The impact of carbon price and firm-level emissions on Swedish firms' profits

Evidence from the EU ETS subject firms in Sweden 2013-2022

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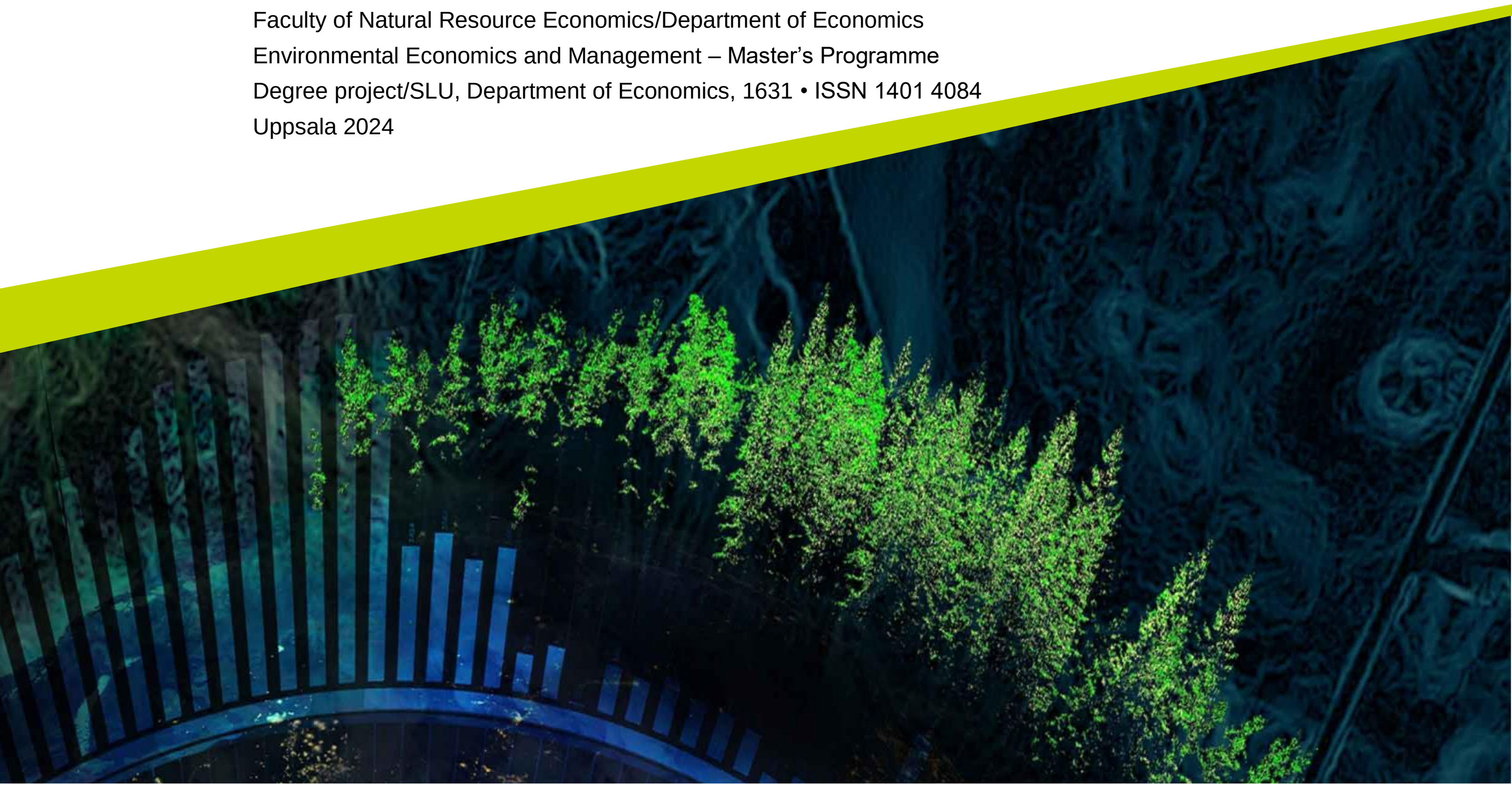

The impact of carbon price and firm-level emissions on Swedish firms' profits. Evidence from the EU ETS subject firms in Sweden 2013-2022.

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Abstract

This study investigates the impact of carbon pricing and firm-level total emissions on the profitability of Swedish firms participating in the European Union Emission Trading System (EU ETS) from 2013 to 2022. By analysing firm-level data, the research aims to determine how changes in carbon prices and in emission levels affect firms' profits. The EU ETS, a cap-and-trade system, is designed to reduce greenhouse gas emissions by setting a limit on emissions and allowing the trading of emission permits. As the system evolves and becomes increasingly restrictive, firms face the dual challenges of purchasing additional permits and reducing emissions to comply with decreasing caps.

The study uses OLS-regression analysis to examine the relationship between carbon pricing, firm-level total emission, and profitability, using firm-level data on profits, emissions and purchases of emissions permits. The results from the thesis find a weakly positive relationship between firm-level EBIT, emissions and permit price as well as a weakly negative relationship between EBIT and a binary variable indicating whether firms were a net buyer of permits or not.

This research provides insights into the economic implications of environmental regulations and offers policy recommendations to enhance the effectiveness of carbon pricing strategies. The results underscore the potential for carbon pricing to achieve sustainable economic growth while mitigating environmental impact, thereby contributing to the broader discourse on climate policy and firm sustainability.

Keywords: EU ETS, Firm-level, Profits, Emissions, Carbon Pricing

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1. Introduction

The effectiveness of carbon pricing mechanisms in balancing environmental goals with economic competitiveness remains a critical issue in climate policy. This thesis explores the research question: What is the correlation between carbon permit prices, firm-level total emissions, and profits among Swedish firms participating in the EU Emission Trading System?” Understanding this relationship is essential for evaluating whether the EU ETS successfully incentivizes emission reductions without unduly compromising firm profitability.

1.1 Background and context

The escalating impact of global warming has prompted significant international action to address greenhouse gas (GHG) emissions. In 1997, the Kyoto Protocol was adopted by the United Nations as a landmark treaty aimed at reducing global emissions through legally binding targets (UNFCCC 2024a). This protocol emerged from growing concerns about environmental degradation driven by increased emissions. Historical data underscores the urgency of the situation: global temperature anomalies have risen from an average of around 0°C in the 1950s to approximately 1°C in the 2020s (NASA 2024), while global emissions have surged by 57% over the past three decades (World Bank 2024a).

In response to this pressing issue, the European Union introduced the European Union Emission Trading System (EU ETS), a cap-and-trade mechanism designed to regulate and reduce carbon emissions across member states. The EU ETS operates by setting a cap on total emissions and issuing permits that can be traded among firms (UNFCCC 2024b). This system aims to create economic incentives for firms to reduce their emissions cost-effectively. Over the years, the EU ETS has undergone several phases, each progressively tightening the cap on emissions and expanding its coverage to include more sectors and industries (European Commission 2024a).

The EU ETS also incorporates a strategy to mitigate carbon leakage, a risk that firms might relocate to regions with less stringent emission regulations. To address this, the system allocates free allowances to industries at high risk of carbon leakage

(European Commission 2024b). However, as the emissions cap continues to decrease annually (European Commission 2024c), the allocation of free permits has also been reduced, potentially influencing firms' purchasing behavior and emission reduction strategies. Additionally, it remains an open empirical question how the reduction of free permits could potentially impact firms' profitability, warranting further investigation to understand the full economic implications.

Cap-and-trade systems, exemplified by the EU ETS, aim to provide flexibility in achieving emission reductions. The EU ETS has evolved through multiple phases, each progressively tightening the cap on emissions and expanding its coverage to include more sectors (European Commission 2024a). The system operates under the "polluter pays" principle, which internalizes the cost of emissions and incentivizes firms to lower their output of CO2-eq (European Parliament and of the Council 2004/35/CE).

1.2 Problem Statement

The interplay between the EU ETS's regulatory framework and its impact on firm behavior is a critical area of inquiry. The system's design, which includes a combination of cap-and-trade regulations and free permit allocations, aims to reduce emissions while maintaining economic competitiveness. However, this dual objective can create conflicts. On one hand, the EU ETS seeks to drive down emissions through market mechanisms, while on the other, it strives to ensure that firms remain competitive by providing free allowances. This dual aim raises questions about whether the EU ETS effectively incentivizes firms to reduce emissions or if the allocation of free permits undermines these incentives.

In this context, this thesis investigates how Swedish firms participating in the EU ETS have been affected by changes in permit prices and emissions regulations from 2013 to 2022. By examining the correlation between carbon permit prices, firm-level total emissions, and firm profitability, the study aims to provide insights into the effectiveness of the EU ETS in achieving its environmental and economic objectives.

1.3 Significance of the Study

The findings of this research are significant for several reasons. First, understanding how firms respond to the EU ETS’s pricing and regulatory changes can inform the ongoing development and refinement of carbon pricing mechanisms. Effective carbon pricing is crucial for reducing emissions and mitigating climate change, and this study contributes to evaluating whether the EU ETS is achieving these goals without compromising firm profitability.

Second, the results of this study offer valuable insights for policymakers. By highlighting the relationship between carbon permit prices, firm-level total emissions, and profits, the research can help policymakers assess whether the current design of the EU ETS is achieving a fair balance between environmental objectives and economic competitiveness. This information is essential for making informed decisions about future revisions to the EU ETS and other carbon pricing mechanisms.

Third, the study provides practical insights for investors and businesses. Understanding how carbon pricing affects firm profitability can guide investment decisions and strategic planning. Firms and investors can use this information to better navigate the challenges and opportunities presented by carbon pricing regulations.

Additionally, the inclusion of a binary variable indicating whether firms are net emitters or not represents a novel contribution to the literature. This variable will allow for a more nuanced analysis of the impact of the EU ETS, addressing a gap in existing research and providing a comprehensive view of how firms' emission profiles influence their responses to carbon pricing.

1.4 Structure of the thesis

Following this introduction, the literature review will provide an overview of existing research on carbon pricing mechanisms, with a focus on the EU ETS and its impact on firm behavior and profitability. This will be followed by the conceptual framework, which outlines the theoretical foundations of the study and the methodology employed. The data analysis section will present the results of the empirical investigation, followed by a discussion of the findings in relation to the research question. Finally, the thesis will conclude with a summary of key insights and recommendations for policymakers, investors, and businesses.

By examining the relationship between carbon permit prices, firm-level total emissions, and profits, this study aims to contribute valuable insights into the effectiveness of the EU ETS and its impact on Swedish firms, providing a foundation for future research and policy development in the field of carbon pricing.

2. Literature review

2.1 Economic Impacts of the EU ETS

2.1.1 Effectiveness in Emission Reduction

The EU ETS is central to the EU's climate strategy, with the objective of achieving at least a 55% net reduction in emissions by 2030 (European Commission 2024c). Empirical evidence suggests that the EU ETS has been somewhat successful in reducing emissions while allowing economic growth. The EU's total economy has grown significantly over the past 30 years, yet total emissions have decreased by 30% (IEA 2024). This trend suggests that the EU ETS has contributed to decoupling economic growth from emissions.

2.1.2 Impact on Firm Profitability

Studies evaluating the impact of the EU ETS on firm profitability present varied findings. Makridou, Doumpos, and Galariotis (2019) found that firms reducing verified emissions and improving energy efficiency generally experienced better financial performance, measured by EBIT by total assets. This conclusion was made by using firm-level data from over a nine year period on 19 different EU ETS subject countries. Conversely, Carratu, Chiarini, and Piselli (2020) observed no significant impact of auctioning European Emission Unit Allowances on profitability, regardless of measurement. The authors combined plant-level and firm-level data from the EU countries to reach this conclusion. This is supported by Abrell, Ndoye Faye and Zachmann (2011) whom did not find a significant relationship between profits and EU ETS, the authors use firm-level data from the EU. Furthermore, they found that turnover is positively related to changes in emissions, meaning that as turnover decreases so should emissions. This is in part contrary to Makridou, Doumpos, and Galariotis (2019), as they found that firms which emissions decreaase lead to better financial performance. This suggests that while the EU ETS may incentivize emissions reductions, it does not uniformly translate into financial effects for firms.

2.1.3 Price Dynamics and Market Behavior

The price of carbon permits in the EU ETS has fluctuated over time, reflecting changes in market conditions and policy developments. According to EEX (2024), permit prices were stable between 2013 and 2017 but increased significantly thereafter. This price increase can be attributed to a combination of factors, including decreased availability of free permits and external events such as the COVID-19 pandemic and the Russian invasion of Ukraine (Ali et al. 2023; BNP Paribas 2023; Li and Li 2021). The higher cost of permits should incentivise firms to reduce emissions. This should be due to two effects, high permit prices will motivate firms to sell permits, since this would increase revenue, as well as not wanting to buy excess permits, since this would increase cost.

2.2 Sector-Specific and Regional Analysis

2.2.1 Sectoral Impact and Adaptation

Lise, Sijm, and Hobbs (2010) found that the cost of permits was often passed on to consumers through higher electricity prices, which led to reduced demand and emissions. This was concluded by analysing 20 European countries' power market. Furthermore, Martinsson et al. (2024) highlighted that carbon pricing in Sweden significantly reduced emissions across various sectors, attributing this to the high marginal cost of emissions and the effectiveness of carbon pricing. Abrell, Ndoye Faye and Zachmann (2011) found that the second phase led to lower emissions across firms from varying sectors in the EU.

2.2.2 Regional Differences

Swedish firms have experienced notable changes in emission levels in response to the EU ETS. During the entire period, 2013 through 2022, emissions in Sweden has declined (Statistics Sweden 2024). The per capita emissions in Sweden for the same period have followed the same projection. The European Union have had similar progression, with the difference being higher per capita emissions (Our World in Data 2024). Greenstone, Leuz and Breuer (2023) found by analysing public firms that while carbon damages vary over firms and regions, the damages still impact profts. Globally, environmental damages equal roughly 44% of firms' profits. Furthermore, the authors Greenstone, Leuz and Breuer (2023) argue that mandatory disclosure of emissions is vital in combating climate change. Corporate carbon damages from the EU are estimated to be lower than the global mean in the study. It is possible that this is due to the disclosure of plant level emissions through EU ETS.

2.3 Gaps in the literature

While existing studies (Makridou, Doumpos & Galariotis 2019; Carratu, Chiarini & Piselli 2020; Abrell, Ndoye Faye & Zachmann 2011) provide insights into the effectiveness of the EU ETS and its impact on firm profitability, there is a need for further research into how changes in permit allocation and price dynamics affect competitiveness. Additionally, Makridou, Doumpos and Galariotis (2019) do not examine how being a net buyer or seller of permits impacts profitability. This the effect should be investigated.

This literature review synthesizes current research on carbon pricing mechanisms, with a particular focus on the EU ETS, its economic impacts, and sector-specific effects. The findings highlight both the successes and limitations of the EU ETS, providing a foundation for further investigation into its role in reducing emissions while maintaining economic competitiveness.

3. Conceptual framework

3.1 Profit Maximising Problem

This section will describe the theoretical basis for firms' reasoning and how the factors in the model can affect the profits. In Equation 1, one can see the proposed profit maximising problem that firms face (Sterner & Coria 2012).

Equation 1. Profit maximising problem for firms.

$$max\ P \cdot q_i - c_i(q_i, a_i) + p_e[e_{i0} - e_i(q_i, a_i)] \quad (1)$$

In Equation 1 P is the output price, q_i is the quanitity of output, i is the respective firms, c describes the costs that a given firm faces which is a factor of the quantity and the abatement (a_i) lastly, p_e is the price of permits with e_{i0} being the free permits that firms are allowed and e_i being emissions (Sterner & Coria 2012).

Equation 1 describes how the emissions and cost of emitting have been internalised into a firm's profit maximising function and ultimately becomes a part of the decision making process. Since there is a price for emitting, firms will optimise their emissions and the amount that firms will emit becomes a financial problem (as well being a social problem). Because it is assumed that firms maximise their profits the pollution level has to be accounted for in their decision making process.

Moreover, the original Equation can be expanded to be more realistic and accurate. One possible expansion would be to expand the output function with insights from the DHSS model (Dasguta & Heal 1971; Solow 1974; Stiglitz 1974), which is shown in Equation 2.

Equation 2. DHSS model.

$$Y = (A_L L)^{1-\alpha-\beta}(K)^{\alpha}R^{\beta} \quad (2)$$

The DHSS model describes production on a macro level, in which Y is the total output of an economy. In this model, the output is a function of effective labor units

($A_L L$), capital (K) and resources (R). Even though this model is on a national level, it is of importance to understanding the firms' problem. A nations output is in its core the collection of firms' production as pictured in Equation 3.

Equation 3. National output.

$$Y = \sum_{i=1}^{n} q_i \tag{3}$$

Furthermore, this means that each firm would have a similar production function to the production function shown in Equation 2. In our specific case this means that the resource (R) in question would be the amount of emissions (e_i) by each firm. This would provide a production function for firms as shown in Equation 4.

Equation 4. Firm-level production function.

$$q_i = (A_L L)^{1-\alpha-\beta}(K)^{\alpha}(e_i)^{\beta} \tag{4}$$

From Equation 4, the final production function for firms in the context of this thesis is obtained which is an alternate DHSS model in its essence. Firms' production will be a function of effective labor, capital and the amount of emissions. Two of these production factors are omitted from this thesis, effective labor and capital. The inclusion of these variables would be preferred, however it is not practically feasible to obtain data on these factors and it is outside the scope of this thesis.

3.2 Solow's Mechanisms

In 1973, Solow published an article discussing economic growth at a national, macroeconomic level. However, given that a nation's economy is composed of smaller firms, as demonstrated in Equation 3, insights from Solow's analysis may be relevant to this thesis. In the article, Solow identifies three potential responses to an increase in resource prices. With the current rise in the price of permits (EEX 2023), a parallel can be drawn between these scenarios. Solow theorizes that a higher resource price will likely: (1) reduce the usage of the resource through enhanced production efficiency, (2) incentivize the substitution of the resource in production, or (3) shift consumption away from resource-intensive markets (Solow 1973).

As the availability of carbon permits decreases and their cost rises, it is probable that all three of these mechanisms will affect firms. Firstly, as firms' allowances diminish, they will need to reduce carbon emissions to prevent increased costs that could erode profits. Secondly, as the cost of emitting carbon escalates, firms may be more inclined to invest in green technologies and renewable energy to mitigate these cost increases. Finally, consumers may shift away from products that become more expensive—assuming firms pass on the additional costs—and those perceived as environmentally harmful.

Theoretically, this suggests that the EU ETS should result in a reduction of emissions across the union due to the increasing prices. Moreover, it aligns with the interests of firms to innovate and reduce their emissions, thereby protecting their profits and securing a competitive advantage.

3.3 Impact of carbon pricing on company profits

The price of carbon permits could both decrease the profits for firms as well as increase the profits, holding the firm size constant. As the price of the permits increases so does the cost of emitting per unit of CO2-eq. This should decrease the profits in one of, or both, two ways. Alternative one is that the price increase leads to a smaller amount of emissions from firms. Assuming that emissions are positively correlated with profits, firms' profits would decrease. Furthermore, this means that it is assumed that carbon price is negatively correlated with emissions. The second alternative is that firms do not alter their production given the price increase. If emissions are unaffected, combined with a higher cost per CO2-eq., the total cost of emissions will increase. This increased cost would affect the profits negatively.

By deriving Equation 1 with respect to the price of permits, one is left with $e_{io} - e_i(q_i,a_i)=0$, a first order condition. From this derivation we can observe that the profits with respect to the permit price will depend on how much a firm is emitting and how many permits have been allocated. This demonstrates that it is vital for firms to manage their permits well and attempt to not emit more than the amount of permits allocated. One important thing to recognise from Equation 1 is that when a firm has a surplus of permits, e_{i0} is larger than e_i, the profits will increase. Meaning that an increased permit price could increase the profits for firms.

There exists a threat to identification in this context. When firm profits are increasing, so does their demand for permits. This means that firms can thereby afford increasingly more expensive permits. This is an argument for the price of permits being positively correlated with firm profits. However it is important to highlight that this correlation would not be directly causal.

3.4 Impact of grant surplus/deficit on profits

The allocation of free permits likely impacts a firm's profitability based on whether it has a surplus or deficit of permits. A surplus occurs when a firm emits less than its allocated allowances, while a deficit arises when emissions exceed allowances. It is hypothesized that firms with deficits will experience lower profits compared to firms with surpluses due to the need to purchase additional permits, increasing costs.

Equation 1 further illustrates the impact of permits on profits. In the case of a surplus, where e_{i0} exceeds $e_i(q_i, a_i)$, firms can sell excess permits on the market, generating additional revenue. This suggests that a surplus benefits profitability in two ways: avoiding the cost of purchasing extra permits and gaining revenue from selling unused permits.

4. Methodology

This section will explain the thesis' research design and statistical methods, as well as the data collection and the variables and operationalisation. For all data the time period considered is between 2013 and 2022 for Swedish firms.

4.1 Data

Table 1. Data and sources

Data	Units	Sources
EBIT	Thousands SEK	Retriever Business
Trading Price	Euro per tonne CO_2-eq.	European Energy Exchange
Emissions	Tonnes CO_2-eq.	Naturvårdsverket
Granted	Tonnes CO_2-eq.	Naturvårdsverket
Surplus/Deficit	Tonnes CO_2-eq.	Naturvårdsverket
Cumulative Inflation	Annual percent	World Riksbank
Exchange Rate	Euro to SEK	Sveriges Riksbank

As one can observe in Table 1, the data needed for the thesis' analysis were: earings before interest and taxes (EBIT), the trading price of emissions allowances, total emissions, free emissions granted, whether a firm was a net buyer or not, the inflation rate and the exchange rate.

Table 2. Descriptive statistics for variables.

Variable	N (n)	Mean	SD	Min	Max
EBIT	2070 (232)	259 995.8	1 600 816	-3.06e07	2.42e07
Emissions	2070 (232)	90 352.91	359 342.4	0.1889613	5 034 733
ETS_SEK	2070 (232)	209.6106	215.3140	37.87818	719.8787
Buyer	2070 (232)	0.3454106	0.4756169	0	1

4.1.1 Earnings Before Interest and Taxes (EBIT)

The data for all firms' EBIT are from the firm's income statements and were gathered from Retriever Business. In total, 232 firms are used in the dataset and the EBIT is in thousands of SEK. All firms are Swedish and from multiple sectors, such as electricity and district heating, metal industry and chemical industry. Retriever Business collects data, financial statements, industry affiliation and other information on Swedish organisations (Retriever Business 2024). EBIT is a widespread measurement of firm profitability and one of the main advantages of using EBIT is that it captures the operating profits. However, as the name suggest, EBIT does not account for interest nor taxes. At a first glance this might seem problematic. However, this allows for a measurement that is demonstrates the profits from a firm's core operations. Equation 1 is used for calculating EBIT (Beams et al. 2009).

Equation 5. EBIT formula.

$$EBIT = Sales + Income\ from\ Subsidiary - Operating\ Expenses - Cost\ of\ good\ sold \quad (5)$$

4.1.2 Trading Price

The European Energy Exchange (EEX) collects annual auction reports on the price and volume for emissions permits measured in euros per tonnes of CO_2. The data includes the auction price for each each auction period, which is each day a transaction was made, and completed transactions is displayed. The EEX is the used auction platform to obtain emission permits (European Commission 2024d).

4.1.3 Emissions

Firm-level total emissions are defined as the cumulative emissions during each calendar year. Cumulative emissions are the total amount of emissions in a given period (IPCC 2021). In this thesis it is measured in carbon dioxide equivalents (CO_2-eq.) annually. This measurement is the most common way to compare and accumulate the emissions from different greenhouse gases (GHG). Individual GHG have varying warming potential, but CO_2-eq. allows for a uniform measurement that equates different GHG to the same measurement based on their global warming potential in tonnes of CO_2 (Eurostat 2024).

Naturvårdsverket (2024a) publish annual data on how much each facility emits and how many free emission grants each facility is. Moreover, Naturvårdsverket also tracks if a facility is in a surplus or deficit each year. This is calculated by subtracting the granted emissions from the emissions. All data mentioned is all tonnes CO_2-eq. Some of the included facilities in Naturvårdsverkets data set had to be omitted from the sample. This was done because of one of two reasons: either the facility did not report emissions for most years; or the organisation that owned the facility was dissolved or no longer existed which deemed it not feasible to collect profit data.

4.1.4 Inflation

Annual inflation rates were collected through the World Bank (2024b). The inflation is measured through consumer price index (CPI), which is one of the most popular inflation indicators used comprehensively.

4.1.5 Exchange Ratess

The Swedish central bank have data on annual average aggregate exchange rate between currencies (The Riksbank 2024). For this thesis, the exchange rate between euros and SEK for the time period was collected.

4.2 Variables and operationalisation

The variable *EBIT* is the dependent variable in the regressions. This variable was calculated by adjusting the EBIT for a firm by the inflation rate for the corresponding year. This was done in order to adjust the profits for inflation. By doing this, the EBIT becomes more comparable and allows for a more accurate value. Since some values of *EBIT* are negative, meaning that a firm reports negative profits, it was not possible to calculate the logarithm.

As the emissions data from Naturvårdsverket is on facility level, and the profit data is on firm-level, this needed to be accounted for. Some of the firms have multiple facilities for the same year. When this was the case, all facilities for the same firm where added to combine the firm's total emissions in the given period. The variable *ln(Emissions)* is corresponding to the the natural logarithm of a given observation.

ETS_SEK is the average annual trading price in SEK and adjusted for inflation. As mentioned above, the EEX publishes annual reports on all completed auctions for each auction period. In order to convert this to annual data the mean price of each year was retrieved. This annual average was then multiplied by the annual average exchange rate to convert the annual trading price to SEK. Finally, the annual trading price in SEK was adjusted for inflation. The variable *ln(ETS_SEK)* is the natural logarithm of each observation of *ETS_SEK*.

The variable *buyer* is a binary variable. This variable stems from Naturvårdsverkets data on surplus and deficits. When a firm have a surplus for a given year, the value of buyer is 0. Consequently, the variable have the value of 1 when the firm have a deficit. This variable attempts to demonstrate how the profits would be affected when a firm has to buy extra permits (beyond the granted permits) which would be an added cost.

4.3 Regression Methodology

The method the thesis is ordinary least squares (OLS) regression that controls for fixed effects and a correlation matrix. The data used in the methods is a panel of Swedish firms taking part in the EU ETS between 2013 and 2022. This thesis uses two models using data in levels, as well as using logged data on both emissions and ETS price.

OLS regression estimates the coefficients to best fit the observed data. This is done linearly and in OLS the values of the parameters are chosen so that the residual sum of squares (RSS) is as small as feasible (Gujarati & Porter 2009). The model estimated in the OLS regression is shown below in Equation 3.

4.3.1 OLS model with variables in levels

Equation 6. OLS model with variables in levels.

$$EBIT_{it} = \beta_0 + \beta_1 \cdot Emissions_{it} + \beta_2 \cdot ETS_{SEK_t} + \beta_3 \cdot buyer_{it} + u_{it} + FE_i \qquad (6)$$

All the variables are specific to a firm and a year, except for ETS_SEK_t. This means that *i* represents a specific firm in the model and *t* represents a year. To expand, this means that each firm's EBIT for a given year is explained by the emissions, trading price and whether they are a buyer or not in the model for the same firm and year. The variable u_{it} is the error term in the model, $u_{it} = \mu_i + v_{it}$. μ does not change across time and is specific to individuals in the data set. v changes with time and is also individual specific.

This regression model describes in equation 7 above how different factors related to the EU ETS influence the profitability of Swedish firms, EBIT. It looks at the impact of a firm's carbon emissions, the price of carbon permits, and whether the firm is a net buyer of these permits on its profitability. The coefficient for emissions (β_1) will indicate whether firms that emit more carbon tend to be more or less profitable. The coefficient for the price of carbon permits (β_2) will show how changes in permit prices affect profitability, with a negative coefficient suggesting that higher prices reduce profits. Lastly, the coefficient for being a net buyer of permits (β_3) will reveal if firms that need to purchase more permits are financially better or worse off compared to those that don't. Overall, this model seeks to understand the financial effects of the EU ETS on Swedish firms, particularly regarding their emissions and the costs they incur under this system.

It is crucial to consider the exogeneity or endogeneity of the independent variables in this model, as it impacts the reliability of the results. The price of carbon permits (β_2) is exogenous, meaning it is determined by factors outside the firm's control and is not influenced by the firm's internal decisions. However, both the emissions variable (β_1) and the buyer dummy (β_3) are endogenous. The emissions variable could serve as a proxy for firm size, which directly influences profitability and may correlate with other unobserved variables that affect EBIT. The buyer dummy's endogeneity is especially significant, as it can lead to biased estimates. Firms may become net buyers due to exogenous reasons, such as belonging to an industry that does not receive free permits, or due to endogenous reasons, like needing additional permits because of increased production or higher profitability. This dual nature of the buyer dummy means it could be correlated with other factors that influence profitability, making it essential to address this potential bias to ensure accurate and meaningful conclusions from the model.

4.3.2 OLS model with logarithms

Equation 7. OLS model with logarithms.

$$EBIT_{it} = \beta_0 + \beta_1 \cdot lnEmissions_{it} + \beta_2 \cdot lnETS\_SEK_t + \beta_3 \cdot buyer_{it} + u_{it} \tag{7}$$

Just as in Equation 6, all the variables in Equation 7 are specific to a firm and a year except for ***$lnETS\_SEK_t$***. The difference between the models is that the natural logarithm for both emissions and trading price is used instead of their natural form. Using logarithms introduce some valuable properties. First, by using logarithms highly skewed data becomes more normalised. As one can observe in Table 2, the data on emissions seems to be skewed by observing the minimum and maximum value present in the data set. Secondly, the introduction of logged variables transforms the model into a linear-log model. In a linear-log model, a one percent change in an independent variable X, leads to a $\frac{\beta_x}{100}$ change in units of the dependent variable.

4.3.3 Further details on regression methodology

Since this thesis deals with a multitude of firms over a decade it was rather evident that panel data would best suit the thesis. Panel data deals with a set of subjects over a period in time. The data set can either be *balanced* or *unbalanced*. In a *balanced* data set, each subject is present in every year. Mathematically this can be expressed as $n = N \cdot T$ where n is the number of observations, N represents the subjects and T the period (Stock & Watson 2015). Consequently, this means that an *unbalanced* data set is missing at least one observation for a subject and in a period. This means that this data set is *unbalanced* since not all firms are present in all years.

An advantage of using panel data is that one can control for fixed effects. Consider the error term $u_{it} = \mu_i + v_{it}$ from Equation 3. If one suspect that there exists some time-invariant effects such as in μ we can account for them using fixed effects. This allows to control for omitted variable bias (OVB) in the model. Since the model does not include a lot of variables it is likely that some unobserved relevant variables are left out. However, they should be accounted for when using fixed effects.

The regressions use robust standard errors. This type of standard errors are heteroskedasticity-robust which means that the results are valid whether or not there exists heteroskedasticity. By using robust standard errors the results will be controlled for heteroskedasticity.

Furthermore, a correlation matrix is also used to describe the relationship between the variables. In a correlation matrix the value between two variables ranges from -1 and 1. If the value is close to -1 then there is a very strong *negative* correlation between the variables, that is if a variable increases the other will decrease. If the value is close to 1 then there is a very strong *positive* correlation, that is if a variable increases the other will also increase. Lastly, if the value is close to 0 then there exists no or a very small correlation between the variables (Stock & Watson 2015).

5. Data Analysis and Results

5.1 Correlation analysis between variables

Table 3. Correlation matrix between variables.

	EBIT	Emissions	ETS_SEK	Buyer
EBIT	1.0000			
Emissions	0.1095	1.0000		
ETS_SEK	0.0234	-0.0050	1.0000	
Buyer	-0.0062	0.1440	0.1487	1.0000

From Table 3 one can observe the results from the correlation matrix. The matrix states that there exists a negative correlation between profits and if the firm has a deficit, as well as between emissions and the price of permits. There is a positive correlation between profits and emissions and the price of permits, as well as between buyer and emissions and price and permits. It is important to note that the negative correlations are very small and there is hardly any correlation between these variables. The same can be said for the correlation between permit prices and profits. The relationships that are most interesting from these results is the correlation between emissions and profits; buyer and emissions; and buyer and permit prices. These correlations are more fascinating since the correlation is stronger. One can deduce that a one unit increase in emissions is associated with a 10.95% increase in profits, increased emissions is linked by 14.4% to be more likely to be a buyer and a higher carbon price is related by 14.87% to be more probable to be a buyer.

5.2 Regression analysis

5.2.1 Regression analysis with continuous variables

Table 4. Regression results with continuous variables.

EBIT	Coefficient	Robust SE	t	P > | t |
Emissions	1.649861	0.55	2.97	0.003
ETS_SEK	398.1682	289.69	1.37	0.171
Buyer	-342 643	206125.50	-1.66	0.098
Constant	135 818.3	62005.97	2.35	0.020
Number of observations				2070
Number of groups				232

Table 4 shows the results from the OLS regression with continuous variables. From the P-values it is evident that emissions is significant at the 99% level, buyer is significant at the 90% level and permit price is not significant. Moreover, one observes from the results that there exists a positive correlation between profits and emissions, and a negative correlation between permit deficit and profits. This means that a firms profits is estimated to increase by almost 1.65 thousand SEK for each tonne of CO_2-eq. If a firm is a buyer the profits will decrease by 342 643 thousand SEK. The results demonstrate a positive relationship between permit price and profits, for each unit increase in permit price the profits will increase by 398 thousand SEK.

5.2.2 Regression analysis with logarithmic variables

Table 5. Regression results with logarithmic variables.

EBIT	Coefficient	Robust SE	t	P > | t |
lnEmissions	31 794.65	19553.39	1.63	0.105
lnETS_SEK	98 583.88	57658.26	1.71	0.089
Buyer	-308 220.3	214784.8	-1.44	0.153
Constant	-379 200.9	332456.2	-1.14	0.255
Number of observations				2070
Number of groups				232

Table 5 depicts the results from the OLS regression with logarithmic variables. The results displays that there is only one significant variable at 90%, the logarithmic price of permits. Since the variable is a natural logarithm the interpretation is not as straightforward as the results in Table 4. A one percent change in carbon prices will lead to a 985.84 thousand SEK increase in profits.

Furthermore this means that a one percent change in emissions are expected to increase proftis by 317.94 thousand SEK, and being a buyer will decrease the firms' profits by roughly 308 000 thousand SEK.

6. Discussion

6.1 Interpretation of results with continuous variables

From the results in Table 4 it is evident that *emissions* and whether the firm is a buyer or not significantly affects the EBIT for Swedish firms, while the carbon price is not significant. However, with the size of the sample one can discuss if the binary variable really is significant or not. In absolute terms then it is undoubtaltly significant at a 90% level. But since the p-value (0.098) is very close to not being significant it does not seem to be a very good predictor of the firms profits.

The fact that the coefficient of *emissions* is highly significant as well being positive this could have negative environmental effects. With emissions being positively linked to profits the motivation for firms to alter their production should be fairly low. This statement builds on the fact that firms are profit maximising and would therefore aim to not lower their emissions since this would negatively affect their profits.

However, this could be combated by the binary *buyer* variable. As suspected, this variable is negatively correlated with profits. Because of the design of the EU ETS, where the amount of allocated permits decreases, more firms will have to purchase permits. This should of course motivate firms to lower their emissions to the point where they are not emiting more than the free allocation.

6.2 Interpretation of results with logarithmic variables

In Table 5, the results with logarithmic variables are displayed. From these results, there is one significant variable present, the price of permits. However, once again the p-value is very high but significant (0.089) and one could further the discussion about whether this variable is a good predictor with the amount of observations. Ignoring this possible problem for now, the variable have a surprising result given the sign of the coefficient. The regression predicts a positive relationship between permit price and profits. This is somewhat surprising since an increase in permit prices should increase the costs for firms. However, as we know from Figure 2, on a national level Swedish firms have been allocated more permits than they would use. This would then lead to a scenario in which a majority of Swedish firms would be sellers, which is further supported with the information from Table 2 where the mean for buyer is 0.34 (<0.5, a majority are not buyers). As the price of permits have increased, so have the revenue from selling permits, assuming the same amount of sold permits.

6.3 Theoretical implications

Starting with the results from the correlation in Table 3. As stated in the results section the most interesting results (due to having higher correlation) are the results between *emissions* and profits; *buyer* and *emissions*; and *buyer* and permit prices. There exists a positive correlation between emissions and profits which is somewhat in line with economic theory. If a firm was to emit more, ceteris paribus, this allows for the same firm to produce more. This could be stated since we assume that emissions affect the production and therefor their profits. Furthermore, since firms are profit maximising this means two things; we assume that firms emissions will affect their profits positively since they will not emit if it makes negative profits; and firms will be aiming to emit as much as possible in order to maximise their profits.

Moreover, being a buyer is positively correlated with emissions. This is highly likely. The more a firm emits, it is more probable that the firm will not be able to operate within their allocated permits. It is possible that can affect where the results from previous research differ. As mentioned above, Makridou, Doumpos, and Galariotis (2019) found that firms that lower their emissions see better financial performance while Greenstone, Leuz and Breuer (2023) found evidence of a correlation between emissions and profits. There are many differenes between the two studies which harms the overall power in this reasoning. Mainly, the first study examined European firms apart of the EU ETS, which the second did not. That is, one of the studies' data are a part of a mechanism which aim to lower the emissions while the other is not. Even though these differences exist we might be able to gain some insight. Assuming that the emissions are connected to the profits the difference in effect (sign) might be related to this correlation. This could mean that the emissions are affecting the profits positively as long as the firm is not a buyer.

Finally, regarding the correlation Table, the exists a positive correlation between the price of permits and the binary variable *buyer*. Finding support for this in existing literature does not seem possible and it does not seem very likely. However, in economic theory this is completely viable and likely. When the amount of buyers on the market increases, so would the competition for permits. Since the amount of permits are decreasing, and the amount of buyers are increasing the demand for permits is also increasing. The higher demand and lower supply should, in theory, lead to higher permit prices. When pondering about the other possible relationship, that the permit price influences the amount of buyers, the results are not very likely. The higher carbon price should incentivise firms to be in line with their allocation, that is, not to be a buyer. Assuming that the carbon price increases, ceteris paribus, the cost for emitting will increase. Making firms want to emit as little as possible. This aspect of the correlation is likely not due to causation. More likely, this correlation is because of how the two variables have progressed over the time span. From Figure 2 and Figure 3 one can observe that both variables started to increases (Figure 2 somewhat depicts the inverse of *buyer*) and that the variables are not related to each other.

There are two regression results reported, one with continuous variables (Table 4) and one with logarithmic variables (Table 5). This of naturally begs the question of which results are most probable and should be preffered in order to answer the research question. From the regressions themselves we obtain F-statistics which can help to give us some answers. For the continuous regression we obtain a F-value of 9.23 and for the logarithmic regression this value is 1.48. Given the amount of observations and degrees of freedom this means that the value for the continuous regression is significant while the logratihmic is not significant. This indicates that the continuous regression is better. Moreover, it can be useful to examine popular reasons for using the different variable types. One reason for using logarithmic variables is that this can address heteroscedasticity by compressing the data (Gujarati 2009). Since the both regressions are using robust standard errors this is already being controlled for. Another reason to use logarithmic variables is to reduce skewness (West 2022). In order to test this a skewness test for the variable *emissions* was preformed in STATA, this variable is most likely to be out of the possible variables. Both of these variables (the continuous and logarithmic) obtained the results of a Pr(Skewness) of 0.00, the Pr(Kurtosis) was 0.00 for the continuous and 0.00. In practice this means that both variables have a skewness and kurtosis of zero. A normal distribution have both a skewness and kurtosis of zero (NIST 2024). If the both results are normally distributed then there are no reason to assume that the logarithmic results should present a better model of reality.

The results from Table 4 are somewhat in line with existing theory and literature. From these results we can deduce that the emissions are positively correlated with profits while being a buyer is negatively correlated with profits, both of these variables are significant. The positive relationship between emissions and profits are in line with Greenstone, Leuz and Breuer (2023). Since the results suggest that there exists a positive relationship between emissions and profits this means that, in theory, firms will not want to lower their emissions since this would negatively affect their profits.

However, since being a buyer is negatively correlated with profits firms will as likely not be willing to purchase additional permits. Relating to Equation 1, this means that an optimal emission for firms would be for e_i to be less than or equal to e_{i0}. This would guarantee as much production as possible without having to purchase supplementary permits.

From Solow's mechanisms in the conceptual framework these results imply that these mechanisms will all play a part in the future. With the amount of free permits declining and firms being unwilling to purchase additional permits they should decrease their use of emitting resources (mechanism 1). Furthermore, firms should want to shift their energy and resource usage to green technology (mechanism 2). Finally, as Lise, Sijm and Hobbs (2010) demonstrated firms often shift the increased costs to consumers meaning that consumption will shift from high emitting firms (mechanism 3).

It is important to be mindful of the possibility of a spurious correlation. From this study we can not conclude that there exists a causal relationship between the significant variables and the firms' profits. The amount of emissions from Swedish firms subject to the EU ETS have been rather constant, with an increasing amount of buyers as of late. However, one can not confidently say that the emissions and amount of buyers have impacted the firms' profits. There are a multitude of factors that could, theoretically, affect profits which complicates the results from this thesis. It is possible that the buyer variable is rather connected with the Covid-19 pandemic. This statement builds on the fact that in 2021 and 2022 there were more emissions from Swedish firms than the amount of allocated permits, this should mean that the amount of buyers as a whole would be higher in those years. Combining these events might help demonstrate how other factors are affecting the results. The pandemic affected the global economy negatively and therefore likely also firms' profits. Being a buyer should also affect firms' profits negatively (see Equation 1). These events occurred in roughly the same time and it is therefore probable that there might be spurious relationship between the pandemic and buyer which affects the firms' profits. This is simply one possible factor that could be confounding the results. There are other events that could be correlated with the amount of emissions, or even firm specific events that affect their profits.

6.4 Practical implications

From the theoretical implications above, one can deduce some practical implications for firms, policymakers and stakeholders.

As discussed above, firms will want to emit as much as possible in order to maximise their profits, but no more than their allocated permits. As the EU ETS is planning to reduce the amount of freely allocated permits in the coming years and phases this can bode unwell for firms apart of the trading scheme. With fewer allocated permits the firms will not be able to emit as much in practice. This will mean that firms that can transfer to green, renewable, energy will gain a comperative advantage. In order to plan for this firms should already be investing in cleaner technology so they may mitigate their profit losses on an extended time frame. Furthermore, as the price of permits have increased this means that the incentive, in time to come, to be a buyer would be increasingly less. This underlines the importance for firms to emit within their allocated permits.

For policymakers these results can in part be a bit worrying. As we are assuming that firms are profit maximising the incentive to be a part of the EU ETS will decrease with the amount of freely allocated permits. This could lead to a scenario in which firms are unwilling to lower their emissions and instead move their production to countries that are not affected by the EU ETS, leading carbon leakage. However, it is not sure how likely this is based on the design of the firms for example, moving energy production to another country is not very straightforward. Moreover, for policymakers the results somewhat imply that the design of the system is working. Firms want to emit but do not want to buy additional permits. This means that emissions should decrease with the amount of free permits. Since the amount of permits are decreasing, this should lead to decreased emissions.

Stakeholders should be interested in the results. Investments in high emitting sectors are not likely to be as fruitful as they might have been. This statement builds on the reasoning above. If these sectors are not able to transfer to green technology consumers will likely shift their consumption as an effect of the increased costs. This will in turn lower the return on investment. Stakeholders should thereby voice their eagerness for firms to shift their production to clean energy sources and emit less. There will exists an opportunity for stakeholders and investors to position themselves well as companies that can cope well with both the EU ETS and with a switch in technology will gain competitive advantages. Possible negative implications could be that investments in sectors and firms that are outside of the EU ETS will increase, both in Europe but mainly outside of Europe as these firms would (theoretically) be free to emit. One does have to remember that a proportion of stakeholders are consumers. This in turn means that stakeholders should also consume in the way they see fit. Consumption by firms that emit less would not have to shift their increased costs to the consumers, and consumers should respond to this by boycotting the high emitting firms. Furthermore, stakeholders can somewhat represent society. Emissions are a damage to society and the damages should be internalised in to the firms' profit functions. Stakeholders should thereby be more willing to invest into firms that emit less as this will be an asset for society in years to come.

6.5 Limitations of the study

There exists a number of limitations in this thesis. These have mainly to do with the data used.

First of all, as described in the data section, the emission data is on facility level while profit data is on firm-level. This means that some organisations have multiple facilities reporting emissions while being a part of the same firm. A possible problem with this is that it is possible that there could be some errors when converting the facility data to firm data. This problem is reinforced with some facilities and firms either rebranding or reorganising in which they change their name making it difficult to know (in some cases) what facility is a part of which firm.

Furthermore, there was evidence of some mergers and acquisitions in the facility-level data. Some firms added facilities during the time period which could affect the data. This could certainly be problematic if a facility was acquired by another firm present in the data. Expanding on a similar problem, there were some firms that defaulted during this period. These defaulted firms were excluded from the data set because it was not feasible to acquire profit data, meaning that there would be a bias in the results. This is a major problem which future research should aim to solve. When excluding the defaulting firms we gain insight into successful firms in respects to coping with the EU ETS, while unsuccessful firms are excluded. Gaining insight in to defaulting firms would be important information in the scope of this thesis since it is likely that those firms profits were more negatively affected by the EU ETS.

Finally, there are other factors affecting profits than those are mentioned in this thesis. By including more variables, such as employment rates or macro level predictors as interest rates, the results should be more accurate. In line with this is the fact that one could include other aspects of the EU ETS mechanisms. The main two being saving of permits and speculation. Firms that have a surplus in a calender year can save permits (Naturvårdsverket 2024b), this is however not included in the data. The reason for this exclusion is that it was not practically possible to capture this in the data since it was not achievable to find information on in firms sold or saved their unused permits. Speculation in this context is done by non-compliance entitites such as banks or funds. The speculation in permits could be a driving factor in the increase of the permit price (European Central Bank 2022). The amount of speculation in to permit prices is difficult to capture in a variable since there are a lot of entities that can speculate. Since this has likely affected to permit price it is however important to note as a limitation and something that future research should aim to capture in their analysis.

In regards to other limitations (besides the data), the approach chosen in this thesis was a more holistic approach which assessed the entirety of the Swedish EU ETS market between 2013-2022. This could prove a bit troublesome and be a limiting factor. The firms are in varying sectors which might make it difficult to draw broad conclusions since each sector is likely to have separate independent factors affecting the results. Results could have been more reliable if single firms or single sectors where analysed. The advantage of using an all-encompassing approach is the fact that this gives insight into how the system affects firms all over and could make it more efficient for law makers. Furthermore, the system is not specific for different sectors which makes this approach equitable for all sectors. Using a more limited approach would allow for more indepth analyses.

A key limitation of this analysis is the potential endogeneity between emissions, permit purchases, and EBIT. These variables are closely interconnected, making it difficult to estimate their effects accurately. Larger firms typically emit more due to their scale and might need additional permits, which in turn is linked to higher profitability. This creates a situation where emissions and permit buying are both influenced by and influence profitability, complicating the analysis.

The endogeneity issue is particularly relevant for the buyer status variable. Firms might become net buyers of permits due to external factors like regulatory changes, or because they are expanding production as a result of higher profitability. This makes it hard to determine whether being a permit buyer impacts profitability or if it's just a reflection of being more profitable. Without addressing this endogeneity, the results could be biased.

Given these complexities, the findings should be interpreted with caution. While the model offers insights into the EU ETS's impact on Swedish firms, the endogeneity between emissions, permit purchases, and profitability is a significant limitation. Future research should consider using more advanced methods to address these issues and ensure more reliable results.

7. Conclusions

The main finding of this study is the fact that emissions do affect Swedish firms' profits, as well as whether the firms are able to emit within their allocated permits. These findings will likely have implications for firms, policymakers and stakeholders.

Firms will be wanting to maintain high emissions as this will maximise their profits ceteris paribus. However it is vital for these firms to move within their allocated permits as this would negatively affect their profits.

For policymakers these results are somewhat worrying. The EU ETS are decreasing both the cap of total emissions as well as the amount of free allowances. This means that firms will not be able to emit as much as they have been able to, which in theory could impact their profits. Firms might want to exit the EU ETS by moving their production to areas outside of the EU ETS thereby leading to carbon leakage. However, policymakers should also be somewhat content with the results as being a buyer negatively affects the firms' profits, which is a key mechanism of the system.

Stakeholders should put pressure on firms to shift their resource use to cleaner technology. This builds on the fact that firms that emit less are less likely to be a buyer and thereby retains profits. Furthermore, by advocating for cleaner technology as this will increase firms' competitiveness increasing return on investments. From a societal point of view, stakeholders should consume from greener firms as they are less likely to shift cost increases to the consumers and because high emiting firms are a damage to society.

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Popular science summary

In recent years climate change has become a critical global issue, demanding governments and organisations to take action to reduce greenhouse gas emissions. One such initiative is the European Union Emission Trading System (EU ETS), a market-based approach aimed at reducing emissions by allowing companies to buy and sell emission permits through a cap and trade system. This study explores how the EU ETS has affected Swedish firms' profits from 2013 to 2022.

The EU ETS works by setting a cap on the total amount of greenhouse gases that can be emitted by firms covered by the system. Companies receive or buy emission allowances, which they can trade with each other. If a company emits more than its allowed amount, it must purchase additional permits. This creates a financial incentive for firms to reduce their emissions.

The research focuses on Swedish firms participating in the EU ETS, analysing how changes in carbon prices and emission levels have influenced their profits. By examining said firms, it was found that while the system can impose additional costs on companies, it also encourages them to innovate and become more efficient in their operations. This can lead to long-term advantages, such as cost savings and increased competitiveness.

Interestingly, the thesis' findings suggest that carbon pricing doesn't necessarily harm a company's profitability since this variable is not significant. A key discovery was that whether a firm is emitting more than their allocated permits will significantly impact their profits. This will incentivise firms to not emit more than their allocation and thereby decrease their emissions. By cause of a firm that is over their allocated emissions will have to purchase additional permits, while one that is within their allocated emissions can sell their unused permits

Overall, this research sheds light on the relationship between environmental regulations and firm profitability, showing that it's possible to achieve both environmental sustainability and business success. The insights gained from this study can inform policymakers as they design effective strategies to combat climate change while promoting economic growth.

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