. Standard economic models assume that carbon pricing is the main driver of decarbonization incentives; however, in these contexts, firms might react differently — either by accelerating innovations or, conversely, seeing little marginal impact (Brown et al., 2022; Choi et al., 2020). Existing studies also insufficiently explore heterogeneity between sectors: while energy intensive industries have been well studied, less is known about how carbon pricing affects service industries, technology firms, and other low to medium emission sectors (Banerjee et al., 2025; Ilhan et al., 2020).

Furthermore, the interaction between EU-ETS and broader national climate strategies, such as carbon taxes, green innovation incentives, or renewable subsidies, remains underexplored (Bartram et al., 2022; Martinsson et al., 2024). The Nordic countries often layer EU-ETS obligations on top of national climate initiatives, creating a policy environment different from countries relying solely on EU-wide mechanisms. Understanding how firms manage these overlapping policy layers would offer critical insights into the real-world complexity of climate governance (Barnett et al., 2020; Ivanov et al., 2023).

Finally, most current research emphasizes environmental or economic outcomes separately but does not fully integrate the social dimension — particularly how carbon pricing affects firms' labor decisions, investment in communities, or broader questions of a just transition. Given the strong social welfare traditions in these economies, studying firm level behavior in response to carbon pricing could also highlight broader social and political factors that influence climate policy success or failure (Hong et al., 2023; Liang & Renneboog, 2017).

Addressing these gaps will allow for a richer, more context-sensitive understanding of the EU-ETS's functioning and effectiveness, and can help improve carbon pricing systems in diverse economic and social contexts globally.

1.3 Organization of the Thesis

The present thesis is divided into six chapters, each of which is further divided into sections and subsections. chapter 1 explains the rationale behind the thesis and its objectives. chapter 2 gives a review of previous studies. chapter 3 states the dataset and describes the method. chapter 4 presents the results, and chapter 5 discusses them and chapter 6 concludes.

2 Literature Review

2.1 Introduction

Carbon pricing, in the form of carbon taxes and cap-and-trade systems, has become a crucial policy tool in the fight against climate change. This chapter reviews existing studies on how carbon pricing affects companies, drawing on insights from various academic articles. The review is organized into thematic sections, each highlighting a specific aspect of the relationship between carbon pricing and corporate behavior.

2.2 Carbon Pricing and Financial Performance

The literature on carbon pricing and financial performance has evolved substantially in recent years, but significant complexities and unanswered questions remain.

Across several studies, a consistent finding is that carbon pricing affects firm-level behavior. Evidence from the Swedish carbon tax shows that higher carbon prices significantly reduce emissions intensity and overall emissions among manufacturing firms, particularly when firms are not financially constrained and when abatement costs are moderate (Martinsson et al., 2024). Elasticities of emissions with respect to carbon prices are economically meaningful and suggest that pricing carbon is an effective policy instrument under the right conditions.

However, when it comes to financial performance, the literature is less unanimous. Bolton and Kacperczyk (2023) document a positive "carbon premium" in stock returns — i e, firms with higher emissions tend to deliver higher expected returns, interpreted as compensation for transition risk. This implies that markets partially price in regulatory and reputational risks associated with being a high emitter. But this narrative is challenged by Zhang (2025), who argue that once lagged data release and firm performance are accounted for, the premium largely disappears or turns negative. In their interpretation, early studies may have captured performance signals rather than genuine compensation for risk. Carbon intensive firms do not consistently offer higher returns; instead, investor preferences, policy shocks, and changing attention to climate risk better explain cross-country variation in carbon returns.

This divide points to a central controversy in the literature: Whether carbon-intensive firms are financially penalized (through higher cost of capital, lower returns) or rewarded (through transition-risk premia). Context matters a great deal. For instance, Ivanov et al. (2023) show that carbon pricing affects credit markets too: High emission private firms face worse loan terms under cap-and-trade policies, while public firms are largely shielded. The differential exposure of public and private firms to transition risk complicates the view that capital markets efficiently and uniformly price carbon-related risk.

Another layer of complexity involves data reliability. Busch et al. (2022)

warn that inconsistencies in corporate carbon performance data, particularly across Scope 3 emissions and third-party estimates, can significantly affect empirical results. This undermines cross-study comparability and suggests that any claims about the pricing of carbon risk should be treated with caution unless data quality and standardization are rigorously addressed.

Despite growing empirical sophistication, large knowledge gaps remain. First, a lack of clear understanding of how carbon pricing interacts with firm-specific characteristics like financial constraints, innovation capacity, or supply chain positioning. The Swedish case shows that smaller and younger firms with high abatement costs respond less to carbon pricing than their more financially resilient peers, implying that access to finance may condition environmental responsiveness (Martinsson et al., 2024).

Second, the role of investors' shifting climate preferences — as shown in attention-based models by Choi et al. (2020) — suggests that valuation effects may not be driven by fundamentals alone, but also by sentiment, signaling, and policy narratives. This casts doubt on any static asset-pricing interpretation of carbon risk.

Going forward, more research is needed to answer several pressing questions. To what extent does carbon pricing translate into long-term financial outperformance for green firms or financial penalties for brown ones? How persistent are these effects across different regions, economic cycles, and regulatory environments? What role do capital market imperfections and investor behavior play in amplifying or dampening the transmission of carbon costs to firm valuations?

While there is broad agreement that carbon pricing affects real outcomes such as emissions, the link to financial performance remains empirically contested and highly context-dependent. Greater attention to data consistency, firm heterogeneity, and dynamic investor behavior will be crucial for advancing the field.

2.3 Carbon Pricing and Emissions Reductions

The literature presents a compelling yet complex picture of the relationship between carbon pricing and emission reduction. Synthesizing the findings reveals strong empirical support for carbon pricing as an effective tool for reducing greenhouse gas emissions, particularly when implemented under favorable institutional and policy conditions. At the same time, the literature reveals important limitations, mixed results across jurisdictions, and several areas of ongoing debate.

The most detailed and methodologically rigorous evidence comes from the Swedish case study. Over a 25-year period, Sweden's carbon tax, one of the highest and most longstanding in the world, produced a measurable decline in emissions within the manufacturing sector. According to Martinsson et al. (2024), emissions from manufacturing firms fell by 31%, with carbon pricing responsible for a large share of that reduction. Their analysis, based on firm-level panel data and sector-specific elasticity estimates, demonstrates that firms facing higher marginal carbon costs — particularly after exemptions were lifted with the introduction of the EU-ETS reduced emissions significantly. This study provides clear evidence of both emission reductions through technological change and some shifts in output away from high emission sectors, though the former dominates.

What is known, therefore, is that carbon pricing can be an effective policy lever when prices are sufficiently high and when firms face real marginal incentives to abate emissions. The Swedish study also makes an important contribution by demonstrating that these effects are not purely theoretical: they hold up in a real-world setting over multiple decades and across business cycles. Moreover, Martinsson et al. (2024) document that firm heterogeneity matters — firms that are smaller, younger, or more financially constrained show lower responsiveness to carbon prices, indicating that internal capacity to adjust plays a critical role.

However, beyond the Swedish case, the literature is more equivocal. While several articles suggest that carbon pricing regimes such as cap-and-trade systems (e g, the EU-ETS) or carbon taxes can lead to emission reductions, the magnitude and mechanisms of these reductions remain contested. For example, Dechezleprêtre et al. (2023) show that EU-ETS-targeted firms in France reduced emissions more than non-targeted firms, but much of the reduction came from changes in production levels or shifts in sourcing, rather than transformative investment in green technologies. This leads to a concern that reductions may, in some instances, result from reallocation or even carbon leakage rather than genuine decarbonization.

A related area of controversy involves the nature of the response: Is it temporary or sustained, and how much of it is due to actual technological innovation? Colmer et al. (2022) question the permanence of the emission reductions under the EU-ETS and suggest that part of the observed decline may stem from firms gaming reporting mechanisms or strategically adjusting output timing. Similarly, Ivanov et al. (2023) highlight that financial market constraints, such as more expensive credit for polluting firms under cap-and-trade regimes, may indirectly reduce emissions not through abatement but through suppressed investment or output — a potentially inefficient or unintended channel.

The issue of policy design also creates divergence in outcomes across studies. While the Swedish system used a high and steadily increasing carbon tax with few initial exemptions (later lifted entirely), the EU-ETS has suffered from over-allocation of permits and fluctuating prices, especially in its earlier phases. Ivanov et al. (2023) emphasize how the credibility and predictability of carbon prices influence firm behavior. If firms perceive carbon prices as unstable or politically reversible, their willingness to make long-term abatement investments diminishes. Therefore, one of the open questions in the literature is how expectations about future policy stringency shape present-day emissions behavior.

Another controversy concerns the distributional effects of carbon pricing and whether they unfairly burden certain types of firms. While Martinsson et al. (2024) show that emission reductions were strongest in larger and more financially robust firms, this raises concerns about equity and competitiveness. Smaller firms, or those with fewer resources to invest in abatement technologies, may bear disproportionate costs or risk being crowded out, especially in the absence of compensatory measures.

Taken together, the literature provides strong evidence that carbon pricing can reduce emissions, but it also makes clear that success depends heavily on the specifics of policy design, firm characteristics, and economic context. There is a broad consensus that marginal cost exposure — not just average tax burdens — is what drives firm behavior. Yet not all firms respond the same way, and the broader economic consequences, such as investment shifts, employment impacts, or sectoral reallocation, are not always well captured in existing models.

Future research should address several unresolved questions. What are the long run dynamic effects of carbon pricing on innovation and productivity?

Can we better separate real abatement from strategic output changes or carbon leakage? How do carbon pricing mechanisms interact with complementary policies like subsidies, public Research and Development (RnD), or green procurement? And how do firms form expectations about carbon prices and adjust their investment and operational strategies in response?

While there is substantial evidence — particularly from Sweden — that carbon pricing reduces emissions effectively, the literature also exposes significant gaps in our understanding of how and why these reductions occur. The credibility of policy, firm-level financial and operational capacity, and the structure of carbon markets all critically influence outcomes. As the world moves toward more ambitious decarbonization targets, answering these questions becomes increasingly urgent.

2.4 Investment in Green Technologies

The relationship between carbon pricing and investment in green technologies has been a focal point of recent literature, particularly in the context of whether pricing mechanisms like carbon taxes and cap-and-trade schemes spur firms to adopt cleaner technologies or merely encourage short-term emissions avoidance. The evidence from the articles in the provided file suggests a generally supportive but nuanced answer to this question.

There is strong empirical and theoretical backing for the idea that carbon pricing creates incentives for firms to redirect investments toward cleaner technologies. One of the most influential studies in this regard is Aghion et al. (2016), which shows that carbon taxes not only reduce emissions but also lead to directed technical change, particularly when the cost of clean technology is declining. Drawing from data on the automotive sector, the authors find that more stringent carbon taxes are associated with increased patenting in cleaner technologies and decreased innovation in polluting ones, indicating a redirection of innovative effort. This aligns with the "induced innovation" hypothesis, which posits that relative input prices shape the direction of technical change.

The literature also surfaces several caveats and unresolved tensions. First, the response to carbon pricing is highly heterogeneous. According to Ivanov et al. (2023), firms that are financially constrained respond differently to carbon price signals than firms with easy access to capital. This matters because investing in clean technology often involves large upfront costs with long payback periods. If firms are credit constrained or face elevated risk premiums due to carbon intensive operations, they may underinvest in innovation or choose short term compliance measures instead, such as offset purchases or output cuts.

Moreover, theoretical contributions such as Mojon et al. (2022) emphasize that carbon taxes alone may be insufficient to drive optimal investment in clean technologies, particularly when financial frictions are present. Their model shows that without complementary policies — such as subsidies for clean RnD or public co-financing — firms may be unable or unwilling to make the socially optimal level of investment in low carbon innovation, even when the carbon price is set efficiently. This insight is based on empirical findings from Ng et al. (2023), who demonstrate in 51 countries that firms facing financial constraints emit more CO2 Equivalent Emissions (CO2e) and invest less in green strategies, further stressing the importance of capital access in mediating the effects of carbon pricing.

Another layer of complexity emerges in the timing and credibility of carbon policies. For example, Meckling et al. (2017) argue that policy sequencing matters greatly: Early stage RnD subsidies may be more effective than immediate carbon pricing in nascent technology markets. Once the technological base has matured, carbon pricing becomes a more potent signal. This sequencing problem creates ambiguity in measuring the direct effect of carbon pricing on green technology investment, particularly in dynamic or developing markets.

Taken together, these findings establish a coherent but conditional narrative: Carbon pricing, when sustained and credible, does lead to increased investment in green technologies, especially when firms are not financially constrained and when policies are embedded in a broader supportive institutional framework. What remains uncertain is the extent to which pricing alone — without complementary instruments — can generate transformative technological change across a broad base of industries.

Key questions for future research include: To what extent do carbon prices drive endogenous RnD in green sectors versus adoption of existing technologies? How does the investment response vary across industries with different abatement cost curves or supply chain dependencies? And crucially, what mix of policy instruments - taxes, subsidies, regulation - best promotes long-term innovation while avoiding over reliance on any single lever?

The literature strongly supports the innovation-inducing potential of carbon pricing but consistently stresses that the pathway from price signal to technological change is shaped by firm characteristics, market structure, and policy context. Carbon pricing can unlock green investment — but it does not operate in a vacuum.

2.5 Carbon Pricing and Firm Relocation

One unintended consequence of carbon pricing is the potential for firms to relocate to regions with lower or no carbon costs. Wagner and Timmins (2009) suggest that firms may move production to jurisdictions with weaker environmental regulations, undermining the effectiveness of carbon pricing. This study finds evidence that industries such as cement, steel, and chemicals have seen increased foreign direct investment in developing countries with lax regulations, particularly after the introduction of the EU-ETS.

Similarly, Walker (2011) shows that job losses in regulated industries can be significant, with some firms moving operations offshore. However, the study also finds that new job opportunities emerge in cleaner industries, partially offsetting losses in carbon-intensive sectors.

Dechezleprêtre et al. (2022) indicate that modest differences in carbon price does not induce carbon leakage by company location shifts.

2.6 The Role of Financial Markets in Carbon Pricing

Investors are increasingly factoring carbon risks into their decision-making. The study Bolton and Kacperczyk (2021) finds that companies with high carbon emissions tend to trade at a discount, as investors anticipate future regulatory costs and potential reputational damage. The study also highlights that firms with strong ESG practices tend to attract more capital and exhibit lower volatility.

Additionally, Engle et al. (2020) shows that climate news significantly affects stock prices, particularly for firms in the energy sector. The study finds that investors increasingly use ESG metrics to hedge against regulatory risks, reinforcing the idea that carbon pricing influences corporate valuation beyond direct financial costs.

2.7 Conclusion

The reviewed literature indicates that carbon pricing has significant effects on firms across multiple dimensions, including financial performance, emissions reduction, technological investment, relocation decisions, and market valuation. While carbon pricing effectively incentivizes emission reductions and technological innovation, challenges such as carbon leakage and financial constraints must be addressed. Complementary policies, such as green subsidies and cross-border carbon adjustments, can enhance the effectiveness of carbon pricing in achieving climate goals while maintaining economic stability.

2.8 Research question

In order for policy makers to understand how EU-ETS carbon pricing affects Nordic & Swedish firms, more granular research is needed. Therefore the following question is investigated:

How does EU-ETS carbon pricing affect Nordic and Swedish firms and emissions? More specifically, how firm emissions, its intensity, and performance are affected by the carbon pricing during the period 2015 through

2023.

3 Empirical setting and research design

3.1 Data

The data is consolidated from five different databases - Börsdata, FinBas, LSEG, Instrat and Riskbanken. Börsdata has the general firm-specific properties and division, Finbas contains all trading data to calculate return (R_i), standard deviation (σ) and Sharpe ratio (s). LSEG provides the emission data for the firms, e g CO2e. Instrat gives the carbon price history and Riksbanken interest rate specification. The distribution of the companies is seen in Figure 3.1. The databases firm specific values are connected through its International Securities Identification Number (ISIN).

Less than 100 companies on the Swedish stock market (Small, Mid, Large cap, NGM, Spotlight, First North) have reported ESG and carbon emissions data before 2015. Consequently, the idea of commencing a study in that period is distant and with limited possibility to make robust findings. All A-shares are excluded from the dataset to avoid confounding the model regarding the firm effect. Natural log is calculated of variables that are large in size and span, such as Assets, Market Cap, etc.

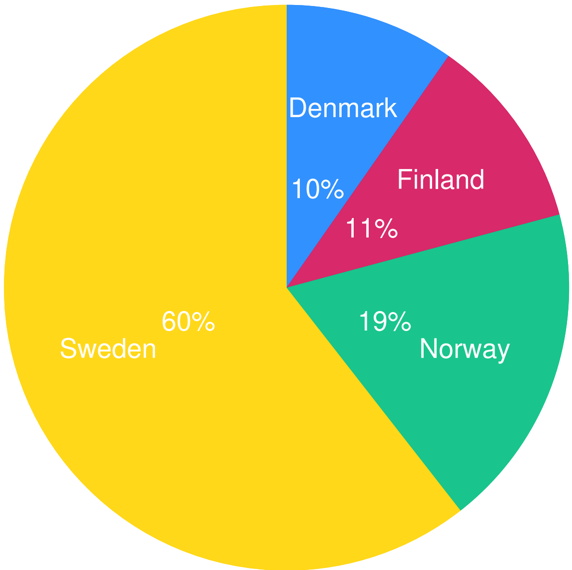

Figure 3.1: Distribution of firms by country

The study is restricted to only listed companies. The data is based on the self reported data from the companies. To keep the scope of the study on a sensible level only scope 1 and 2 are included in the firm specific emissions, i e total emissions. Scope 3 is thus excluded as the connection to the company actions are more distant than scope 1 and 2. See Appendix B for details on the definitions of the scope and what Greenhouse Gases (GHG) that are considered.

The descriptive statistics of the variables used can be seen in table 3.1.

3.2 Panel data setup

Two panel data sets are created with different dependent variables in order to analyze different aspects of the firm affects. Independent variables and control variables for each ensemble is picked with correlation deflection in

Table 3.1: Descriptive statistics for variables

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
CO2totToRev	1,605	137.3	453.8	0.00311	7,695
ln(CO2tot)	1,618	9.745	3.194	-1.897	17.72
EnvInnovationScore	2,117	31.58	32.03	0	99.88
ResourceuseScore	2,117	50.09	32.37	0	99.83
EmissionsTrading T/F	2,115	0.0931	0.291	0	1
PolicyEmissions T/F	2,117	0.774	0.419	0	1
WasteToRev	927	661.1	4,506	0.0154	67,810
DebtToEquity	5,464	1.229	7.717	0	419.3
DebtToCapital %	5,557	39.85	223.4	0	13,920
ReturnOnEquity	5,910	-22.47	219.9	-8,724	869.4
Return	7,969	0.159	0.960	-0.997	20.42
OperatingMargin %	5,921	-3,846	94,990	-4,513,000	5,334
ln(Assets)	6,341	20.19	2.726	7.350	29.04
ln(MarketCap)	5,584	20.47	2.365	12.45	28.66
ln(ShareholdersEquity)	6,207	19.42	2.562	7.822	27.30
ln(Debt)	5,393	18.66	3.177	4.466	28.08

mind and thus multicollinearity. A heat plot 3.2 is created for the variable ensembles to visualize the correlation. All independent variables are also winsorized at 1% level.

3.3 Model specification

Consider a panel regression model of the form

$$Y_{it} = \beta_0 + \beta_1 \text{Carbon Price}_t + \beta_2 X_{it} + \alpha_i + \gamma_t + \epsilon_{it} \tag{3.1}$$

where

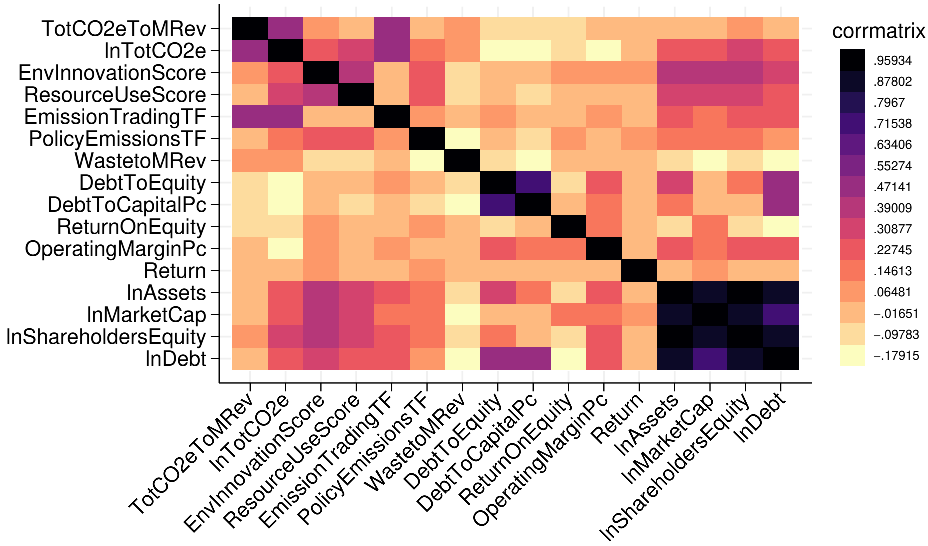

Figure 3.2: Heat plot for regression variables

Y_{it}	dependent variable
Carbon Price_t	yearly average carbon price
X_{it}	vector of firm-specific control variables
α_i	firm fixed effects to control for time-invariant firm characteristics
γ_t	year fixed effects to account for macroeconomic or policy shocks
ϵ_{it}	error term

Whether the hypothesis is rejected or not depends on the significance of the β_1.

$$\begin{cases} H_0\colon\ \beta_1 = 0 \\ H_1\colon\ \beta_1 \neq 0 \end{cases} \qquad \text{for } p < 0.05 \tag{3.2}$$

H_0 implies that carbon pricing cannot be proved to affect the dependent variable in statistically significant way.

H_1 implies that carbon price cannot be excluded as an impact factor of the dependent variable.

The panel data setup in Equation (3.1), where firm level outcomes Y_{it} are regressed on the carbon price, firm-specific controls, and both firm and year fixed effects, mirrors the empirical strategies employed in several studies analyzing the effects of carbon pricing on firm behavior.

A closely related specification is used in Ilhan et al. (2023) but for climate disclosure which uses log(Assets), debt-to-assets, book-to-market ratio as controls. Martinsson et al. (2024), who estimate the impact of Sweden's carbon tax on firm-level CO2e emissions in the manufacturing sector. Their model includes firm fixed effects to control for time invariant firm heterogeneity (e g, sector, production processes) and time fixed effects to account for year specific shocks such as macroeconomic fluctuations, policy adjustments, or technology diffusion. They also incorporate firm level controls like size, capital intensity, and export status, aligning closely with the structure of X_{it} in Equation (3.1).

Similarly, Bolton and Kacperczyk (2023) adopt a fixed effects panel model to estimate the relationship between carbon emissions and firm level financial performance across countries. Their model controls for firm characteristics and year effects to isolate the role of carbon exposure and regulatory context in determining stock returns and risk premia, again consistent with the framework used in this study.

The structure is also echoed in Ivanov et al. (2023), who analyze how carbon pricing regimes affect firms' access to credit. They include fixed effects to control for unobserved firm heterogeneity and year dummies to capture evolving macro financial conditions and regulatory timelines.

The specification in Equation (3.1) is a well-established and empirically validated approach in the carbon pricing literature, offering a robust way to isolate the effect of temporal variation in carbon prices while controlling for firm level heterogeneity and time varying confounders.

3.4 Variable selection

3.4.1 Carbon price & emissions

The variables included in the first ensemble plays a distinct and theoretically grounded role in explaining firm level emissions and environmental performance. Their inclusion reflects both economic reasoning and practical relevance in understanding how firms respond to carbon pricing within a multivariate context (Bolton & Kacperczyk, 2023; Busch et al., 2022). More detailed explanation of the variables are offered in Appendix B.

The core independent variable, *CO2e price*, is central to the analysis — it represents the external cost imposed on emissions and captures the main policy lever through which emissions reductions are incentivized. Theoretically, firms facing higher carbon prices should have a stronger incentive to reduce emissions intensity or absolute emissions to limit costs, making this the primary explanatory variable in all specifications (Bolton & Kacperczyk, 2023; Ivanov et al., 2023).

Operating margin is included to capture profitability. A more profitable firm might be better positioned to invest in emissions reducing technologies or afford the cost of compliance. At the same time, highly profitable firms may be operating in emission-intensive sectors where high margins are sustained by energy- or resource-heavy production, so the direction of its effect is not a priori obvious. Its inclusion helps control for these sectoral differences and internal financial capacity (Hsu et al., 2023).

Log of total assets is a proxy for firm size, which influences emissions both through scale and capacity. Larger firms typically emit more in absolute terms but may also benefit from economies of scale in emissions reduction investments. They are more likely to have formalized sustainability strategies and internal resources dedicated to carbon management, making this a key control variable (Sautner et al., 2023).

Market capitalization (log) adds another dimension of firm size and market value, capturing how publicly traded firms are priced by investors. It can also reflect investor expectations and scrutiny, which may influence environmental behavior. Including both asset and market-based measures of size ensures a more complete accounting of firm capacity and exposure (Bolton & Kacperczyk, 2021).

Log of debt helps measure financial leverage and potentially risk exposure. Firms with higher debt might be less flexible in adjusting to regulatory costs or undertaking green investments. At the same time, leverage can also finance transformation. This variable thus helps control for different financial strategies and constraints (Strebulaev, 2007).

Log of shareholders' equity balances the debt variable and gives insight into the firm's capital structure. A higher equity base may suggest greater financial stability or lower default risk, which can influence the firm's ability to absorb or respond to carbon pricing (Feldhütter & Pedersen, 2024).

Environmental innovation score captures a firm's technological orientation and proactive engagement with environmental improvement. Firms with higher innovation scores may already be investing in cleaner processes or products, making them more responsive to carbon pricing. It also reflects forward-looking behavior rather than just current emissions outcomes (Brown et al., 2022; Pástor et al., 2021).

Return on Equity (ROE) measures profitability relative to shareholder investment and serves as a broader indicator of financial health. High ROE may signal more efficient management and greater flexibility to implement emissions strategies — or, alternatively, a focus on short-term returns that comes at the cost of long-term environmental investment (Gantchev et al., 2024).

Debt-to-capital ratio gives further nuance to the firm's financial structure, specifically how much of its capital is financed by debt. This complements the earlier leverage indicators and captures risk tolerance and balance sheet pressure under regulatory costs (Houston & Shan, 2021).

Policy emissions exposure ($PolicyEmissions\ T/F$) is a binary variable indicating whether a firm is subject to emissions-related regulation. This distinction is important because firms subject to such policies are more likely to be directly affected by carbon pricing, which could amplify or mediate its effect on emissions. Including this variable helps isolate the direct pricing effect from regulatory exposure (Zhang, 2025).

Lastly, the constant term and fixed effects for time and sector are methodological necessities. They ensure that baseline differences across industries and over time are controlled for, accounting for unobserved heterogeneity such as economic cycles, sector-specific trends, and regulatory developments (Choi et al., 2020; Faccio et al., 2021).

Altogether, the variables included form a comprehensive model that balances theoretical rigor with empirical relevance, aiming to isolate the effect of carbon pricing while accounting for firm heterogeneity, financial characteristics, and broader environmental engagement.

3.4.2 Carbon price & performance

The second ensemble, investigates how carbon pricing affects firm-level financial performance — specifically returns and *Sharpe ratio*s — each variable included in the regression has a clear theoretical rationale and contributes to a well-rounded understanding of how climate policy interacts with firm-level risk and return (Bolton & Kacperczyk, 2023; Hsu et al., 2023).

The central variable of interest, *CO2e price*, is again crucial. It represents the market cost of emitting greenhouse gases and functions as a financial stressor or pricing signal that firms must internalize. From a financial perspective, increasing carbon prices may raise operational costs, alter future cash flow expectations, or increase uncertainty — each of which could negatively impact both raw returns and risk-adjusted performance (as reflected in Sharpe ratios) (Ivanov et al., 2023; Zhang, 2025). Its inclusion is essential to test whether firms experience a direct financial penalty under carbon pricing, which would be a critical consideration for investors and policymakers alike.

Beta is a standard control in financial performance regressions and measures the firm's sensitivity to overall market movements. Including beta ensures that the observed relationship between carbon pricing and returns isn't confounded by broader market dynamics. For instance, a firm with a high beta might experience higher returns simply because it moves more strongly with the market, not because of carbon pricing. Controlling for this allows us to isolate the pricing effect (Faccio et al., 2021).

Log of assets serves as a proxy for firm size. In the context of financial performance, firm size can influence risk, liquidity, and investor perception. Larger firms often have more diversified operations and potentially more resources to manage policy changes like carbon pricing. Including asset size helps control for these structural advantages or disadvantages that may affect financial outcomes (Sautner et al., 2023).

Debt-to-equity (D/E) ratio captures the firm's leverage and financial risk. High leverage can magnify returns in good times but also amplify losses or vulnerability under policy shocks. If carbon pricing increases operating costs or uncertainty, more leveraged firms may see more pronounced financial effects. This variable helps differentiate between firms that can absorb shocks and those that may be more fragile (Feldhütter & Pedersen, 2024; Strebulaev, 2007).

Resource use score measures how efficiently a firm uses physical resources. Efficient resource users may be better positioned to respond to carbon pricing through optimization or circular strategies, which could translate into better financial outcomes or risk mitigation. Including this score provides insight into whether operational sustainability correlates with financial resilience (Avramov et al., 2022; Pedersen et al., 2021).

Waste-to-revenue (revenue in million US dollar) quantifies how much waste a firm generates per unit of revenue and reflects operational externalities. While this measure is an environmental performance proxy, it may also have financial implications if investors penalize inefficiency or if firms face additional costs from waste management or reputational harm. Including it allows for testing whether internal operational waste influences financial outcomes in the carbon pricing context (Hsu et al., 2023).

Emissions trading (T/F) captures whether a firm is part of the EU-ETS or another formal emissions trading scheme. Being under a cap-and-trade regime may change how firms experience and respond to carbon price changes, either by increasing compliance costs or by providing flexibility through trading. This variable helps identify whether direct exposure to trading mechanisms interacts with carbon price sensitivity (Bartram et al., 2022; Martinsson et al., 2024).

Policy emissions (T/F) indicates whether the firm operates in a sector where emissions are likely to be regulated or targeted by climate policy. It allows for differentiation between firms structurally impacted by climate regulations and those more peripherally affected. Its role is especially important in the financial regressions, as regulatory exposure can drive risk perceptions, capital costs, and investor behavior (Ilhan et al., 2020; Li et al., 2024).

Lastly, the constant term and fixed effects for time and sector are essential to absorb unobserved heterogeneity. Time fixed effects control for macroeconomic shifts, policy changes, or global financial events — like the Coronavirus disease 2019 (COVID-19) pandemic or energy shocks — that could influence returns over time. Sector fixed effects capture the structural differences in financial performance between industries with different carbon intensities and regulatory exposure (Banerjee et al., 2025; Choi et al., 2020).

Together, these variables provide a comprehensive framework to assess whether and how carbon pricing affects firms not only operationally, but also in terms of market performance. This model helps answer a crucial question for sustainable finance: do environmental policy tools like carbon pricing materially influence the financial risk-return profile of firms, and can investors reliably price this into their decision-making?

3.5 Model estimation strategy

Using a fixed effects model, enables the natural differences of conditions prevailing in the firms for specific sectors to be compared on more equal terms.

The data is restricted to nine years; 2015-2023, because by the time of writing ESG data for 2024 has not been published yet.

3.6 Research ethics

This research relies exclusively on publicly available financial and emissions data sourced from official databases, company reports, and regulatory disclosures. As such, it does not involve human subjects, private or sensitive information, or any form of personal data, and therefore does not pose ethical risks related to privacy or confidentiality. All data is used in accordance with the terms of use specified by the data providers, and sources is appropriately cited to maintain transparency and academic integrity. The analysis will be conducted objectively, and no attempt will be made to manipulate or misrepresent data to support a predetermined outcome. Since the study does not involve direct interaction with individuals or proprietary firm information, formal ethical approval is not required, though the research will still adhere to general principles of responsible conduct of research, including honesty, accuracy, and accountability.

4 Results and analysis

4.1 Carbon price & emissions

The regression results presented in the table 4.1 suggest a clear and consistent relationship between carbon pricing and firm-level emissions outcomes in both the broader Nordic region and Sweden specifically. Across all models, the variable for carbon price (CO2ePrice) shows a statistically significant and negative association with both total emissions and emissions intensity. This implies that increases in carbon pricing under the EU Emissions Trading System are linked with measurable reductions in firm emissions, both in absolute terms and relative to revenue. The effect holds across different model specifications, reinforcing the robustness of this finding. These results are in line with Bolton and Kacperczyk (2023), who provide evidence that firms exposed to carbon pricing reduce emissions in response to regulatory pressure, particularly when cost incentives are credible and sustained. Similarly, Sautner et al. (2023) observe that firms adjust emissions and operations when exposed to elevated carbon costs, confirming the direct regulatory channel visible here.

In addition to emissions reductions, higher carbon prices are also significantly associated with improved environmental performance as measured by emissions-related ESG scores. This suggests that firms may be responding to higher carbon costs not only by reducing emissions but also by enhancing their environmental disclosures or overall sustainability performance. These responses may reflect strategic adaptation, such as investments in cleaner technologies or improved reporting practices aimed at managing reputational risk and investor expectations. This dual adjustment mechanism aligns with findings from Hsu et al. (2023), which show that firms respond to environmental pressure both operationally and via narrative and ESG signaling, often to preserve investor confidence. Similarly, Inderst and Opp (2025) highlight the tension between actual environmental impact and perceived ESG efforts, which may help explain the separation between emissions reductions and ESG scoring seen in the current results.

Control variables such as firm size (measured by market capitalization and assets) and profitability exhibit mixed effects. Larger firms tend to have lower emissions intensity but are also positively associated with higher environmental scores, potentially indicating better capacity to manage carbon risks or to invest in emissions reductions. This echoes findings from Azar et al. (2021), who document that large firms tend to perform better on environmental disclosures and ESG ratings, although this does not always translate into greater emissions reductions. Variables related to firm capital structure, such as debt and equity, also show significant associations, hinting at the role of financial health in environmental strategy. This finding parallels the observations in Strebulaev (2007) and Feldhütter and Pedersen (2024), where capital structure flexibility is linked to greater adaptability to external shocks, including regulatory pressures.

Interestingly, environmental innovation scores are strongly linked to higher emissions performance scores but show limited connection to direct emissions reductions. This may suggest that while innovation is valued and reported, its tangible effect on emissions may take time to materialize. Brown et al. (2022) support this view, showing that the emissions-reducing effects of environmental RnD typically appear with lag, and innovation may first improve reputation or metrics rather than core operations.

The PolicyEmissions indicator, which denotes whether a firm has specific emissions policies or processes that are aimed to drive continuous improvements, shows a strong positive relationship with emissions performance scores but no consistent effect on actual emissions. This could indicate a disconnection between formal policy exposure and real environmental impact, raising questions about whether formalization is driving substantive change or primarily influencing public reporting. This potential gap between policy formality and operational reality has been similarly noted in Ilhan et al. (2023), who argue that disclosures and governance frameworks often overstate corporate environmental action unless aligned with measurable reduction goals.

Comparing the models across scope, the results are largely consistent between the Nordic region and Sweden alone. However, the models limited to Swedish firms tend to have higher explanatory power, particularly in models explaining total emissions (see Appendix Figure A.1) and emissions scores (see Appendix Figure A.2). This may reflect Sweden's more integrated or stringent national climate policies complementing the EU-ETS, or more homogenous firm behavior within a single national context. This interpretation echoes Martinsson et al. (2024), who show that Sweden's layered carbon pricing regime creates stronger and more consistent firm-level responses than EU-wide mechanisms alone.

Overall, the table provides strong empirical evidence that carbon pricing through the EU-ETS is associated with reduced emissions and improved environmental performance at the firm level. It also highlights the importance of firm characteristics and financial variables in shaping environmental outcomes. However, the divergence between actual emissions reductions and ESG scoring also raises important questions about the depth of corporate responses and the need for more rigorous integration of emissions impact into sustainability evaluations. These findings contribute to a growing literature emphasizing that while market-based mechanisms like carbon pricing are effective, their interaction with firm strategy, financial structure, and policy context deserves further investigation. The pattern observed here aligns well with the broader argument in Pástor et al. (2021), who stress that real sustainability performance needs to be matched with economic incentives and verifiable impact to drive meaningful change.

4.2 Carbon price & performance

The table 4.2 presents the relationship between carbon pricing and financial performance — measured through return and Sharpe ratio — for firms in the Nordic region and Sweden. One of the most striking patterns is the consistently negative and statistically significant coefficient of CO2ePrice across all specifications. In both the full Nordic sample and the Sweden-specific models, increases in carbon prices are associated with lower firm returns and lower risk-adjusted performance (Sharpe ratios). These results suggest that as carbon pricing rises, firms tend to experience a decline in stock performance, possibly due to increased operational costs, shifting capital expenditures toward compliance and mitigation, or heightened uncertainty linked to environmental regulation. This aligns with the findings of Bolton and Kacperczyk (2023) and Zhang (2025), both of which document a negative correlation between carbon exposure and firm performance in global equity markets, emphasizing how markets penalize firms with greater carbon intensity.

The significance of this negative relationship, particularly for Sharpe ratios (where the t-statistics are notably high), implies that the effect is not only economically meaningful but also robust across different model settings. Firms exposed to higher carbon prices appear to be delivering returns with greater volatility relative to risk, which may reflect investor concerns over their ability to adapt or pass on carbon costs, especially in more emissions-intensive sectors. This risk amplification is consistent with the broader risk channel explored by Banerjee et al. (2025), who show that climate-related shocks can heighten systematic risk and reduce risk-adjusted returns, especially for carbon-intensive firms.

Other control variables such as beta perform as expected: beta is positively associated with returns, indicating that more market-sensitive firms tend to yield higher returns, though its impact on Sharpe ratios is minimal. Firm size (measured by ln(Assets)) shows weak and inconsistent effects across models, while leverage (DebtToEquity) and ESG-related variables like ResourceUseScore or WasteToRevenue do not exhibit statistically significant relationships with either return or Sharpe ratio. This limited relevance of ESG metrics echoes concerns raised by Avramov et al. (2022) and Giglio et al. (2025), who argue that ESG indicators can lack consistency and explanatory power in predicting firm-level financial outcomes. Likewise, Hsu et al. (2023) show that environmental performance may not be priced uniformly across markets, especially where ESG signal quality is low.

Interestingly, the binary indicators for emissions policy exposure (PolicyEmissions and EmissionsTrading) are not statistically significant, despite the inclusion of sector and time fixed effects. This suggests that it is not merely being subject to regulation that affects performance, but rather the actual level of the carbon price that matters most. This further supports the interpretation that financial markets are responsive to the economic signal embedded in carbon pricing itself, rather than to categorical policy exposure. Similar conclusions are reached in Sautner et al. (2023), who find that market reactions are stronger when firms face actual cost exposure, not merely regulatory classification. Additionally, the emphasis on pricing over policy categorization complements findings by Bolton and Kacperczyk (2021), who show that investors increasingly price climate risk in proportion to its tangible financial implications.

Overall, the findings from table 4.2 point to a financial downside for firms as carbon prices increase, at least in the near term. This highlights a potential tension between environmental regulation and short-term shareholder returns, especially in regions or sectors where firms may not yet have fully internalized or hedged their carbon exposure. It also underlines the need for more nuanced investor strategies in carbon-intensive or policy-sensitive sectors, as well as for firms to improve carbon risk management if they are to maintain financial performance under tightening climate regulation. This recommendation is in line with conclusions from Stroebel and Wurgler (2021) and Liang and Renneboog (2017), who argue that climate-aligned governance and risk planning are becoming increasingly critical for sustaining firm value in the evolving regulatory landscape.

Table 4.1: Regression on emissions

VARIABLES	(1) CO2toRev	(2) ln(CO2tot)	(3) EmissionsScore	(4) CO2totToRev	(5) ln(CO2tot)	(6) EmissionsScore
CO2ePrice	-1.752***	-0.0158***	0.0613***	-0.334***	-0.0109***	0.0914***
	(-5.248)	(-8.274)	(3.831)	(-3.386)	(-4.544)	(4.300)
OperatingMargin %	-0.474***	0.000689	0.000125	0.0219	-0.0143***	0.000150
	(-6.152)	(1.560)	(0.440)	(0.142)	(-3.896)	(0.523)
ln(Assets)	-92.66***	-0.406***	5.920***	-2.851	-0.0683	6.198***
	(-4.081)	(-3.158)	(5.393)	(-0.484)	(-0.481)	(4.692)
ln(MarketCap)	-99.81***	-0.562***	1.528***	-18.01***	-0.331***	2.751***
	(-7.694)	(-7.567)	(3.076)	(-4.883)	(-3.695)	(4.654)
ln(Debt)	-34.88	0.647***	2.444***	-13.93**	0.532***	1.927**
	(-1.499)	(5.709)	(3.246)	(-2.403)	(4.617)	(2.242)
ln(ShareholdersEquity)	226.0***	0.848***	-5.604***	32.25***	0.499**	-5.489***
	(6.145)	(4.469)	(-4.017)	(3.382)	(2.428)	(-3.357)
EnvInnovationScore	-0.159	0.0171***	0.190***	0.0332	0.0209***	0.189***
	(-0.452)	(8.517)	(11.29)	(0.321)	(8.347)	(8.428)
ReturnOnEquity	1.489**	0.00897***	0.0435**	-0.420*	0.00374	0.0443**
	(2.487)	(2.636)	(2.549)	(-1.783)	(0.678)	(2.163)
DebtToCapital %	3.846**	-0.0116	-0.174***	0.804**	-0.00196	-0.0811
	(2.480)	(-1.468)	(-2.959)	(1.972)	(-0.226)	(-1.133)
PolicyEmissions T/F	-19.59	0.798***	28.13***	-14.50	0.698***	25.43***
	(-0.569)	(4.066)	(20.82)	(-1.531)	(3.044)	(14.87)
Constant	259.3	-0.992	-70.76***	112.6**	-5.082***	-101.5***
	(1.549)	(-1.060)	(-10.10)	(2.097)	(-3.980)	(-10.54)
Observations	1,363	1,371	1,756	708	715	1,010
R-squared	0.095	0.400	0.512	0.076	0.519	0.577
Number of sektorid	10	10	10	9	9	9
Scope	Nordic	Nordic	Nordic	Sweden	Sweden	Sweden
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Bransch FE	No	No	No	No	No	No
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.2: Regression on performance

VARIABLES	(1) Return	(2) Sharpe	(3) Return	(4) Sharpe
CO2ePrice	-0.00160**	-0.0180***	-0.00232***	-0.0197***
	(-2.015)	(-22.12)	(-2.828)	(-17.78)
Beta	0.0400***	0.00148	0.0429***	0.00157
	(29.51)	(1.069)	(27.49)	(0.745)
ln(Assets)	-0.0251*	-0.0211	-0.0284	-0.0356
	(-1.653)	(-1.360)	(-1.538)	(-1.428)
DebtToEquity	-0.0163	0.0130	-0.0236	0.0595
	(-0.788)	(0.615)	(-0.526)	(0.985)
ResourceUseScore	-0.000641	-0.000698	0.00112	-0.000382
	(-0.562)	(-0.598)	(0.793)	(-0.201)
WasteToRevenue	-3.96e-06	-7.53e-06	-4.59e-06	-7.92e-06
	(-0.510)	(-0.948)	(-0.640)	(-0.820)
EmissionsTrading T/F	0.0223	-0.0727	0.0625	-0.0840
	(0.320)	(-1.018)	(0.703)	(-0.702)
PolicyEmissions T/F	0.0859	0.138	0.0331	0.188
	(0.830)	(1.306)	(0.270)	(1.137)
Constant	0.757**	1.000***	0.841*	1.355**
	(2.147)	(2.771)	(1.938)	(2.317)
Observations	504	504	322	322
R-squared	0.649	0.520	0.720	0.534
Number of sektorid	10	10	8	8
Scope	Nordic	Nordic	Sweden	Sweden
Sector FE	Yes	Yes	Yes	Yes
Bransch FE	No	No	No	No
Time FE	Yes	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5 Discussion

The regression results covering the period from 2015 through 2023 offer valuable insights into how carbon pricing has influenced both environmental and financial outcomes for firms operating in the Nordic region and Sweden. However, interpreting these results requires careful consideration of both the empirical findings and the broader economic, regulatory, and geopolitical context in which they are embedded. Noteworthy is also that the data is self-reported by the companies, which aligns with concerns raised in Avramov et al. (2022) regarding the potential noise and strategic bias in ESG disclosures.

Over this nine-year span, the EU-ETS has undergone significant reform Martinsson et al. (2024), particularly from Phase III to Phase IV (starting in 2021), leading to a notable increase in carbon prices. From historically low and often volatile levels before 2017, the carbon price steadily rose and reached record highs by 2022. This structural change is reflected in the results: the consistent and significant negative association between carbon prices and firm-level emissions suggests that the tightening of the carbon market has had its intended environmental effect. Firms appear to be responding to higher carbon costs by either reducing emissions or altering production practices to become more carbon-efficient. These results align closely with those of Bolton and Kacperczyk (2023) and Sautner et al.

(2023), who find that firms exposed to carbon pricing and policy stringency tend to actively reduce emissions and adjust operational behavior in response to escalating compliance costs.

The positive relationship between carbon pricing and ESG-style emissions scores further supports this view, although it may also indicate increased emphasis on disclosure and environmental reputation management in response to investor and regulatory pressure. This duality mirrors the findings in Hsu et al. (2023) and Inderst and Opp (2025), who suggest that while firms may improve their environmental image through ESG reporting, these enhancements do not always reflect real emissions reductions — posing risks of symbolic compliance.

From a financial standpoint, the results show that increasing carbon prices have a statistically significant negative effect on both returns and Sharpe ratios. This suggests that for the period studied, markets have perceived higher carbon prices as a financial burden on firms, perhaps due to increased input costs, compliance expenses, or strategic shifts in capital allocation. These findings are strongly aligned with the conclusions of Zhang (2025) and Banerjee et al. (2025), who both show that carbon exposure is associated with lower expected returns and greater systematic risk, particularly for firms with high baseline emissions. The observed decline in Sharpe ratios resonates with the argument in Faccio et al. (2021), which emphasizes that firms exposed to environmental shocks suffer greater volatility due to market re-pricing of transition risk.

At the same time, the economic backdrop during this period was far from stable. The COVID-19 pandemic disrupted industrial production and emissions levels in 2020, while the 2021–2022 global energy crisis and inflation shocks further altered cost structures and firm behavior. These macroeconomic disturbances could have distorted the carbon price signal in the short term and introduced noise into the firm-level responses. For instance, emissions reductions in 2020 may reflect lockdown effects more than genuine decarbonization, while 2022 saw temporary shifts in energy use and emissions due to fuel switching and geopolitical constraints. This observation echoes the macro-sensitivity noted by Schlenker and Taylor (2021), who find that climate and macroeconomic shocks interact in ways that complicate the interpretation of climate-related financial performance.

This context raises questions about the internal validity of the regression estimates. While fixed effects help control for unobserved sector and time heterogeneity, structural breaks and time-varying shocks could still bias the results. The lack of bransch-level fixed effects, for example, means that within-sector variation at a more granular industry level is not fully accounted for. This could matter if, say, heavy industry firms responded very differently to carbon pricing than service firms within the same broad sector. Similar concerns are raised by Choi et al. (2020), who highlight the importance of disaggregating by firm and industry type to uncover heterogeneity in climate risk pricing.

Moreover, the results reflect average treatment effects across the sample period but may obscure important heterogeneity over time. The effect of carbon pricing may have been weak or muted during the early years (2015–2017) when prices were low, and more pronounced after 2019 when prices rose substantially and net-zero commitments gained traction. A dynamic or time-interacted model might reveal whether firm responses intensified as carbon pricing became more stringent and credible. This time-dependence of carbon risk impact is a central insight in Stroebel and Wurgler (2021), who argue that markets underprice transition risk until regulatory shocks make them salient.

From an external validity perspective, the findings are most directly applicable to market economies embedded in a relatively strong institutional and regulatory context like the Nordic countries. These countries typically exhibit high levels of environmental awareness, strong governance, and proactive climate policies, which may not generalize to other EU member states or to regions outside the EU-ETS framework. This point is consistent with the observations of Krueger et al. (2020), who note that institutional quality shapes both the intensity and the transmission of climate risk in capital markets.

In sum, while the results point to a clear environmental benefit of carbon pricing — emissions reduction and improved ESG outcomes — they also suggest short-term financial tradeoffs, at least for publicly listed firms. This underscores the transitional nature of climate policy impacts: firms are in the process of adapting, and the balance between cost and competitiveness will likely shift as cleaner technologies mature and policy frameworks stabilize. The time frame of 2015 to 2023 captures both the early and transitional stages of this policy evolution, which enhances the relevance of the findings but also highlights the need for caution in interpreting them as definitive or permanent effects. Longitudinal extensions, sector-specific deep dives, and incorporation of firm-level climate strategies could further improve understanding of how carbon pricing shapes corporate behavior and performance in the long run — an agenda closely mirrored in Pástor et al. (2021).

6 Conclusions

The results and broader discussion point to a set of meaningful and nuanced conclusions about the effects of carbon pricing on firms in the Nordic region and Sweden during the 2015–2023 period. First and foremost, the evidence strongly supports the view that carbon pricing through the EU Emissions Trading System has had its intended environmental effect: higher carbon prices are consistently associated with reductions in both absolute emissions and emissions intensity. This suggests that firms are responding to the financial signal embedded in the price of carbon, likely by improving operational efficiency, adopting cleaner technologies, or shifting business models toward lower-carbon practices.

At the same time, the results indicate that this transition is not without cost — at least in the short to medium term. Carbon pricing appears to exert downward pressure on firm financial performance, with negative effects on both returns and risk-adjusted returns. The reduction in Sharpe ratios, in particular, suggests that higher carbon prices may be introducing greater uncertainty and volatility into the market's assessment of firm value. This could reflect not only operational cost increases but also investor sensitivity to regulatory risk and carbon exposure, especially in capital markets where ESG factors are becoming more prominent in pricing and investment decisions.

The findings also hint at a transitional phase: while firms are clearly adjusting to carbon pricing, the adjustment process has financial costs that markets are still digesting. This is especially relevant given the steep increase in carbon prices after 2018 and the broader political and economic disruptions over this period, including the COVID-19 pandemic and the global energy crisis. These contextual factors likely compounded the challenges firms faced and amplified the financial consequences of carbon pricing in ways that may not fully persist in a more stable or mature carbon pricing environment.

Moreover, the divergence between environmental performance metrics (such as ESG scores) and actual emissions reductions reminds us that disclosure and substantive impact are not always aligned. Some firms may be improving their environmental reputation or reporting practices without achieving proportionate emissions reductions, suggesting a need for investors and regulators to look beyond surface-level ESG indicators.

In conclusion, carbon pricing has proven effective at driving emissions reductions among firms, but it also presents short-term financial headwinds, particularly in terms of returns and market volatility. The results affirm the logic of using market-based instruments for climate policy, while also underlining the importance of policy stability, technological innovation, and financial support mechanisms to help firms manage the transition. For investors and policymakers, these insights reinforce the importance of balancing environmental ambition with economic resilience during the critical years of industrial decarbonization.

A Figures

The body of the box plot presents first and third quartile and middle line median. The whiskers presents the quartile minus 1.5 times the innerquartile.

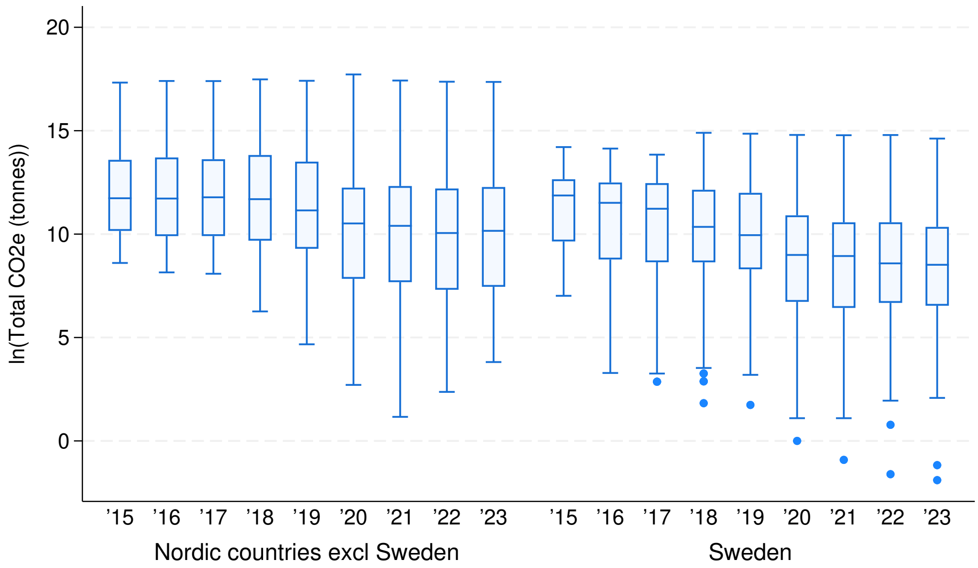

Figure A.1: Box plot Total CO2e over time

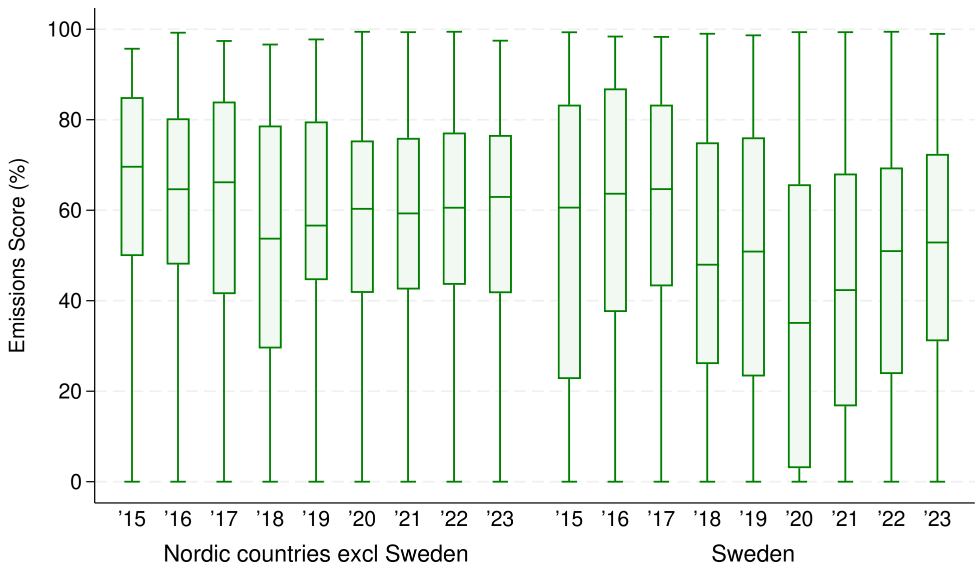

Figure A.2: Box plot Emissions Score over time

B Data variables

- **Listing** Specifies what list on the stock exchange the stock resides: First North, Large Cap, Mid Cap, Small Cap, Nordic Growth Market, Oslo Bors, Oslo Expand, Oslo Growth, Prelist, Spotlight.
- **Sector** Categories divided into: Perishables, Energy, Financial & Real Estate, Health Care, Industrial, Information Technology, Utilities, Materials, Consumer Discretionary & Communication Services.
- **Sharpe ratio** Measurement of risk adjusted return: (Return - Risk free rate) / standard deviation
- **Standard deviation** Measurement of variation of a stock's price.
- **CO2totToRev** Total Carbon dioxide (CO2) and CO2e / Million in revenue \$: Total CO2 and CO2e emisson in tonnes divided by net sales or revenue in US dollars in million. See *CO2tot* for specification.
- **CO2tot** Total CO2 and CO2e in tonnes. Total CO2 emission = Direct (scope 1) + Indirect (scope 2). The following gases are relevant: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hudrofluorocarbons (HFCs), perfluorinated compound (PFC), sulfur hexafluoride (SF6), nitrogen trifluoride (NF3). Follows GHG protocol to all emission classifications by type.

- **EnvInnovationScore** Environmental Innovation Score: Environmental innovation category score reflects a company's capacity to reduce the environmental costs and burdens for its customers, and thereby creating new market opportunities through new environmental technologies and processes or eco-designed products.

- **ResourceuseScore** Resource Use Score: Resource use category score reflects a company's performance and capacity to reduce the use of materials, energy or water, and to find more eco-efficient solutions by improving supply chain management.

- **EmissionsTrading T/F** Emissions Trading True/False: Does the company report on its participation in any emissions trading initiative? Emissions trading (cap & trade) is a market-based approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. If a company claims to participate in an emission trading scheme in the future it is graded as false.

- **PolicyEmissions T/F** Policy Emissions True/False: In the scope are the various forms of emissions to land, air or water from the company's core activities - processes, mechanisms or programs in place as to what the company is doing to reduce emissions from its operations - system or a set of formal, documented processes for controlling emissions and driving continuous improvement

- **WasteToRev** Total Waste / Million in revenue $: Total amount of waste produced in tonnes divided by net sales or revenue in US dollars in million. Total waste = non-hazardous waste + hazardous waste - only solid waste is taken into consideration, exceptionally if the liquid waste reported in ton then the summation to derive total including liquid waste - for sector like mining oil & gas, waste generation like trailing, waste rock, coal and fly ash, etc are also considered.

- **DebtToEquity** Total Debt to Common Equity represents the ratio of Debt - Total Debt divided by the value of Common Shareholders Equity. Denominator should be positive. It is applicable to all industries.

- **DebtToCapital %** Total Debt Percentage of Total Capital represents the ratio of Total Debt divided by the value of Total Capital, multiplied by 100. Numerator should be zero or positive. Denominator should be positive. Numerator should be zero or positive.

- **ReturnOnEquity** Return on Average Total Equity in % (Income before Discontinued Operations & Extraordinary Items) measures the ability of a Company to generate earnings from its stockholders investments in the Company. Return on Average Total Equity in % (Income before Discontinued Operations & Extraordinary Items) represents Income before Discontinued Operations & Extraordinary Items / Total Shareholders Equity * 100. Denominator should be positive. The data item is calculated for Annual periodicity only.

- **Return** Yearly stock price return including dividends.

- **OperatingMargin %** Operating Margin in % represents the ratio of Operating Profit before Non-Recurring Income/Expense divided by the value of Revenue from Business Activities - Total revenue, multiplied by 100. Denominator should be positive.

- **Assets** Total Assets represents the total assets reported by the company and in the sum of current assets and non-current assets.

- **MarketCap** Market Capitalization represents the sum of market value for all relevant issue level share types. The issue level market value is calculated by multiplying the requested share type by latest close price. The measure supports default, free float and outstanding share types. The default shares type is the most widely reported outstanding share for a market and it is the most commonly used outstand or listed shares.

- **ShareholdersEquity** Total Shareholder's Equity including Minority Interest & Hybrid Debt: It includes debt which has the characteristic of both debt and equity reported in the equity section, non-controlling interest included within equity and Total Shareholders' Equity Attributable to Parent Shareholders.

- **Debt** Total Debt: represents the total value of all borrowings reported by the company. It includes both short term and long term debt.

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