SCHOOL OF ECONOMICS AND MANAGEMENT

Has the EU ETS been efficient in reducing carbon dioxide emissions without harming firm revenue?

A study of the price development of EUAs and its impact on carbon dioxide emissions and revenue within the Swedish iron and steel industry

By Elin Raab, elin.raab@gmail.com

Abstract: The increasing urgency of climate change has raised the need for effective climate policy. The European Union emissions trading system (EU ETS) is the world's first and largest 'cap and trade' policy which aims at reducing carbon dioxide emissions at the most cost-efficient allocation. The iron and steel industry is the largest emitter of carbon dioxide emissions in the Swedish industry sector. Yet, it has a high potential of green innovation, such as the development of fossil free steel. The purpose of this thesis is to examine to what extent the price development of the tradable allowances (EUAs) has had on carbon dioxide emissions and revenue for firms within the Swedish iron and steel industry. This thesis conducts a quantitative study on the price development of EUAs and the impact on carbon dioxide emissions and revenue. The research question is answered by the empirical analysis of this thesis, previous research and the theoretical framework. The findings of this thesis indicate that an increase in the price development of EUAs is associated with a reduction in carbon dioxide emissions and an increase in revenue for firms in the Swedish iron and steel industry.

Programme code: EOSK12

Bachelor's Thesis, 15 ECTS

Supervisor: Finn Hedefalk

Examiner: Kirk Scott

Word count: 12 367

Table of Contents:

1. Introduction

Global warming is one of, if not the, most pressing current issue globally. The estimations of the IPCC (2023) show that global warming will exceed 1.5 degrees celsius during the 21st century and that it is difficult to counteract a warming of 2 degrees celsius. Human activity has already resulted in climate change in the form of extreme weather which has disastrous consequences on the ecological, social and economic sustainability (IPCC, 2023). Those regions that have taken the smallest part in causing climate change are being disproportionately affected, which is why regions with a high proportion of the amount of greenhouse gas emissions must implement emission reducing policies (IPCC, 2023).

Carbon pricing is one of the most prominent climate policies. It is used as a tool of reducing the impact of climate change caused by carbon dioxide emissions. Carbon pricing comes either in the form of a tax on carbon dioxide emissions or in the form of an emission trading system (Parry, Black & Zhunussova, 2022). Sweden implemented a tax on carbon dioxide emissions already in 1991, which mainly covers the transportation sector (Angner, 2023). The concept of emission trading systems (ETSs) was first introduced by Montgomery in 1972 and is a market based instrument that aims at allocating emission reduction where it is the most cost effective. An ETS is a 'cap and trade' system, where the governing unit sets a cap on the amount of emissions (Parry, Black & Zhunussova, 2022). Firms that are regulated within the ETS need to acquire tradable allowances for each unit of carbon dioxide that they emit. The aim of ETSs is to meet the emission reduction target set by the cap, while also implementing long-term solutions for emission abatement (Martin et al, 2016).

The European Union implemented such a system in 2005, as part of a number of legislative proposals to reach the climate ambitions of the Kyoto protocol (EEA, 2005). The European Union Emissions Trade System (EU ETS) covers up to 40 % of greenhouse gas emissions in the EU (European Commission, 2021). Installations within the EU ETS are required to acquire one European Union Allowance (EUA) for each tonne of carbon dioxide emitted. In Sweden, the carbon tax applies to the emissions that are not covered by the EU ETS, but for the installations that are covered by the EU ETS, the tax does not apply (Parry, Black & Zhunussova, 2022).

The EU ETS has gone through several phases with different conditions of emission trading. It is unsure whether the conditions set by the European Union have been sufficient in achievement emission abatement at the most efficient cost allocation. Furthermore, the price development of the tradable allowances has experienced fluctuations and volatility, which is another reason why the efficiency of the climate policy of the European Union has been questioned. In April 2023, the European Parliament voted for a new directive that will broaden the scope of the EU ETS. Currently covering up to 40 % of greenhouse gas emissions, after the new directive is implemented, that will be increased to 75 % of the emissions of all participating nations of the EU ETS.

The iron and steel industry is covered by the EU ETS and is the sector in Sweden with the highest amount of carbon dioxide emissions (The Swedish Environmental Protection Agency, 2022). Yet, the sector has a high potential for emission abatement technology, like the development of fossil free steel (Åhman et al, 2018). The advancement of fossil free steel depends on the design of climate policy, which the political framework of the European Union can support, according to Åhman et al (2018).

1.1 Aim of the Study

The aim of this study is to investigate whether the EU ETS has been effective at reducing carbon dioxide emissions within the Swedish industry sector, without harming economic performance. The sector that will be included in the study is iron and steel, since it is the industry that account for the most amount of carbon dioxide emissions in Sweden (Bergek et al, 2019). Additionally, the iron and steel industry has a high potential in green innovation, like the development of fossil free steel (Åhman et al, 2018). Furthermore, this thesis focuses on the industry sector since it has a higher environmental impact than the energy sector in Sweden, unlike in the EU zone, where it is the opposite (The Swedish Environmental Protection Agency, 2022). The reason why the thesis only covers carbon dioxide emissions out of the different greenhouse gases is due to the fact that it is the only greenhouse gas that has been regulated by the EU ETS during the entire trading period, since its implementation in 2005 (European Commission, n.d.). This thesis investigates whether the price point of the carbon dioxide allowances of the EU ETS has been enough to incentivise regulated firms to decrease carbon dioxide emissions. If the price of the allowances have been too high for regulated firms, firms may be incentivised to decrease production, which in turn results in a decrease in revenue. Had the price been too low, firms would have no reason to limit emissions, meaning that both revenue and carbon dioxide emissions would have remained unchanged. This leads to the research question:

- To what extent does the price development of EUAs impact revenue and carbon dioxide emissions within the iron and steel industry in Sweden?

The methodology chosen to answer the research question is a quantitative approach using a linear regression model with a stepwise selection. The impact of the price of EUAs will be tested on both revenue and carbon dioxide emissions, meaning that the quantitative methodology has two dependent variables. In addition, the linear regression model includes two additional control variables, which will be added with a stepwise selection, in non-adjusted, semi-adjusted and fully adjusted models.

There is a gap in the previous literature on the impact that the price development of EUAs has had on both emission reduction and revenue for regulated firms. Furthermore, it is of importance to evaluate the restrictions of the EU ETS, to investigate whether the implications create a strong enough price of pollution to drive a clean transition. In addition, the EU ETS is in constant revision, with new directives from the European Parliament most recently in April 2023, which strengthens the relevance of the study.

1.2 Background

1.2.1 The Social Cost of Carbon Dioxide Emissions

In order to limit the increasing threat of climate change and its devastating consequences, many policy makers argue that the price of emitting carbon dioxide should be high. From an economics point of view, the price of global warming is seen as an externality. Already in 1921, Arthur Pigou coined the concept of an externality in The Economics of Welfare, which was the founding work that would later turn into what economists know as a Pigouvian tax. Pigou (1921) meant that the social cost of an externality will be limited when implementing a tax the same size of the social cost. The negative externality is a market failure, that is internalised on the market by imposing a cost on the producer that causes it.

In the case of global warming as a negative externality, Nordhaus (2017) estimates the value of the social cost of climate change. His estimations include costs caused by damages on the economy, environment, infrastructure, health and well-being, among others. The social cost of climate change is in USD per tonne of carbon dioxide and is described by Nordhaus (2017) as the cost of welfare caused by an additional tonne of carbon dioxide emissions. He concludes that the social cost of climate change will continue to increase and that the consequences of climate change will continue to affect people for decades to come, which is why the emitter should be held accountable by paying for emitting. By imposing a cost on emitting, Angner (2023) describes how it incentivises polluters to decrease the amount of carbon dioxide emissions. The price of production increases, and so does the price of the good or service, which also incentivises customers to change their consumer behaviour (Angner, 2023). Firms are therefore eager to limit the price of production, by investing in low-emission technology, which is why Angner (2023) means that imposing a price on carbon dioxide emissions stimulates innovation in sustainable solutions. While it could be understood that reducing carbon dioxide emissions would signify a drop in productivity and GDP, Angner (2023) argues that the incentive to develop low-emission technologies instead makes the market more effective and increases GDP.

The consequences of global warming should have an economic value. Parry, Black and Zhunussova (2022) discuss the difference between carbon taxation and an emissions trade system. By implementing a tax on carbon dioxide, they mean that the policy makers set the price of the tax and the amount of carbon dioxide emitted depends on the price point of the tax. In the case of emissions trading systems, the policy makers set a cap on emissions, meaning that the price of emitting is not set, but the amount of emissions is (Parry, Black and Zhunussova, 2022). Furthermore, they mean that it is difficult to impose a tax that accurately represents the social cost of carbon dioxide emissions. As Nordhaus (2017) means that the social cost of carbon dioxide emissions is steadily increasing, the tax level would also have to increase, which is politically challenging, according to Parry, Black and Zhunussova (2022). Additionally, controlling the cap instead of the price of emissions enables price alignment, as long as the cap of emissions is in accordance with climate policy.

1.2.2 The EU ETS

1.2.2.1 Background

The European Union Emissions Trade System (The EU ETS) is the first emissions trading system in the world (European Commission, 2021). The European Union had an early ambition for climate policy, arguing already in 1992 at the Rio summit for emission reduction targets (Convery, 2009). In 1997, during the United Nations Framework Convention for Climate Change (UNFCCC), the Kyoto Protocol was agreed upon (European Union, 2015; Convery, 2009). The agreement set legally binding emission reduction targets for 37 industrialised countries, which created a sense of urgency regarding implementing emission reduction policies, to meet the required targets (European Union, 2015; Convery, 2009). The Kyoto Protocol stated that the greenhouse gas emission rate should be reduced by 8 % in the period 2008-2012 compared to the emission rate in 1990 (EEA, 2005). In 2005, the European Environment Agency (EEA) released a report on market based instruments and environmental policy. It is mentioned that, a few years prior, emissions trading systems were only coined in academics, not to be put into practice anytime soon. Yet, the European Union saw the need of implementing policy instruments that would result in the EU meeting the targets agreed upon in the Kyoto Protocol (EEA, 2005). As a result, the EEA (2005) states that a market based instrument, an ETS, will be implemented in 2005 after it was accepted by the European Parliament in 2003. In 2005, the EU ETS was the largest emissions trading system in the world, as well as the only ETS operating across national borders (EEA, 2005).

At the time of implementation, the EU ETS was based on six principles: (1) that it is a ‘cap and trade’ system, (2) that the primary focus is on carbon dioxide emissions from large industries, (3) that the EU ETS operates in phases, where the features of each phase is reviewed before the start of a new phase, (4) that the allocation plan of emission allowances is decided periodically, (5) that the compliance framework is stringent and (6) that the EU ETS endorses emission reduction opportunities, not only in the EU but also in the rest of the world, with the aim of establishing compatible systems with developing countries (EEA, 2005).

1.2.2.2 ‘Cap and trade’

A ‘cap and trade’ system means that there is a set number of emission allowances (EUAs) within the EU ETS (EEA, 2005). The installations that are regulated by the EU ETS must acquire one EUA per tonne of carbon dioxide emitted. At the end of each trading period (which is a year) the firm must either pay for their deficit or can decide to sell their surplus (European Union, 2015). The price of each EUA is set by the supply and demand mechanism on the market which also depends on the cap on emissions (European Union, 2015). In that way, the EU can control the amount of emissions in order to achieve the environment policy targets at the lowest cost (European Union, 2015). Carbon pricing that uses taxation as the chosen policy does not control the amount of emissions, but it does control the cost of emitting. In a 'cap and trade' system, the price alignment will follow automatically, when the cap follows the set mitigation goals (Parry, Black & Zhunussova, 2022). It is difficult to ascertain the optimal price to internalise the negative externalities of emissions, which is why a market based instrument and a set cap on emissions could be a more optimal emission reduction policy (EEA, 2005). Furthermore, the cap on emissions is decreased each year by a linear reduction factor (LRF) (European Commission, 2021). The scarcity of allowances creates a cap stringency, which naturally increases the price of EUAs on the market, which creates more effective price incentives to lower emissions (European Union, 2015).

1.2.2.3 Free allocation and carbon leakage

There are three different ways that firms can acquire EUAs: auctioning, purchasing through a secondary market and by free allocation (Bordignon & Gamannossi degl'Innocenti, 2023). In the initial years of the EU ETS, EUAs were allocated to firms for free (European Union, 2015). The main reasons for this was hindering carbon leakage and limiting opposition from the industry sector. Carbon leakage refers to the fact that firms within an area with a stringent climate policy where the cost of emitting is high may choose to move production outside of that area in order to limit the cost of production (Kruse-Andersen & Sørensen, 2022). Beck, Kruse-Andersen and Stewart (2023) mean that the countries covered by the EU ETS have a high tendency of carbon leakage. Furthermore, the authors mean that the sectors that are regulated by the EU ETS are more likely to have a higher rate of carbon leakage than sectors that are not covered by the EU ETS. Free allocation of EUAs was therefore used to offset incentives for carbon leakage (European Union, 2015). However, free allocation creates no price incentive for regulated firms to apply emission abatement technologies and due to the fact that firms will not trade EUAs under free allocation, there will be no abatement cost minimisation (Botelho, Fernandes & Pinto, 2011).

1.2.2.4 The Development of the EU ETS

So far, the EU ETS has gone through three different phases and is currently on the fourth. The phases have seen different regulations and directives which have affected the evolution of the carbon market, and thereby the price development of EUAs. For the purpose of this study, it is therefore of relevance to evaluate and examine the different features of the four trading phases of the EU ETS.

Phase 1

The first phase was proposed to act as a pilot phase, before the 2008-2012 period which was restricted by the Kyoto Protocol (EEA, 2005). The first phase was between 2005-2007, and included the EU27 countries (European Union, 2015). During phase 1, the cost of non-compliance was a fine of €40 per tonne of carbon dioxide emission that was missing from the EUAs surrendered at the end of each trading period (European Commission, n.d). The emission intensive firms within the industry sector needed to comply with the EU ETS and among the greenhouse gases, the EUAs covered only carbon dioxide emission (European Union, 2015). Due to the risk of carbon leakage and the need of support from the participating firms, allowances were allocated for free (European Union, 2015). The free allocation of allowances followed 'grandfathering', which meant that the amount of free allowances allocated to firms was determined by historical greenhouse gas emissions (Bordignon & Gamannossi degl'Innocenti, 2023; European Union, 2015). Each installation within the EU ETS received a number of allowances, which was decided by the National Allocation Plan (NAP) (European Union, 2015). The sum of all NAPs was equal to the cap on emissions. Before the implementation of the EU ETS in 2005, each EU member state had to submit their own NAP stating the amount of allowances needed and to which installations they would be allocated (European Union, 2015). One main concern of the NAP system was that the allocation of EUAs was too ample, meaning that the member states had overestimated the amount of allowances needed (Long & Kaminskaite-Salters, 2007). This has been proven true, and as a result, the first phase experienced an over-allocation of allowances to EU ETS regulated firms, which created no incentive of emission abatement (European Union, 2015).

Phase 2

Phase 2 lasted between 2008-2012 and was the first commitment period of the Kyoto Protocol. The fine of non-compliance was increased from €40 to €100 for each EUA missing at the end of each trading period (European Commission, n.d). During phase 2, the EU ETS expanded to Norway, Liechtenstein and Iceland and it included the same sectors as during phase 1, with the aviation sector entering the EU ETS in 2012 (European Union, 2015).

Phase 2 used the NAP, like during phase 1. Yet, the experiences of phase 1 showed that the over-allocation of allowances due to the ambiguity of the NAPs hindered achieving the targets agreed on in the Kyoto Protocol, which was why the conditions of NAP were altered (European Commission, 2005). To prevent a surplus of allowances exceeding the amount of carbon dioxide emitted, the European Commission proposed to make the NAPs less vague and more transparent by creating a standardised model for member states as well as reviewing the rules and conditions of the NAP in phase 1 (European Union, 2015). However, several member states were still against the regulations of the NAPs and the majority of emission allowances were allocated for free.

Phase 3

Phase 3 lasted between 2013-2020. Several new industries were added to the EU ETS, such as aluminium, petrochemicals, carbon capture and storage, nitric, adipic and glyoxylic acid production (European Union, 2015). It included the same countries as during phase 2, but with the inclusion of Croatia in 2013 (Bordignon & Gamannossi degl'Innocenti, 2023).

During phase 1 and 2, allowances had been allocated for free which had resulted in windfall profits, mainly in power production (European Union, 2015; Long & Kaminskaite-Salters, 2007). Therefore, there ought to be no free allocation of allowances in the power production sector, since the start of phase 3 (European Union, 2015; Garcia-Torea et al, 2022). Auctioning became the main way of acquiring EUAs, which reduced the amount of free allocation (European Union, 2015). Furthermore, the NAP system used in phase 1 and 2 was replaced by National Implementation Measures (NIMs), where the allocation plan of each member state was determined on an EU level, instead of on a national level (European Union, 2015). This ensured that the same conditions applied for all participating actors which induced transparency on the market (European Union, 2015). Furthermore, the cap of emissions had previously been adjusted to the NAPs, but with the transformation to NIMs, the cap was EU-wide and had an annual linear reduction factor (LRF) of 1.74 %. Regarding free allocation, benchmarking became the new practice, instead of grandfathering (Bordignon & Gamannossi degl'Innocenti, 2023; European Union, 2015). The EU ETS regulated firms with the lowest amount of emissions gained their allowances for free, while firms emitting above the benchmark had to acquire the excess allowances through auctioning. This created a price pressure on EUAs as well as strong incentive for firms to establish ways to decrease their emission rates (Bordignon & Gamannossi degl'Innocenti, 2023).

Phase 4

As part of the European Green Deal, the EU launched 'Fit for 55', which promotes a 55 % decline in greenhouse gas emissions by 2030 as well as climate neutrality in the EU by 2050 (European Council, 2023a). The 'Fit for 55' program is in compliance with the Paris Agreement, which was signed by the UNFCCC in 2015 and entails the objective to keep global warming below 2 degrees celsius (European Commission, 2021). For the revision of phase 4, several measures were implemented in order to comply with the 'Fit for 55' program.

There was a surplus of EUAs on the carbon market, which was due to a number of reasons, such as the economic crisis in 2008, high imports of international emission allowances, the acceleration of renewable energy (Bordignon & Gamannossi degl'Innocenti, 2023). In 2019, the Market Stability Reserve (MSR) was implemented and had two main objectives: (1) monitor and report the amount of EUAs in circulation and (2) adjusting the supply of EUAs to avoid serious shocks (Eur-Lex, 2015). The MSR was one of the measures taken to increase the restrictions of the EU ETS to increase the price of EUAs and thereby increase firm incentive to emission abatement.

The cap on emission has had a decline rate of 1.74 %, which is increased to 2.2 %, in order to increase the price pressure of EUAs as well as the emission abatement incentive for firms. The European Commission (2021) suggests that the linear reduction factor shall be increased to 4.22 %. A reduction rate of 4.22 % of the cap on emissions will lead to an overall emission reduction of 61 % compared to in 2005 (European Commission, 2021), which is in line with the 'Fit for 55' package. In April 2023, the European Parliament agreed on a revision of the EU ETS, which included an increase in the LRF to 4.3 % during 2024-2027 and 4.4 % during 2028-2030 (European Council, 2023b). Increasing the LRF is another measure to increase the price point of EUAs.

The new directives that were decided on in April 2023 include the addition of the maritime sector, road transport, buildings and waste management (European Parliament, 2023). The amount of free allocation of carbon allowances will be increased and ultimately phased out. As the new directives state, free allocation of EUAs will be completely discontinued by 2034 (European Parliament, 2023). To reduce the risk of carbon leakage, the revisions of the European Commission (2021) include the addition of a Carbon Border Adjustment Mechanism (CBAM) which will be implemented in 2026. The CBAM works as a carbon tariff, meaning that the products imported from outside of the EU need to account for the greenhouse gas emissions of production. The aim of the CBAM is to impede the economic gains for European producers to move production to regions with cheaper or with no carbon pricing (European Commission, 2021).

To further boost innovation and the transition to low emission production, the EU ETS started the Innovation Fund and the Modernisation Fund (European Commission, 2021). The Innovation Fund has the objective of making emission abatement technology more available for regulated firms. The Modernisation Fund enables technological development in member states with lower income and that have a higher dependency on coal (European Commission, 2021). The funds work as financing instruments and the implementation of the funding proposal includes the objective of removing the exception of financing fossil fuel installations in low-income member states (European Commission, 2021).

1.3 Theoretical framework

The theoretical framework of this thesis highlights three central theories behind the design of the EU ETS. The first section discusses the ‘polluter pays’ principle, which is fundamental in explaining the economic instrument of emissions trading systems. The second section explores the Coase theorem and the applications of its conditions on emissions trading. The third section presents the Porter hypothesis, which is an essential theory in explaining how the economic performance of emitting firms can benefit from climate policy, such as the EU ETS. The inclusion of these three theories are essential in explaining how the design of the EU ETS and the price of EUAs affect carbon dioxide emissions and revenue of regulated firms, which is of importance for the purpose of this thesis.

1.3.1 The ‘Polluter Pays’ Principle

Negative externalities on the climate, such as carbon dioxide emissions, will lead to consequences affecting everyone, not just the ones who caused the negative externality. The ‘polluter pays’ principle (PPP) is based on the notion that the polluters should pay for the negative externality, in order to try and limit the damages it causes (OECD, 2008). The principle enables internalisation of market failure and follows the notion that the price should be similar to the social cost, while ensuring that it is the polluter that bears the cost (OECD, 2008). Furthermore, the negative effects of carbon dioxide emissions are a global issue, mainly affecting developing countries, who have a smaller share in contributing to the problem, but have to face the same, or worse, consequences (Tan, 2023). The ‘polluter pays’ principle is therefore a central feature within the climate justice debate.

1.3.2 The Coase Theorem

In 1960, Ronald Coase introduced the Coase theorem, which states that resources will be efficiently allocated when transaction costs are low and property rights are clearly defined. He criticised the idea of Pigou (1920) which argues for using taxes and subsidies to internalise negative externalities on the market. The Coase theorem suggests that externalities do not need such governmental regulations besides from issuing clear property rights that are tradable at low transaction costs. If the conditions of the Coase theorem hold, bargaining between two parties will result in the most efficient allocation of resources, regardless of how the property rights were assigned.

Deryugina et al (2021) found that applying the Coase theorem on environmental policy can be more effective than policy intervention such as taxation and subsidies, when reducing negative externalities. In the case of emissions trade systems, the carbon dioxide emitted is accounted for using tradable allowances. These allowances establish clear property rights and can be traded between firms within the ETS. These conditions enable Coasian bargaining, which should reduce the negative externalities caused by carbon dioxide emissions, according to Coase (1960). Lai, Lorne and Davies (2020) mean that emissions trade systems stem from the Coase theorem and that the tradable allowances create incentives for innovation and emission reduction, due to the fact that the system establishes clear property rights at almost no transaction costs. Bordignon and Gamannossi degl’Innocenti (2023) highlight the fact that the Coase theorem states that the initial free allocation of emission allowances should not affect firm incentive, even if the cost of compliance has been reduced.

1.3.3 The Porter Hypothesis

Porter and van der Linde (1995) explain that the Porter hypothesis states that the overall performance of emitting firms can be improved by government emission reduction policies. The authors propose that environmental regulation creates incentives for firms to invest in clean production technology which in turn increases efficiency which also induces cost saving measures. The cost saving measures caused by green innovation can be enough to cover both the costs of compliance to the environmental regulation as well as the cost of investing in new innovation, if the regulation is properly designed (Porter & van der Linde, 1995). Therefore, instead of viewing environmental regulation as an impediment of growth, firms should see it as a competitive opportunity.

The design of the environmental regulation should follow three standards in order to stimulate innovation, according to Porter and van der Linde (1995). First of all, the regulation should boost all opportunities for innovation, not just focusing on one element of change. Secondly, the regulation should be designed in a way that encourages continuous advancement in green innovation. Thirdly, the regulation should be designed in a manner with no uncertainty, meaning that participating agents are well-informed of the coordination of the regulation.

If the regulation is stringent enough and follows these three standards, it will not only stimulate innovation, but also competitiveness (Porter & van der Linde, 1995). Of the six principles that the EU ETS was based on by the time of implementation, principle five states that the compliance framework must be stringent and principle six states that the EU ETS must encourage all opportunities of green innovation, which is in line with the Porter hypothesis. Furthermore, the Porter hypothesis states that the investment in emission abatement technology increases productivity, which should indicate a larger market share and an increase in revenue for the firm. Therefore, the trade-off between climate policy and competitiveness can be eliminated.

1.4 Literature review

The aim of this thesis is to explore to what extent the price development of the tradable allowances of the EU ETS has impacted revenue and carbon dioxide emissions of regulated firms within the iron and steel industry in Sweden. To further support the empirical analysis, the purpose of this literature review is to provide a summary of the most relevant research findings on the topic. This section provides a review of the relevant literature on three topics that are of importance to the research of this paper. The first subsection regards emission reduction and carbon pricing, the second one regards the EU ETS and its effect on industry competitiveness and revenue, while the third subsection reviews the effect the EU ETS has had on carbon dioxide emissions.

1.4.1 Emission reduction and carbon pricing

There is a wide array of literature on the topic of emission reduction. It is generally agreed that reducing the amount of greenhouse gases and advancing a green energy transition is needed to limit the negative impact on the climate (IPCC, 2023; Khan & Johansson, 2022; Parry, Black & Zhunussova, 2022; le Quéré et al, 2019). Carbon pricing can come in the form of a carbon tax as well as an emissions trading system (Khan & Johansson, 2022; Parry, Black and Zhunussova, 2022) and has been viewed as a cost-efficient policy to incentivise firms and households to change their consumer behaviour (Khan & Johansson, 2022). Yet, the literature contains differing views on the efficiency of carbon pricing on emission reduction.

The latest IPCC report (2023) states that economic tools, such as carbon pricing, can be an effective policy for both reducing emissions as well as stimulating green innovation and emission abatement technology (IPCC, 2023). Similarly, Parry, Black and Zhunussova (2022) argue that carbon pricing should be the main policy for carbon dioxide emission mitigation. They mention that carbon pricing is efficient at enabling decreasing carbon dioxide emissions, stimulating investment in green innovation and generating revenue for the government which can further finance mitigation policies. However, Khan & Johansson (2022) mean that carbon pricing is less effective when the policy includes exemptions and modifications, such as free allocation of carbon allowances within an emissions trading system. The IPCC report (2023) also mentions these inefficiencies, meaning that the price of emitting has not been high enough to promote adequate emission reduction.

The IPCC report (2023) mentions that the measures aimed at decreasing carbon dioxide emissions have not been stringent enough to create a significant impact on climate action. Nevertheless, the report highlights the importance of implementing expansive carbon pricing policies that are adjusted to national circumstances and promotes a high cost of emitting, for it to be efficient at reducing greenhouse gas emissions. Furthermore, the report also promotes an addition of climate action policies, such as removing all fossil fuel subsidies, along with carbon pricing, to fully support a shift towards reducing carbon dioxide emissions and stimulating investment in a green energy transition. le Quéré et al (2019) reach similar conclusions, where they mean that the green energy advancement is not enough on its own to enable emission reduction. To reduce emissions, they point towards strong policy implementation to reduce the amount of fossil fuel in the energy use. Khan & Johansson (2022) argue that carbon pricing is a necessary policy for reducing greenhouse gas emissions. Yet, they conclude that the policy is not enough on its own, and that it requires to be complemented by additional climate action policies, similarly to the arguments lifted in the IPCC report (2023) and by le Quéré et al (2019).

The previous literature supports a stringent climate policy, where carbon pricing is a key element in emission reduction alongside additional policy tools, such as removing subsidies. Yet, carbon pricing must be without any inefficiencies to promote reducing emissions.

1.4.2 The EU ETS and its effect on industry competitiveness and firm revenue

Since emission trading systems imply additional costs for regulated firms, some scholars discuss the concern that emission trading systems may harm firm revenue and competitiveness (De Bruyn et al, 2008; Joltreau & Sommerfeld, 2019; Koch & Themann, 2022; Marin et al, 2018; Woerdman & Nentjes, 2019).

Khan and Johansson (2022) argue that the optimal policy preserves industry competitiveness while also incentivising investment in carbon dioxide emission abatement technologies. Joltreau and Sommerfeld (2019) reason that the additional costs induced by the EU ETS on regulated firms may lead to a loss in productivity and a loss in market share compared to non-regulated firms. However, when investigating the effect of the EU ETS in firm revenue and industry competitiveness, they found no negative effect on competitiveness or on firm productivity. Martin et al (2016) share a similar reasoning regarding the potential loss in market share and productivity. Yet, they also find that there was no negative impact on economic performance or on competitiveness. Both Joltreau and Sommerfeld (2019) and Martin et al (2016) argue that the main reason why competitiveness and productivity levels were not negatively affected is the fact that a large number of EUAs have been allocated to regulated firms for free and that the price of EUAs has been too low. Furthermore, Joltreau and Sommerfeld (2019) argue that this may impede investment in emission abatement technology. The results of Martin et al (2016) point towards an increase in green investment for EU ETS regulated firms. Yet, they highlight the fact that the costs reduced by emission abatement technologies do not cover the investment cost in green innovation. Therefore, these scholars argue that if the price of EUAs is either too low or if the allowances have been issued for free, industry competitiveness will not be harmed but it will not incentivize investment in emission abatement technology.

Regarding the issue of firm productivity, it is discussed whether the EU ETS has had a negative impact on productivity to reduce the firm's need for carbon allowances. If the policy is viewed as too costly, firms may respond by decreasing productivity as a way of decreasing carbon dioxide emissions, instead of developing their production using low-emission technologies (Woerdman & Nentjes, 2019). de Bruyn et al (2008) investigate the production costs of EU ETS regulated firms within different industry sectors in the Netherlands. When the EUAs were auctioned, and not issued for free, they found an increase in the production costs, but that the increase did not result in a decrease in productivity. Instead, de Bruyn et al (2008) mean that the EU ETS incentivises firms to invest in emission abatement technologies. They argue that it is more profitable for firms to increase investment in green technology instead of decreasing productivity, in order to lower the costs caused by the EU ETS.

Similarly to de Bruyn et al (2008), Koch and Themann (2022) found that the EU ETS has no negative effect on productivity, Marin et al (2018) argue that the EU ETS has a positive effect on profit, investment and labour productivity and Dechezleprêtre et al (2023) found that revenue was increased for EU ETS regulated firms. Koch and Themann (2022) argue that the EU ETS is more beneficial for technically advanced firms. They therefore mean that the productivity divide between technologically leading firms and firms that are technologically less advanced is increasing due to the emission trading policy. Marin et al (2018) mention the positive effect on economic performance may be due to the high cap on emissions. They mean that the cap was not high enough to incentivize firms to limit production, since the cost of compliance was low. In their results, Dechezleprêtre et al (2023) found that revenue increased for EU ETS regulated firms. They also see an increase in emission abatement technology and they conclude that the EU ETS led to a decrease in carbon dioxide emissions, without harming economic performance of the regulated firms.

These scholars suggest that the EU ETS has not had a negative impact on firm revenue. While compliance to the EU ETS increases the cost for regulated firms, it is not translated into a fall in revenue. Instead, the scholars support the notion that the EU ETS incentivizes investment in low emission technology when the cost of compliance is high and that it does not have a significant effect on revenue when the cost is low.

1.4.3 The EU ETS and its effect on carbon dioxide emissions

Jung and Song (2023) investigate the effect of implementing an emissions trading system on carbon dioxide emission reduction for countries both within and outside of the EU. Their results showed that implementing an ETS resulted in a decline in the positive relationship between economic growth and carbon dioxide emissions on a national level. They mean that an emissions trading system increases the burden of carbon dioxide emissions for firms, which in turn incentivises firms to develop their production to low emission. The latest IPCC report (2023) would agree with this line of reasoning, yet it is stated that emission trading systems are only effective if the price point of carbon allowances is high enough. Therefore, whether the effect of the EU ETS has been high enough to reduce carbon dioxide emissions has been reviewed by several scholars.

Dechezleprêtre et al (2023) mean that the EU ETS does cause a decrease in carbon dioxide emissions of regulated firms, yet issuing allowances for free limits the emission reducing effect, which is in line with the points raised in the latest IPCC report (2023). However, Bayer and Alkin (2020) mean that low prices of EUAs do not have a negative effect on carbon dioxide emission reduction. If regulated firms view the political commitment of carbon regulation as a credible future policy, they mean that firms will still be motivated to implement low emission production. Therefore, Bayer and Alkin (2020) mean that the regulations of the carbon allowance market are adequate to incentivise firms to advance low emission production, even though prices are low. Löfgren et al (2014) investigate the effect the EU ETS has had on emission reducing strategies for regulated firms in Sweden. They would disagree with Bayer and Alkin (2020), since they argue that the price of EUAs has been too low to incentivise firms to invest in emission abatement technology. While Bayer and Alkin (2020) argue that a generous emission cap does not harm incentives to reduce carbon dioxide emissions, Löfgren et al (2014) argue for the opposite. The investment behaviour of regulated firms is driven by price signals, which is why they found that the price of EUAs need to be at least €25 to induce a long-term effect on reducing carbon dioxide emissions.

These scholars found differing results regarding the effect that the EU ETS has on emission reduction. Löfgren et al (2014) mean that the price of emitting has been too low, but their study involves only phase 1 and 2 of the EU ETS, which indeed did see low prices of the EU ETS compared to in later years. This can be a reason why the results differ, simply because the EUAs have gone through different price levels. This line of reasoning increases the relevance of this study, since it is of importance to evaluate the price point of EUAs and the effect that it has on carbon dioxide emissions.

Both the findings of the literature review and the theoretical framework provide a substantial complementation to the empirical analysis of the study. Previous research has found that climate policy must be stringent and without any inefficiencies of carbon pricing. Furthermore, the general finding is that the increase in the cost of compliance with the EU ETS does not harm revenue nor incentivise a decrease in production. Therefore, the price increase of EUAs has been successful in improving the economic performance of firms regulated by the EU ETS. This is in line with the propositions of the Porter hypothesis, which promotes the notion that stringent climate policy creates a competitive opportunity for firms. Moreover, the literature reviewed in this section emphasises that an increase in the cost of emitting incentivises EU ETS regulated firms to decrease carbon dioxide emissions. The 'polluter pays' principle highlights that imposing a cost on polluting firms internalises the market failure, which the findings of the reviewed literature suggests. The findings of this section mean that free allocation of allowances reduces the incentive to reduce emissions. One feature of the Coase theorem suggests that the initial allocation of property rights has an insignificant impact on firm incentive. This goes against the findings of the literature review. Yet, the Coase theorem argues for allocating emission reduction at the most cost-efficient allocation, which the conditions of the theorem enable. The findings in the literature support that the EU ETS does incentivise emission reduction without harming economic performance, which is in line with the Coase theorem, only that it does not apply to free allocation of carbon allowances.

2. Methodology

The methodology for this thesis uses a quantitative approach to test the implication that the price development of EUAs has had on carbon dioxide emissions and revenue for firms within the Swedish iron and steel industry. The methodology includes a linear regression model, with a stepwise selection. The regression analysis contains two additional control variables, which are GDP growth and consumer price index (CPI). GDP growth is added as a control variable due to the reason that the level of productivity is closely related with carbon dioxide emissions as well as firm revenue, the two dependent variables. The CPI is added as a control variable since it is the most accurate estimator of inflation, which has an impact on price development. For the purpose of the analysis, the control variables are added in order to more accurately estimate the statistical significance of EUA prices on the dependent variables and to avoid research bias and improve the validity of the study.

2.1 Data

The data used in this paper are time-series data with one observation each year over a time period between 1990-2023. The variables included are continuous. The data of EUA prices is the average annual closing spot price in euros per tonne of carbon dioxide. It was gathered from the European Energy Exchange (EEX). The data on carbon dioxide emissions are in kilo tonnes and revenue is an index, with base year 2015. Both the data on carbon dioxide emissions and revenue are within the iron and steel industry and were gathered from Statistics Sweden. The control variable of CPI is also an index, with the base year 1980 and GDP growth is an annual percentage. Both CPI and GDP growth were gathered from Statistics Sweden.

Data on the annual average closing spot prices of EUA exist from the year of the implementation of the EU ETS (2005) until 2023. Data on carbon dioxide emissions per industry exist from 1990 until 2021, while the data on revenue exist from 2000 until 2022. The linear regression model using carbon dioxide emissions as the dependent variable uses the data between 1990-2021, where the EUA prices will be put at €0,00 for the years

1990-2004. The linear regression model where revenue is the dependent variable uses data between 2000-2021, where the EUA prices will be put at €0,00 for the years 2000-2004.

2.1.1 Misspecification

In the linear regression model, one assumption is that the linear model and the variables are correctly specified. By using the power of the predicted values of the dependent variable, the Ramsey-RESET test is used to test whether the linear variables of the linear regression model are misspecified. The null hypothesis of the test is that the variables are correctly specified. The P-values of the results of the Ramsey-RESET test on the two fully adjusted models of the dependent variable of carbon dioxide emissions and revenue are 0.158 respectively 0.872. This indicates that the null hypothesis has failed to be rejected. Therefore, the fully adjusted model is correctly specified.

2.1.2 Multicollinearity

Multicollinearity occurs when several independent variables are strongly correlated. Would that be the case, the outcome of the regression model would be inaccurate since the standard errors of the coefficient estimates (beta) will be too high. To test for multicollinearity, a variance inflation factor (VIF) is used. The higher the value of a VIF, the higher the correlation between the two explanatory variables. The results of the VIF test show that there is no concern of multicollinearity, meaning that the independent variables are not strongly correlated.

Variable	**VIF**
GDP growth	1.04
CPI	3.98
EUA prices	3.92
Mean VIF	2.98

2.2 Stepwise linear regression model

The regression model follows a stepwise model with a forward selection. The regression model includes one independent variable and two control variables, which have differing statistical significance on the dependent variable. In the stepwise regression, the control variables are added to the regression model one by one, which indicates how the control variables affect the significance of the independent variable on the dependent variable. For the purpose of this study, a stepwise regression analysis is needed to ascertain how the consumer price index and GDP growth affect the statistical significance of the EUA price development on both carbon dioxide emissions and revenue within the Swedish industry.

The variables included in the regression analysis are the price of EUAs, carbon dioxide emissions, revenue, GDP growth and CPI. Since there are two dependent variables (carbon dioxide emissions and revenue) there will be two separate stepwise regressions, each with one of the dependent variables, but with the same independent variables. The first linear regression model is non-adjusted, with the one independent variable (EUA prices). The second model is semi-adjusted, with the addition of GDP growth as a control variable. The third model is fully adjusted and includes the dependent variable, EUA prices, GDP growth as well as the CPI.

The fully adjusted model is thus:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3} + \epsilon_i$$

Where y_i is the dependent variable, either carbon dioxide emissions or revenue, β_0 is the intercept of the dependent variable, the coefficients β_1, β_2 and β_3 depict the rate of change of the independent variables in the fully adjusted model, which are EUA prices, GDP growth and CPI. ϵ_i Is the error term. The significance level of this analysis is 0.05. The null hypothesis states that the EUA prices have had no significant impact on (1) carbon dioxide emissions or (2) revenue.

3. Results

This section includes the results from the quantitative analysis. The characteristics of the dataset will be presented under descriptive results. The results of the linear regression model will be presented in the subsection of empirical results.

3.1 Descriptive results

3.1.1 The Price development of EUAs

Figure 1 shows the price development of EUAs, 2005-2023. The price of EUAs is set on the market and is highly influenced by the restrictions of the EU ETS (European Union, 2015). During phase 1, the NAP system resulted in member states acquiring a number of EUAs that was larger than their actual emissions. Free allocation and over-allocation of EUAs during phase 1 of the EU ETS meant that the average closing spot price of allowances was free (European Commission, n.d.), which is shown in figure 1. During phase 2, free allocation of allowances was decreased compared to in phase 1, which resulted in a price increase.

The low prices between 2012-2017 was a result of an oversupply of EUAs (Bordignon & Gamannossi degl'Innocenti, 2023). Over-allocation declined between 2013-2016 due to a short-term solution of back-loading (delaying auctioning of a number of allowances) which decreased the excess supply of EUAs (Bordignon & Gamannossi degl'Innocenti, 2023; European Union, 2015). The implementation of the MSR in 2019 was a long-term solution to control volatility and ensure stability of the carbon market, preventing a surplus in the supply of allowances and thereby preventing prices that are too low (European Commission, 2021). Furthermore, the increase of the LRF in phase 4 has further reduced the supply surplus of EUAs, which in turn increased the price of allowances.

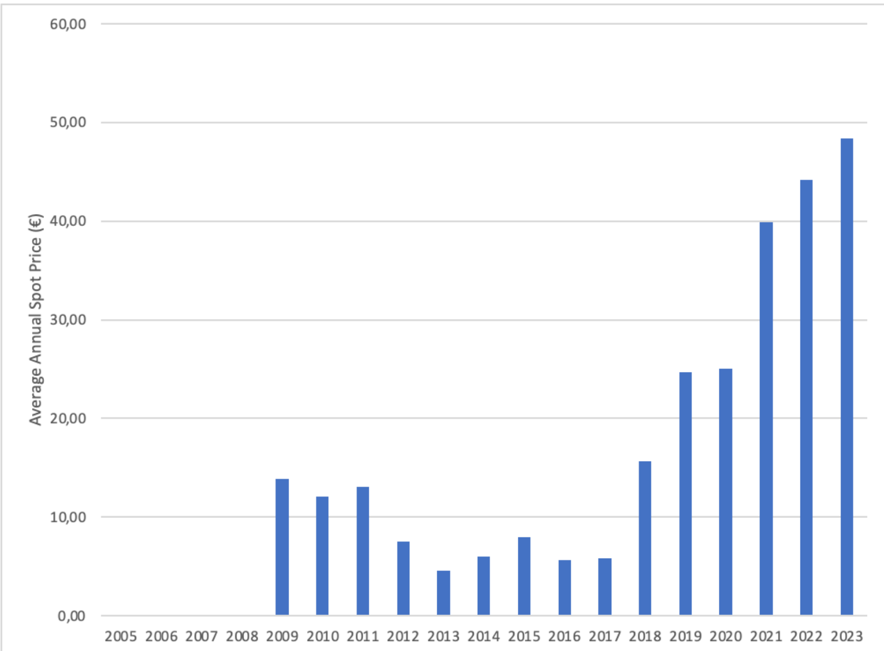

Figure 1: Average Annual Closing Spot Prices of EUAs, 2005-2023

3.1.2 Carbon Dioxide Emissions, Revenue, GDP Growth and CPI

Figure 2a shows the carbon dioxide emissions in the Swedish iron and steel industry between 1990-2021. Figure 2b shows the revenue in the Swedish iron and steel industry between 2000-2022. Both revenue and carbon dioxide emissions fell during the year 2007-2008, while the price of EUAs increased in 2009, as seen in figure 1. Figure 2b and figure 1 show that the revenue curve and the price development of EUAs followed a similar trend in the years after 2009. Figure 2a shows that carbon dioxide emissions increased after the fall in 2008. But after 2008, the emission rate did not reach the same level as before 2008. Furthermore, before the implementation of the EU ETS in 2005 and when the price of EUAs was zero, carbon dioxide emissions had an increasing trend. Figure 2c shows the GDP growth in Sweden, between 1994-2022. Figure 2d shows the consumer price index in Sweden, 1990-2022. Figure 2c shows that GDP growth fell during 2008 and increased the following year. The consumer price index has seen a steady increase during 1990-2020, with a more prominent increase in the years of 2021 and 2022, which can be seen in figure 2d. There has been a general similarity between the trend in revenue and the trend in GDP growth. When the growth of GDP has been negative, there has been a fall in revenue. When GDP growth has been positive, revenue has increased. Both revenue and the CPI have increased between 1990-2022 and 2000-2022. Both revenue and CPI saw a more prominent increase after 2020. Furthermore, revenue has fluctuated while CPI has been steadily increasing. The results of figure 2a and 2d show no similarity between the trends of carbon dioxide emissions and CPI, which could also be observed in table 1, where CPI had no statistical significance on carbon dioxide emissions.

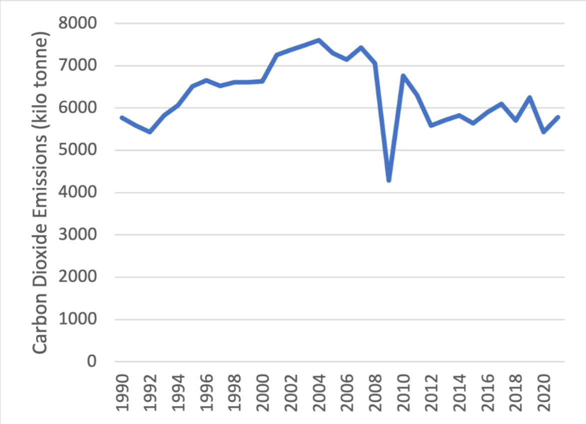

Figure 2a: Carbon dioxide emissions in the Swedish iron and steel industry, 1990-2021

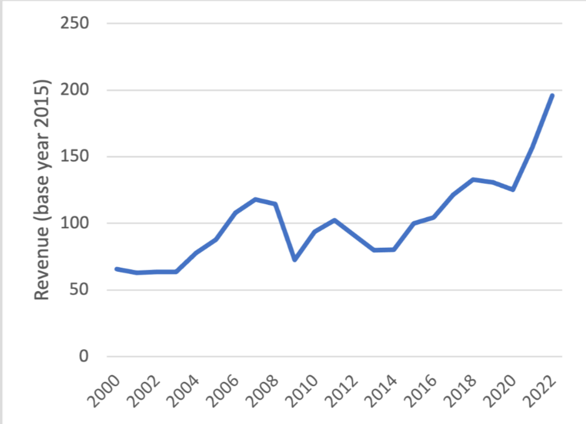

Figure 2b: Revenue in the Swedish iron and steel industry, 2000-2022

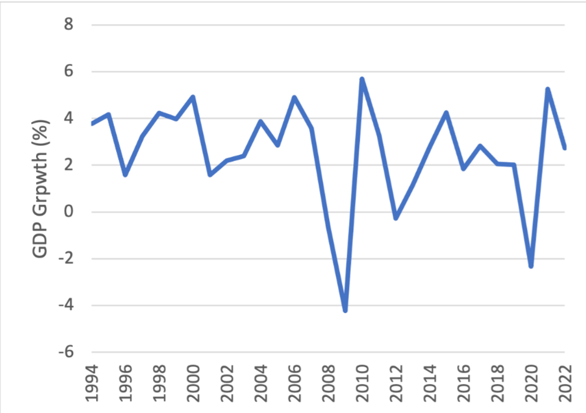

Figure 2c: GDP Growth in Sweden, 1994-2022

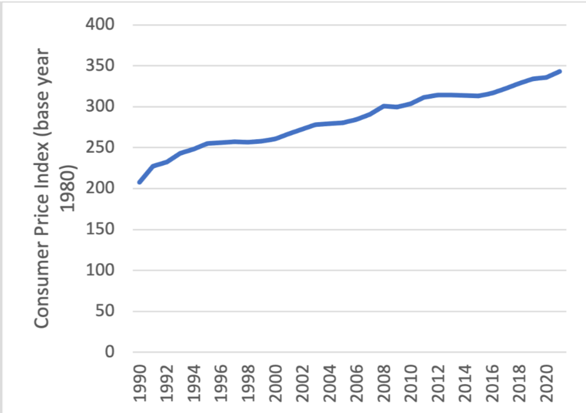

Figure 2d: Consumer Price Index in Sweden, 1990-2022

3.2 Empirical results

Table 1 shows the non-adjusted, semi-adjusted and fully adjusted linear regression models in the iron and steel sector, with carbon dioxide emissions as the dependent variable. The coefficient of EUA Prices is negative for all three models, indicating that a €1 gain in the price of carbon allowances corresponds to a decrease in carbon dioxide emissions, in kilo tonnes. The significance of EUA prices on carbon dioxide emissions is significant on the 5 percent level in the non-adjusted model. It is significant on the 1 percent level in the semi-adjusted model and it is significant on the 10 percent level in the fully adjusted model. This means that the null hypothesis, that the price of carbon allowances does have a significant impact on carbon dioxide emissions, can be rejected for the non-adjusted and semi-adjusted models, but not for the fully adjusted model. GDP growth is statistically significant on the 1 percent level on the semi-adjusted model and on the 5 percent level on the fully adjusted model. The coefficient of GDP growth is positive, which indicates that a 1 percent growth in GDP corresponds to an increase in carbon dioxide emissions. The CPI does not show a significant effect on carbon dioxide emissions.

Table 1: Dependent Variable: Carbon Dioxide Emissions

Explanatory variable	Non-adjusted	Semi-adjusted	Fully adjusted
EUA Prices	-35.19**	-38.65***	-36.35*
	(13.39)	(11.55)	(18.76)
GDP Growth		141.68***	139.45**
		(50.76)	(53.67)
CPI			-1.05
			(6.64)

****p<0.01 **p<0.05 *p<0.1.*
Standard errors are in parenthesis

Table 2 depicts the non-adjusted, semi-adjusted and fully adjusted linear regression models in the iron and steel sector, with revenue as the dependent variable. The EUA Prices show a statistically significant impact on revenue on the one percent level for both the non-adjusted and the semi-adjusted model. The fully adjusted model shows no significant impact of EUA Prices on revenue. This means that the null hypothesis, that the price of carbon allowances does have a significant impact on revenue, can be rejected for the non-adjusted and semi-adjusted models, but not for the fully adjusted model. The coefficient of EUA Prices is positive and illustrates that a €1 increase in the price of carbon allowances corresponds to an increase in revenue. GDP Growth has no significant impact on revenue in the semi-adjusted model. In the fully adjusted model, GDP Growth has a statistically significant impact on revenue on the 10 percent level. The CPI shows a significant impact on revenue at the one percent level in the fully adjusted model. This means that the CPI is the independent variable that best can explain the changes in revenue.

Table 2: Dependent Variable: Revenue

Explanatory variable	Non-adjusted	Semi-adjusted	Fully adjusted
EUA Prices	2.08***	2.09***	0.59
	(0.33)	(0.33)	(0.54)
GDP Growth		1.93	2.82*
		(1.77)	(1.49)
CPI			0.82***
			(0.26)

****p<0.01 **p<0.05 *p<0.1.*

Standard errors are in parenthesis

4. Discussion

The findings of the empirical and descriptive results indicate that the price development of EUAs does impact carbon dioxide emissions and revenue in the Swedish iron and steel industry, to some extent. According to the empirical results, a positive price development corresponds to a decrease in carbon dioxide as well as an increase in firm revenue. The statistical significance of the semi-adjusted model, where carbon dioxide emissions was the dependent variable, indicates that the null hypothesis should be rejected. However, EUA prices were more statistically significant on revenue than GDP growth in the semi-adjusted model. Yet, in the fully adjusted model, GDP was more statistically significant than EUA prices on revenue. However, CPI had the most statistical significance on revenue.

One prominent feature of the descriptive results is that the year of 2008 saw a distinct fall in both carbon dioxide emissions, revenue and GDP growth. The price of EUAs may have had less of an impact on carbon dioxide emissions and revenue, compared to GDP growth. Therefore, the fall in both carbon dioxide emissions and revenue could be better explained by a fall in productivity levels, than by the price of EUAs. This notion is strengthened by the fact that GDP growth had a more statistically significant impact on carbon dioxide and revenue than EUA prices in both fully adjusted models. Furthermore, the EU ETS was just starting phase 2 in 2008, which was underlined by several inefficiencies (such as NAPs, over-allocation of allowances, grandfathering, low price points of EUAs, etc) which resulted in the fact that the targets of the Kyoto Protocol were not reached. The findings in the previous literature suggest that an increase in the cost of compliance does neither harm revenue nor raise the incentive to decrease the level of production. Therefore, the increase in the price point of EUAs was not the most prominent reason for the drop in revenue in the Swedish iron and steel industry.

The previous literature supports the notion that climate policy must be stringent and that carbon pricing must be without inefficiencies in order to achieve emission reduction. This is in line with the findings of this thesis, which showed that carbon dioxide emissions of the Swedish iron and steel industry decreased when the price of EUAs increased. Previous literature also highlights the fact that free allocation and over-allocation of allowances do not generate a high enough cost of compliance, which does not incentivise emission reduction and does not affect the economic performance of EU ETS regulated firms. This is also supported by the findings of the results, where an increase in the price of EUAs lead to a decrease in carbon dioxide emissions in the Swedish iron and steel industry. Furthermore, the descriptive results showed that before the implementation of the EU ETS and when the price of EUAs was zero, carbon dioxide emissions increased. When the price of EUAs increased, carbon dioxide emissions did not increase.

The results of the regression analysis show that an increase in the price of EUAs indicates an increase in revenue. This is in line with the theoretical framework that states that pricing negative externalities is beneficial for a firm’s economic performance. The Porter hypothesis means that stringent climate policy creates opportunities for innovation and competitiveness which would indicate a positive effect on revenue. The policy implications of the EU ETS should therefore be evaluated from the premises of both the theoretical framework and the empirical results. The first standard of stringent climate policy states the policy should favour all opportunities of innovation. Second, the policy should boost continuous innovation. Third, the policy should be regulated in a manner that minimises uncertainty for all participating agents. The regulations of the EU ETS have been weak and have undergone several adjustments. Consequently, the EU ETS has experienced fluctuation and volatility in the price development of EUAs. Recent new directives, such as the MSR and an advancement of the LRF has contributed in decreasing the price uncertainty by stabilising the supply of EUAs and also by annual reports on the exact amount of EUAs on the carbon market. This is in line with the third standard of stringent climate policy, according to the Porter hypothesis. Due to these adjustments of the EU ETS regulations, uncertainty has decreased which should strengthen the incentive of innovation and thereby economic performance of regulated firms. Firms will be better informed on future costs of the emissions that their production generates, which enables a smoother transition towards emission abatement.

The new directives have raised climate ambition within the EU which is reflected in a higher price point of EUAs. The increase in the LRF will generate further price pressure on EUAs, making it even more favourable for regulated firms to invest in emission reduction technologies. This is supported both by the Porter hypothesis as well as the results of the regression analysis, where an increase in the price of EUAs corresponds to an increase in firm revenue. The second standard of stringent climate policy according to the Porter hypothesis states that innovation should be continuously encouraged, which is strengthened by an increase in the price of EUAs. Transitioning into a low-emission production can increase a firm's productivity and market share, improving the overall economic performance. However, investment in green innovation is costly, at least in the short-run. If the price of emitting is not high enough, the costs of investing will not be covered and the incentive of implementing green innovation is insufficient. Furthermore, would the price development of carbon allowances seem to be decreasing due to insufficiency in the regulations of the EU ETS, firms would not prioritise implementing emission abatement technologies. Increasing the stringency of the EU ETS climate policy also increases the price of EUAs, which will encourage green innovation, according to the Porter hypothesis.

The first standard of the Porter hypothesis states that the climate policy should boost all opportunities of innovation. The implementation of the Innovation Fund and the Modernisation Fund work as financing instruments aimed to incentivise a low-carbon transition for low-income member states and regions that have a high fossil fuel dependency. The new directives that were agreed on in the European Parliament in April 2023 include the addition of several new sectors in the EU ETS as well as the CBAM, which will both broaden the scope of the emissions trading systems, while preventing carbon leakage. These are several directives that will strengthen the impact of the EU ETS and consequently encourage innovation in several different sectors. As the first standard of the Porter hypothesis states, stringent climate policy should boost all opportunities of innovation, which the development of the EU ETS has adopted. The additions of several new directives will enhance the implications of EU ETS on green innovation, due to the fact that the emissions trading system has become more stringent as a climate policy.

To achieve internalisation of negative externalities on the market, the price of carbon allowances should reflect the social cost of carbon dioxide emissions. The Coase theorem states that this is achieved by establishing clear property rights at low transaction cost, which is the foundation of the EU ETS. Therefore, Coasian bargaining should succeed in arriving at the most effective price point of EUAs. However, inefficiencies on the carbon market such as free allocation and a supply surplus of tradable allowances has made the EU ETS insufficient at establishing a price point of EUAs that efficiently creates incentives of emission abatement investments, which is evident in the descriptive results. The results of the regression analysis show that an increase in the price of EUAs corresponds to a decrease in carbon dioxide emissions, which explains why it is important that the EU ETS succeeds in keeping the price of the tradable allowances high, in order to achieve emission reduction. Furthermore, due to the acceleration of global warming and climate change, the welfare loss of each tonne of carbon dioxide emissions is progressively increasing. Therefore, the cost of carbon dioxide emissions is growing, which supports a continuous increasing price point of EUAs. Therefore, it can be argued that Coasian bargaining is incomplete at achieving emission reduction at the most cost-minimising allocation, without rigid regulations of the EU ETS. Still, Coasian bargaining can be an efficient driver in the price point of the tradable allowances.

According to the Coase theorem, it does not matter how allowances were initially allocated. Coasian bargaining will ensure internalisation of negative externalities when property rights are clearly defined and transaction costs are low. According to the theory, this would imply that the price of EUAs does not have a significant impact on firm incentive to reduce emissions, as long as the conditions of the Coase theorem hold. Yet, as the previous literature, as well as the findings in the results imply, a higher price point does cause an increased incentive for emission abatement. Furthermore, free allocation of carbon allowances has been proven insufficient at creating strong incentives for firms to implement low-emission production technology.

Free allocation of carbon allowances does not support the ‘polluter pays’ principle, which is one of the theoretical frameworks that the EU ETS was founded on. The ‘polluter pays’ principle is a central part of market based instruments to reduce greenhouse gas emissions. The principle states that the negative impacts on the climate is internalised on the market, when the polluter bears the cost of emitting. The principle does not hold when the cost that emitting firms need to pay is not high enough to cause emission reduction incentives. This is especially the case when regulated firms are excepted from paying for their emissions, like in the case of free allocation. It is also the case when there is a surplus of allowances on the market and the price of emitting is too low. Furthermore, the negative externalities of carbon dioxide emissions have a negative effect globally. From a climate justice perspective, it is only righteous that the polluter bears a high cost for emissions.

The development of the EU ETS has seen a weak policy setup in the initial years, characterised by free allocation, a surplus in the supply of tradable allowances and providing countries within the emissions trading system with too much control of their allocation of EUAs. The deficiency of the initial years of the EU ETS has been improved based on several adjustments of the policy design. Over the course of the different phases of the EU ETS, the emissions trading system has been continuously revised. Changing the allocation system of allowances from NAPs to NIMs led to a gain in EU-wide control of the distribution of EUAs which also enabled hindering over-allocation of allowances. The implementation of the MSR and increasing the LRF has increased the price point of EUAs which has strengthened the stringency of the policy which has increased incentives for firms within the iron and steel industry in Sweden to decrease carbon dioxide emissions. Furthermore, the price increase has also corresponded with a positive increase in firm revenue. Implementing the Innovation Fund and the Modernisation Fund will boost green innovation and support the transition to low carbon production where income is low and fossil fuel dependency is high. These financing instruments will further advance the stringency of the climate policy of the EU ETS. Therefore, due to the several revisions and improvements of the emissions trading system, the EU ETS has become more strict and rigid, which is shown in the price development of EUAs.

4.1 Limitations

The methodology uses time series data, which should be tested for stationarity. The data set used in this thesis is not tested for stationarity, which is a limitation to the study, since it does not account for the fact that the variables may have a unit root. Therefore, when interpreting the results of the linear regression analysis, this should be taken into consideration. Additionally, the estimations of the linear regression models would have been more precise with a larger dataset, however that would not have been possible, considering the fact that the EU ETS was implemented in 2005. However, Sweden has had a carbon taxation policy since 1991, although the tax has mainly been applied to the transportation sector. Valuing the price of EUAs at €0 during the years before the implementation of the EU ETS is therefore of relevance when examining the price effect on carbon dioxide emissions and revenue in the iron and steel sector in Sweden. Yet, the size of the scope should be taken into consideration when interpreting the results of the regression analysis.

5. Conclusion

This thesis aimed to explore the impact of the price development of the tradable allowances of the EUs emissions trading system on both carbon dioxide emissions and revenue in the Swedish iron and steel industry. Assigning a price to emissions, so-called carbon pricing, has been the main policy instrument aimed at reducing carbon dioxide emissions. The EU ETS is a market based instrument which uses tradable allowances, whose price point is set on the market, with a continuously decreasing total amount of allowances. The EU ETS is a climate policy that is one of several instruments within the EU that aims to achieve the European Green Deal. The iron and steel industry has the highest amount of carbon dioxide emission within the Swedish industry sector. Simultaneously, the iron and steel industry has a high potential of transitioning towards emission abatement technologies, such as the development of fossil free steel, which is why this thesis investigated that particular sector.

The analysis was based on previous literature, a theoretical framework and a quantitative methodology. The findings of this thesis indicated that the impact of the price development of EUAs on carbon dioxide emissions has been negative, meaning that a price increase of EUAs translates into a decrease of carbon dioxide emission in the Swedish iron and steel sector. The previous literature included similar findings. Inefficiencies of the EU ETS resulted in a low price point of EUAs, which generated no incentive for firms to reduce carbon dioxide emissions. When the price of EUAs increased, the previous literature found that EU ETS regulated firms were incentivised to reduce carbon dioxide emissions, without decreasing the level of production. The 'polluter pays' principle states that the emitter should bear a high cost of emitting, in order to internalise the negative externality caused by the pollution, in this case, carbon dioxide emissions. Assigning property rights to carbon dioxide emissions by issuing EUAs at low transaction costs is supported by the Coase theorem, which states that an externality is reduced at the most cost-efficient allocation if the two conditions apply. The Porter hypothesis states that a well-designed and stringent climate policy should not only be efficient in reducing emissions, but also beneficial for the economic performance of regulated firms. Thus, the findings of this thesis and of the previous literature as well as the theoretical framework used, support the notion that a high price point of EUAs and stringent climate policy is needed for incentivising firms to reduce carbon dioxide emissions.

To decrease the cost of compliance, firms might respond by reducing productivity instead of investing in emissions abatement technologies. Yet, the results of this thesis found that an increase in the price of EUAs did not have a negative effect on revenue. Instead, the regression analysis found that a price increase had a positive association with revenue in the Swedish iron and steel industry. The findings of the previous literature imply that the EU ETS has not had a negative effect on firm competitiveness nor on revenue. Yet, the initial trading phases of the EU ETS experienced free allocation and a surplus of allowances, resulting in a low cost of compliance for firms. The previous literature found that while this generated no negative impact on firm revenue or competitiveness, it did not incentivise emission reduction. When the price of EUAs increases, so does the cost of compliance for EU ETS regulated firms. Yet, the previous literature found that the increase in the cost of compliance does not indicate a fall in revenue. Like the Porter hypothesis states, stringent climate policy should be beneficial for a firm's economic performance and can create a competitive advantage for firms, which is supported by the fact that the results of this thesis showed that firm revenue was not negatively affected by a price increase in EUAs. Therefore, the findings of the previous literature and of this thesis, as well as the theoretical framework, imply that a price increase in EUAs does not harm revenue in the Swedish iron and steel industry.

The early stages of the EU ETS were characterised by weak policy implications, inefficiency of the carbon market and low price points of EUAs. As a result, there was no firm incentive to decrease carbon dioxide emissions and revenue was not affected. After several revisions and new directives, the end of phase 3 and the start of phase 4 of the EU ETS saw a higher incentive to reduce carbon dioxide emissions, due to the increase in stringency of the climate policy. Meanwhile, firm revenue was not harmed. The future developments of the EU ETS, such as the implementation of the CBAM, the continuous increase of the LRF and the removal of all free allocations of EUAs by 2034, will create further price pressure on regulated firms. This will in turn incentivise green innovation and investment in emission abatement technologies, strengthening the implications of the climate policy and enabling a transition towards low carbon production. Further research is needed on firm behaviour and how it is affected by the expansion of the EU ETS. Especially in regard to investment in emission abatement technologies.

6. Bibliography

Angner, E. (2023). *How Economics Can Save the World*, Dublin: Penguin Random House.

Bayer, P. and Aklin, M. (2020). The European Union Emissions Trading System reduced CO_2 emissions despite low prices, *Proceedings of the National Academy of Sciences of the United States of America*, 117(16), pp. 8804–8812. https://search-ebscohost-com.ludwig.lub.lu.se/login.aspx?direct=true&AuthType=ip,uid&db=edsjsr&AN=edsjsr.26929647&site=eds-live&scope=site [Accessed 10 April 2023]

Beck, U.R., Kruse-Andersen, P.K. and Stewart, L.B. (2023). Carbon leakage in a small open economy: The importance of international climate policies, *Energy Economics*, 117. doi:10.1016/j.eneco.2022.106447.

Bergek, A., Fahnestock, J., Hellsmark, J., Karltorp, K. and Ulmanen, J. (2019). Statens roll för klimatomställning i processindustrin. RISE Rapport 2019:05. RISE Research Institutes of Sweden.

Bordignon, M. and Gamannossi degl'Innocenti, D. (2023). Third Time's a Charm? Assessing the Impact of the Third Phase of the EU ETS on CO2 Emissions and Performance, *Sustainability (Switzerland)*, 15(8). doi:10.3390/su15086394.

Botelho, A., Fernandes, E. and Pinto, L.C. (2011). An Experimental Analysis of Grandfathering versus Dynamic Auctioning in the EU ETS, in Isaac, R.M. and Norton, D.A. (eds) *Experiments on Energy, the Environment, and Sustainability. Research in Experimental Economics*, vol. 14. Bingley, U.K.: Emerald, pp. 37–76. https://search-ebscohost-com.ludwig.lub.lu.se/login.aspx?direct=true&AuthType=ip,uid&db=ecn&AN=1299203&site=eds-live&scope=site [Accessed May 2 2023]

Coase, R. (1960). The Problem of Social Cost, *Journal of Law & Economics*, 56(4), 837–878.

Convery, F.J. (2009). Origins and Development of the EU ETS, Environmental and Resource Economics, *The Official Journal of the European Association of Environmental and Resource Economists*, 43(3), pp. 391–412. doi:10.1007/s10640-009-9275-7. [Accessed April 24, 2023]

de Bruyn, S., Nelissen, D., Korteland, M., Davidson,M., Faber, J., and van de Vreede, G. (2008). Impacts on competitiveness from EU ETS: An analysis of the Dutch industry. Delft, the Netherlands: CE Delft. [Accessed February 24, 2023]

Dechezleprêtre, A., Nachtigall, D. and Venmans, F. (2023). The joint impact of the European Union emissions trading system on carbon emissions and economic performance, *Journal of Environmental Economics and Management*, Volume 118, 2023, 102758, ISSN 0095-0696. https://doi.org/10.1016/j.jeem.2022.102758. [Accessed February 24, 2023]

Deryugina, T., Moore, F. and Tol, R.S.J. (2021). Environmental applications of the Coase Theorem, *Environmental Science & Policy*, Volume 120, Pages 81-88, ISSN 1462-9011. Available online: https://doi.org/10.1016/j.envsci.2021.03.001 [Accessed February 24, 2023]

Eur-Lex. (2015). Decision (EU) 2015/1814 of the European Parliament and of the Council of 6 October 2015 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and amending Directive 2003/87/EC (Text with EEA relevance). *Official Journal of the European Union*. Strasbourg. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2015.264.01.0001.01.ENG#:~:text=to%2Ddate%20link-,Permanent%20link,-Download%20notice [Accessed March 22, 2023]

European Commission. (2005). Further guidance on allocation plans for the 2008 to 2012 trading period of the EU Emission Trading Scheme. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52005DC0703 [Accessed April 24, 2023]

European Commission. (2021). Revision of the EU Emissions Trading System. https://commission.europa.eu/document/download/8c85f2e9-fd90-4356-b966-823b3c60b860_en?filename=revision-eu-ets_with-annex_en.pdf [Accessed March 1, 2023]

European Commission. (n.d). Development of EU ETS (2005-2020) https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/development-eu-ets-2005-2020_en [Accessed March 13 2023]

European Council. (2023a). Fit for 55. https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/ [Accessed March 22, 2023]

European Council. (2023b). Fit for 55: Council and Parliament reach provisional deal on EU emissions trading system and the Social Climate Fund. https://www.consilium.europa.eu/en/press/press-releases/2022/12/18/fit-for-55-council-and-parliament-reach-provisional-deal-on-eu-emissions-trading-system-and-the-social-climate-fund/ [Accessed May 2, 2023]

EEA. (2005). Market-based instruments for environmental policy in Europe. *EEA Technical Report*. ISBN 92-9167-782-5. ISSN 1725-2237. [Accessed April 24, 2023]

European Parliament. (2023). Revision of the EU Emissions Trading System. https://www.europarl.europa.eu/doceo/document/TA-9-2023-0098_EN.pdf [Accessed April 24, 2023]

European Union. (2015). EU ETS Handbook. https://climate.ec.europa.eu/system/files/2017-03/ets_handbook_en.pdf [Accessed April 13, 2023]

Garcia-Torea, N., Larrinaga, C., Giordano-Spring, S. & Rivière-Giordano, G. (2022). Accounting for Carbon Emission Allowances: An Empirical Analysis in the EU ETS Phase 3, *Social and Environmental Accountability Journal*, 42(1–2), pp. 93-115–115. doi:10.1080/0969160X.2021.2012496. [Accessed May 2, 2023]

IPCC. (2023). Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, (in press).

Joltreau, E. and Sommerfeld, K. (2019). Why does emissions trading under the EU Emissions Trading System (ETS) not affect firms' competitiveness? Empirical findings from the literature, *Climate Policy*, 19:4, 453-471, DOI: 10.1080/14693062.2018.1502145 [Accessed March 1, 2023]

Jung, H. and Song, C.K. (2023). Effects of emission trading scheme (ETS) on change rate of carbon emission, *Scientific Reports*, 13(1), pp. 1–13. doi:10.1038/s41598-023-28154-6. [Accessed April 20, 2023]

Khan, J. and Johansson, B. (2022). Adoption, implementation and design of carbon pricing policy instruments, *Energy Strategy Reviews*, 40. doi:10.1016/j.esr.2022.100801. [Accessed April 20, 2023]

Koch, N. and Themann, M. (2022). Catching up and falling behind: Cross-country evidence on the impact of the EU ETS on firm productivity, *Resource and Energy Economics*, 69. doi:10.1016/j.reseneeco.2022.101315. [Accessed April 20, 2023]

Kruse-Andersen, P.K. and Sørensen, P.B. (2022). Optimal carbon taxation in EU frontrunner countries: coordinating with the EU ETS and addressing leakage, *Climate Policy*. doi:10.1080/14693062.2022.2145259. [Accessed April 25, 2023]

Lai, L.W.C., Lorne, F. and Davies, S.N.G. (2020). A reflection on the trading of pollution rights via land use exchanges and controls: Coase Theorems, Coase's land use parable, and Schumpeterian innovations, *Progress in Planning*, 137, p. N.PAG. doi:10.1016/j.progress.2018.10.001. [Accessed April 25, 2023]

le Quéré, C., Korsbakken, J.I., Wilson, C., Tosun, J., Andrew, R., Andres, R.J., Canadell, J.G., Jordan, A., Peters, G.P. and van Vuuren, D.P. (2019). Drivers of declining CO2 emissions in 18 developed economies, *Nature Climate Change*, 9, 213–217. https://doi.org/10.1038/s41558-019-0419-7. [Accessed April 20, 2023]

Long, S., & Kaminskaite-Salters, G. (2007). The EU ETS latest developments and the way forward. *Carbon & Climate Law Review*, 2007(1), 64-72. [Accessed April 20, 2023]

Löfgren, A., Wråke, M., Hagberg, T. and Roth, S. (2013). The Effect of EU-ETS on Swedish industry's investment in carbon mitigating technologies. *Working Papers in Economics 565*, Department of Economics, University of Gothenburg. [Accessed February 24, 2023]

Marin, G., Marino, M. and Pellegrin, C. (2018). The Impact of the European Emission Trading Scheme on Multiple Measures of Economic Performance, Environmental and Resource Economics: *The Official Journal of the European Association of Environmental and Resource Economists*, 71(2), pp. 551–582. doi:10.1007/s10640-017-0173-0. [Accessed February 24, 2023]

Martin, R., Muûls, M. and Wagner, U.J. (2016) The impact of the European Union emissions trading scheme on regulated firms: What is the evidence after ten years?, *Review of Environmental Economics and Policy*, 10(1), pp. 129-148–148. doi:10.1093/reep/rev016. [Accessed February 24, 2023]

Montgomery, W.D. (1972). Markets in licenses and efficient pollution control programs, *Journal of Economic Theory*, Volume 5, Issue 3, Pages 395-418, ISSN 0022-0531, https://doi.org/10.1016/0022-0531(72)90049-X. [Accessed February 24, 2023]

Nordhaus, W. (2017). Revisiting the social cost of carbon, *Proceedings of the National Academy of Sciences of the United States of America*, 114(7), pp. 1518–1523.

https://search-ebscohost-com.ludwig.lub.lu.se/login.aspx?direct=true&AuthType=ip,uid&db=edsjsr&AN=edsjsr.26479373&site=eds-live&scope=site [Accessed April 20, 2023]

OECD. (2008). The Polluter Pays Principle: Definition, Analysis, Implementation, *OECD Publishing*, Paris, https://doi.org/10.1787/9789264044845-en.

Parry, I., Black, S. and Zhunussova, K. (2022). Carbon Taxes or Emissions Trading Systems?. International Monetary Fund. https://search-ebscohost-com.ludwig.lub.lu.se/login.aspx?direct=true&AuthType=ip,uid&db=cat07147a&AN=lub.7196734&site=eds-live&scope=site [Accessed March 21, 2023]

Pigou, A. C. (1921). The Economics of Welfare. London: Macmillan.

Porter, M.E. and van der Linde, C. (1995). Toward a New Conception of the Environment-Competitiveness Relationship, *The Journal of Economic Perspectives*, 9(4), pp. 97–118. https://search-ebscohost-com.ludwig.lub.lu.se/login.aspx?direct=true&AuthType=ip,uid&db=edsjsr&AN=edsjsr.2138392&site=eds-live&scope=site [Accessed April 17, 2023]

Tan, K.C. (2023). Climate reparations: Why the polluter pays principle is neither unfair nor unreasonable. *WIREs Climate Change*, e827. https://doi.org/10.1002/wcc.827

The Swedish Environmental Protection Agency. (2022). Utsläppshandel - EU ETS. https://www.naturvardsverket.se/amnesomraden/utslappshandel/ [Accessed March 1, 2023]

Woerdman, E. and Nentjes, A. (2019). Emissions Trading Hybrids: The Case of the EU ETS. *Review of Law & Economics*, Vol. 15 (Issue 1), pp. 20140054. https://doi-org.ludwig.lub.lu.se/10.1515/rle-2014-0054 [Accessed March 1, 2023]

Åhman, M., Olsson, O., Vogl, V., Nyqvist, B., Maltais, A., Nilsson, L.J., Hallding, K., Skånberg, K. and Nilsson, M. (2018). Hydrogen steelmaking for a low-carbon economy: A joint LU-SEI working paper for the HYBRIT project. *EESS report no 109 and SEI working paper WP 2018-07*. Stockholm Environment Institute, Stockholm and Lund University, Lund. [Accessed March 24, 2023]