Bachelor's programme in Development Studies

The cornerstone of EU climate policy: does it impact innovation? Long-term evidence from the Swedish Pulp and Paper Industry

by

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Abstract

The EU Emissions Trading System (ETS) is a cornerstone of the union's strategy to mitigate climate change and innovation is integral to emissions reduction, as well as an aim of the policy. To study if the EU ETS is associated with increased innovation, the Swedish Pulp and Paper Industry (PPI) poses an interesting case. Not only is Sweden itself a leading innovator, but its PPI have rapidly reduced emissions in recent decades, compared to other Energy-Intensive Industry covered by policy in the country. From this view, the thesis aims to contribute to the literature about the impact of the EU ETS on innovation by presenting what is likely the hitherto first estimate that uses Literature-Based Innovation Output (LBIO) data, which is arguably a stronger indicator than R&D and Patent indicators that are used in previous studies. To enable this, the study constructs a dataset comprising of a treatment and a control group, where long-term LBIO data from the SWINNO database is used. To estimate the association, the dataset is employed in a Difference-in-Differences regression model for the years 1991-2018, where the EU ETS was implemented in 2005. It was found that the EU ETS has no association, or possibly a weak positive association with innovation in the Swedish PPI, which confirms the main finding of the previous research that covers other industries and countries as well. Moreover, it is proposed that the EU ETS led to a low additional price increase of emitting carbon dioxide for the pulp and paper firms, compared to the price before it was implemented when the price of fossil fuels and the Swedish Carbon Tax likely were important factors. Thus, potentially explaining the low association of the EU ETS with increased innovation in the Swedish PPI.

Keywords: Environmental Policy, Carbon Pricing, Emissions Trading System, Hicks Induced Innovation Hypothesis, Emissions Reduction, Pulp and Paper Industry

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List of abbreviations

CEPI	Confederation of European Paper Industries
CO2	Carbon Dioxide
DiD	Difference-in-Differences
EC	European Commission
EEI	Energy-Intensive Industry
ETS	Emissions Trading System
EU	European Union
EUA	European Union Allowance
IEA	International Energy Agency
IIH	Induced Innovation Hypothesis
IPCC	Intergovernmental Panel on Climate Change
LBIO	Literature-Based Innovation Output
NAP	National Allocation Plan
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of the Petroleum Exporting Countries
PH	Porter Hypothesis
PPI	Pulp and Paper Industry
R&D	Research & Development
SDG	Sustainable Development Goals
Swedish EPA	Swedish Environmental Protection Agency
SWINNO	Swedish Innovation Database
UN	United Nations
WB	World Bank

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1 Introduction

The EU Emissions Trading System (ETS) is typically described as a cornerstone of the union's strategy to mitigate climate change, covering around 40% of total emissions (EC, n.d.a). When the policy for pricing and capping carbon emissions was implemented in 2005, it was one of the first ETSs in the world and the largest one by a considerable margin (WB, 2005, pp.4, 32). Since then, the share of global emissions that ETSs cover worldwide have more than tripled and currently covers around 17.7% (WB, 2022b). While the expansion of the policy may have played a role in increased investment in low-carbon technologies globally, ETSs have been insufficient in achieving deep emissions reduction (IPCC, 2022, p.17). Furthermore, accounting for around 41% of all carbon pricing revenue in the world (WB, 2022a, p. 17), it is fair to say that the EU ETS is one of, if not the, most important environmental policy in the world.

The problem is that the empirical evidence of the impact of the EU ETS on innovation, which plays a key role in reducing emissions, arguably is limited. Whereas there have been previous studies of this (e.g. Löfgren et al. 2014; Laing et al., 2014; Bel & Joseph, 2018; Rogge et al., 2011a), the author of this thesis has not found any evidence that is based on object-based innovation indicators. The defining contribution, then, is that the study will present evidence of innovation of economic use, rather than proxies of it. By constructing a dataset based on this indicator of innovation from a perspective that is markedly longer than most of the previous research, the study therefore aims to contribute to the literature and our understanding of the association of the policy with innovation.

Even though innovation that reduces carbon emissions is the main point of interest to the study, the reason that we need it extends well beyond this aspect. Not only is it acknowledged as elemental for sustainable development, but by virtue of Goal 9 of the SDGs, it is held up as especially important for sustainable industrialization (UN, 2022). Since the EU ETS primarily covers energy-intensive industry (EEI) while explicitly aiming to induce innovation through cap-and-trade principles (EC, n.d.a), the focus of this study is relevant in terms of policy evaluation, the wider debate concerning the ability of environmental policy to induce innovation and global climate targets.

This will be studied with a focus on the EEI of the Swedish Pulp and Paper Industry, where it is especially interesting to study the impact of the EU ETS for many reasons. First, Sweden ranks as the highest performing innovation system in the EU (EC, 2021, p.6) and has the fourth highest R&D spending in the world (OECD, 2022), which are widely acknowledged as important inputs of innovation. Secondly, while being the largest producer of pulp and third largest producer of paper in Europe (CEPI, 2021, p.8, 13) the Swedish PPI is often held up as an example of an energy-intensive industry to rapidly lower its emissions in recent years (e.g. Lipiäinen et al., 2022). Still, however, the IEA (2021) suggests that the worldwide PPI is not on track to meet the Net Zero by 2050 climate target. This leads one to wonder if the EU ETS have had anything to do with this, by focusing on the important emissions reducing mechanism of innovation.

1.1 Research Problem

The issue of understanding if the EU ETS is associated with increased innovation is fundamentally related to how long and with what indicators that we measure it. Foremost, as some previous evidence of Swedish innovations have found the average development of time to be 4.71 years (Sjöö et al., 2014, p. 41), it is likely that it also takes time until we can observe and study the association. Secondly, when it comes to studying innovation, the different methods of doing this all have distinct strengths and weaknesses, which is likely to have a significant influence on the outcome of the study. This is where this study comes in, as it will have a longer-term perspective than most of previous research, while likely being the hitherto first study to investigate if the EU ETS is associated with increased innovation that uses Literature-Based Innovation Output (LBIO) data to measure and indicate innovation.

1.2 Aim and Scope

In order to contribute to the literature, the principal aim of the thesis is to estimate if the EU ETS is associated with increased innovation, based on object-based outputs over a long time period. To do this, the thesis aims to identify a treatment and a control group based on a set of selection criteria, primarily by using data from the SWINNO database (Sjöö et al., 2014; Kander et al., 2019) but also other relevant sources such as the Swedish EPA (n.d.a) and the firm's own websites. Here, a main scope limitation of the dataset and thus the study relates to access of firm level data, which limits the study in establishing a causal association of the Difference-in-Differences (DiD) regression model to which the dataset is applied. This issue is primarily related to control variables, which are key in order fully validate the parallel trend assumption that is required for causal inference (Fredriksson & Oliviera, 2019). Nevertheless, through solid selection criteria and by using a set of relevant control variables building on a theoretical framework, it appears feasible to offer a reasonably robust estimation of the association between the EU ETS and innovation, based on the longitudinal data that is constructed in the dataset of unregulated and regulated firms before (1991-2004) and after (2005-2018) the policy was implemented.

Furthermore, due to the use of selection criteria, it seems reasonable to mention that the study will not cover all firms of the Swedish PPI, but rather ones of particular attributes. Nevertheless, the installations that are regarded as related to the regulated firms that meet the selection criteria represent approximately 44% of the entire PPI (including printing works) in 2018 (Swedish EPA, n.d.a; n.d.b). Thus, the scope of the study is not markedly limited in this sense. The principal aim of the thesis is therefore to answer the following main research question:

Is the EU ETS associated with increased innovation in the Swedish Pulp and Paper Industry?

The answer to this question builds on the dataset that is constructed and the DiD regression model, which therefore represents the bulk of the empirical analysis. Furthermore, with the aim of complementing and discussing the association that is found by answering the research question, the thesis will use the following sub-question as a point of departure for the discussion:

How can the association be explained?

The idea for the sub-question is to base the answer on the variables that are included in the regression model and the long-term emissions trends to offer a plausible explanation of the association that is found, based on a theoretical framework. Thus, the answer will be predominantly quantitative and descriptive, and focus on describing and analysing the long-term trends and patterns of the relevant variables, before and after the implementation of the EU ETS.

1.3 Definitions and delimitations

To comprehend the above-mentioned aims, the term *innovation* needs to be defined. The definition in the thesis follows the data on innovation that is used, which defines innovation included in the database as "an entirely new or significantly improved good, process or service that is, or is going to be, transacted to the market" (Sjöö et al., 2014, p. 17). Therefore, the database, henceforth referred to as SWINNO, encapsulates product innovations that are of economic relevance to the market to a much further extent than process innovations, which "is defined as being withheld from the market and applied in-house only" (Sjöö et al., 2014, p. 16). Accordingly, process innovations will be included in the database when commercialized, i.e. are brought to market, but the amount of innovations that are captured remains limited "in industries where process innovations are more important than product innovations" (Sjöö et a., 2014, p.16). In the Swedish (and Finnish) PPI, Kvimaa & Kautto (2008) suggests that the scope for environmental improvements have historically been substantially greater in the production process than of the actual pulp and paper products. Therefore, a delimitation of the study is that the estimation the association of the EU ETS with innovation will likely be primarily based on product innovations.

The definition of innovation also has implications for the specific type of innovation that is most relevant to the EU ETS, which can broadly be seen as such that benefits the climate and/or environment. Common antecedents of such innovation are "eco" (e.g. EC, 2013), "low-carbon" (e.g. Teixidó et al., 2019) or simply "environmental" (e.g. Kivimaa & Kautto, 2010). In SWINNO, the trade journal from which an innovation is captured needs to be explicitly mention environmental factors as a driver of the innovation to be classified as an environmental innovation (Sjöö et al., 2014, p. 37). In order to increase the number of innovations that are covered in the study, this thesis will instead simply study innovation, which encompasses the ones that have an environmental origin, but also other kinds. In this sense, whereas other common ways of studying innovation, such as R&D are proxies of innovation of economic use (Kander et al., 2019) innovation as it is defined in this study is a proxy of the environmental characteristic. This issue with proxies in studying innovation is common, however, and not seen as a limitation to the overall contribution of the study. This is because the characterisation of innovation is a delicate process and certainly beyond the scope of this thesis. For example, Kivimaa & Kautto (2010) describes that even environmental innovations in the PPI can have negative environmental externalities, e.g. through increased energy consumption due to a recycling process.

1.4 Outline of the Thesis

The thesis will now proceed to the previous research, based on which a theoretical framework will be developed. This will be followed by a discussion of the data is used for the construction of the dataset, based on which the DiD regression model will be employed. Thus, a discussion of the method for how this is done will follow which is then analysed in the empirical analysis where the main research question will be answered, after which the sub-question will be answered in the discussion. Lastly, a conclusion of the main findings of the study is provided.

2 Theory

2.1 Previous research

2.1.1 The EU ETS and Innovation

The link between environmental policies, such as the EU ETS, and innovation as it is typically understood is based on the frequently cited John Hicks Induced Innovation Hypothesis (IIH) (see, for example, Newell et al., 1999; Popp, 2002; Johnstone et al., 2010) which suggests that:

> A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind - directed to economising the use of a factor which has become relatively expensive (Hicks, 1963, p. 124).

The hypothesis underpins both cap-and-trade systems and carbon taxes (Teixidó et al., 2019). Both policies are relevant to this study, since the EU ETS that was implemented in 2005 builds on the principles of cap-and-trade (EC, 2020), while the carbon tax that Sweden was one of the first countries in the world to implement in 1991 have existed in parallel (Andersson, 2019). Through such policies, the main idea is to increase the relative price of using CO2 as a factor of production, thus encouraging the firm to lower its use of it (Teixidó et al., 2019). However, the relative price of CO2 can change from exogenous factors as well. For example, in a study of the impact of the Swedish carbon tax and EU ETS on technical development between 1998-2008 of the Swedish PPI, Lundgren et al. (2015) found fossil fuel prices to have a significant impact, while it was only moderate for the policies.

Furthermore, while the two policies serve the same overall purpose of lowering emissions, how they increase the relative price of using CO2 is different since a cap-and-trade sets a cap on the aggregate quantity of emissions, whereas a carbon tax is an excise duty for each unit of emissions (Goulder & Schein 2013; Hammar & Åkerfeldt, 2011). The difference between the two is that the market sets the price per unit of emissions in a cap-and-trade system and is therefore uncertain, whereas the state sets the price per unit of emissions in a carbon tax and the market decides the amount of emissions (Goulder & Schein, 2013, p.14). Which of the two policies is superior in reducing emissions is a contentious issue.

A clear proponent of cap-and-trade is the EC (2020) who suggest that it is a cost-efficient strategy for reducing CO2 emissions, which is why the EU ETS builds on its principles. EU Allowances (EUAs) are rights to emit that are allocated to installations either for free, which is often referred to as grandfathering, or through auctions (Vlachau, 2014). One EUA is equal to 1 ton of CO2-equivalents (1tCO2e), which is the unit that can be *traded* between installations once it has been allocated to them (EC, 2020). The total number of EUAs that are allocated is equal to a *cap*, which is lowered over time and thus reduces total emissions within the system (EC, 2020).

In principle, the number of EUAs that are allocated to each installation is based on their historical emissions or benchmarking after consulting with them (Vlachau, 2014). The installations could, for example, be pulp and paper mills, as were approximately 900 out of the 11 500 installations that were covered by the system when it was implemented (Gullbrandsen & Stenqvist, 2013). In addition, concerns for international competitiveness and carbon leakage are integral (Verde et al., 2019), which is similarly the case for determining sector specific carbon tax rates in Sweden (Andersson, 2019). The former concern pertains to installations, firms and industries that are deemed to be especially exposed to international competition, while the latter concern is based on the notion that firms may move their production to countries with less stringent regulation and the notion that emissions contribute to climate change equally no matter where they are emitted (Verde et al., 2019). Where these two concerns are deemed to be applicable, the allocation of EUAs tend to be more generous and grandfathered to a further extent (Verde et al., 2019). Whereas the theory of cap-and-trade suggests that the allocation should not change the firm's behaviour, much evidence proposes that grandfathering does negatively affect innovative responses (Martin et al., 2012; Bel & Joseph, 2018), where some have even specifically highlighted this problem in the Swedish PPI (see Stenqvist & Åhman, 2016; Gullbrandsen & Stenqvist, 2013).

The purpose of the system has developed since Phase 1 (2005-2007), which had modest emissions targets and the aim of learning for Phase 2 (2008-2012), when the policy would help member states in reaching climate targets for the first commitment period of the 1997 Kyoto Protocol (Newell et al., 2013; EC, n.d.a). During the first two phases, the allocation was decentralized through National Allocation Plans (NAPs), implying that each member state allocated EUAs to form their own cap, the sum of which formed the cap of the entire EU (EC, n.d.a). In Phase 3 (2013-2020), a single EU wide cap replaced the national caps, while the rules for allocation were harmonized across all member states, including those pertaining to carbon leakage and international competitiveness (Verde et al., 2019; EC, n.d.a). Moreover, whereas grandfathering was the main method of allocation in the first two phases, auctions were established as the default method in 2013 (Verde et al., 2019). While it is clear in the data that grandfathering has decreased, it seems to have done so relatively less in the Swedish PPI compared to all other stationary industrial installations, which can be seen in figure 1.

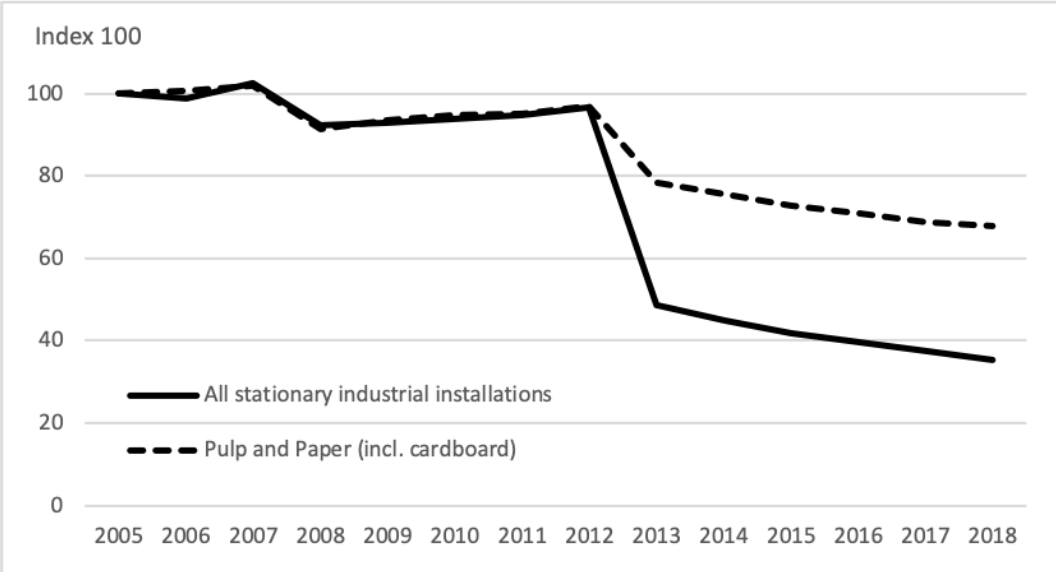

Figure 1: Grandfathering of EU Allowances in Sweden (European Environment Agency, 2022).

The main mechanism through which the EU ETS is typically believed to have an impact on innovation is through *stringency,* which follows John Hicks IIH and thus implies that the more stringent the emissions target the more innovation should follow (Johnstone et al., 2010). Likely the most dominant critique of the EU ETS in spurring innovation refers to a lack of stringency (see e.g. Rogge et al., 2011b; Bel & Joseph, 2018; Lundgren et al., 2015). In the first phase, for example, EU member states were found to have taken advantage of the NAPs to allocate excessive amounts of EUAs to increase international competitiveness (Convery & Redmond, 2007), leading to an EU wide cap that exceeded business-as-usual emissions levels (Aldy & Stavins, 2012). Since the price is uncertain and set by market mechanisms in a cap-and-trade system (Goulder & Schein, 2013), the stringency can be illustrated by the price of EUAs (Rogge et al., 2011b). The price levels are typically described as having been low overall (see e.g. Gullbrandsen & Stenqvist, 2013), and appear to have fallen together with the start of Phase 3.

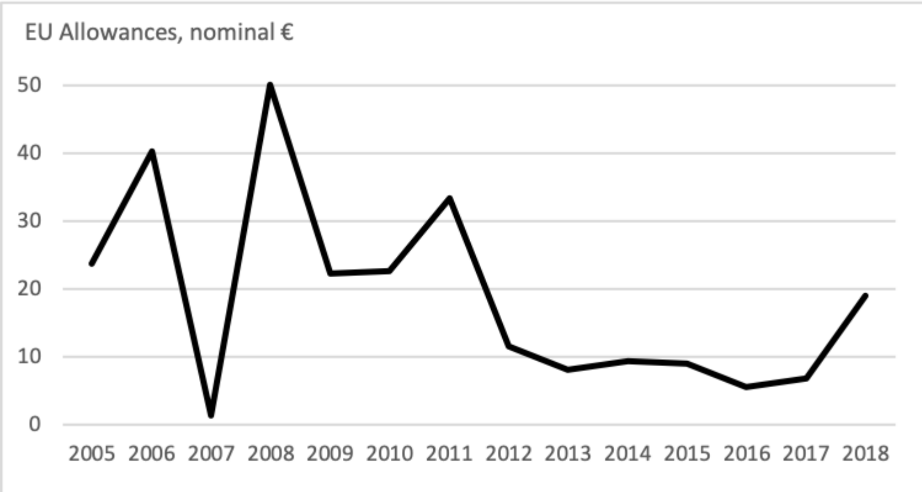

Figure 2: Price of EU Allowances (WB, 2022b; Eurostat, 2022).

However, whereas Hicks IIH suggests a compromise between climate targets and competitiveness, the highly influential Porter Hypothesis (PH) suggests that:

> properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them. Such "innovation offsets," as we call them, can not only lower the net cost of meeting environmental regulations, but can even lead to absolute advantages over firms in foreign countries not subject to similar regulations (Porter & Van der Linde, 1995, p. 98).

In reference to the hypothesis, many scholars have distinguished between a “narrow”, a “weak” and a “strong” PH (see e.g. Jaffe & Palmer, 1997; Kozluk & Zipperer, 2014; Franco & Marin, 2017). The first to do this was Jaffe & Palmer (1997), who describes that the “narrow” PH is about the design of environmental policies, where it is suggested that regulation placed on the outcome of a production process, rather than the process itself, are more likely to spur innovation. Here, it is seen as though market-based policies, such as tradeable allowances or excise taxes are superior in doing this (Franco & Marin, 2017), and is thus applicable both to the EU ETS and the Swedish Carbon Tax. Moreover, the “weak” PH is based on the view of the firm as profit maximising and simply relates to the type of innovation that is induced (Jaffe & Palmer, 1997), in other words, “environmental regulation will lead to an increase in environmental innovation.” (Kozluk & Zipperer, 2014, p.162). This version clearly follows the already outlined view of environmental policy and innovation as it relates to the economisation of a specific production factor, as per Hicks IIH. More contentious is the "strong" PH, where "Critics generally focus on the free-lunch argument, that is, that if there were productive opportunities available, they would have already been exploited by the firm." (Kozluk & Zipperer, 2014, p. 159). The free-lunch argument is based on the hypothesises that "there are factors preventing firms from fully exploiting their efficiency or technological potential; under this assumption, regulation triggers improvements by making inefficient behaviours costlier, creating a potential win-win situation. (Cainelli et al., 2020, p.3). The empirical research does however appear to disregard Porter's "strong" hypothesis. For example, Broberg et al. (2013) differentiates environmental performance as driven either by the market or by policy, where the former was found to increase performance efficiency while the latter was not. Thus, whereas the "narrow" and "weak" PH does seem to be generally agreed upon and in line with Hicks IIH in the literature, the "strong" does not.

The main problem of Hicks IIH and the previously mentioned research then, appears to be that innovation is simply not the only way a firm may respond to environmental policy. Instead, firms could just as well *adopt* already existing products and processes, which often minimizes the cost of compliance (Teixidó et al., 2019). The underlying cause of this problem relates to the nature of new knowledge as a public good, which is known to inhibit private firms to commit to the long-term R&D investments needed to produce new knowledge, since it may spill over to other firms, hence prohibiting the innovator from receiving the full profit (Newell et al., 2013; Popp, 2019). Indeed, a central issue regarding market-based policies such as the EU ETS "concerns the degree to which they encourage long-term investment in new technologies rather than solely short-term fuel-switching and energy-conservation" (Newell et al., 2013, p. 132). Here, a recent study by Lipiäinen et al. (2022) suggests that the fuel-switch from fossil to biofuels have played a major role in emissions reductions of the Swedish (and Finnish) PPIs in the 2000s. Moreover, substantial energy-efficiency improvements have also been observed in recent decades and are attributed a central role in the emissions reductions of the Swedish PPI (see e.g. Lipiäinen et al. 2022; Stenqvist, 2015). Returning to Hicks IIH, then, determining whether the EU ETS is associated with this apparent economisation of CO2 through innovation (and not adoption) becomes a matter of defining what innovation actually is. For example, how significant of an improvement does an energy-efficiency improvement need to be to count as a process innovation, and how is this best determined? Furthermore, to understand innovation one also needs to account for differences between industries in terms of the technologies and market structures, e.g. if larger firms are more innovative than smaller ones, or if innovation is more common in certain industries than others (Malerba & Orsenigo, 1996).

2.1.2 The measurement problem in the empirical evidence

This thesis argues that being able to answer the above question helps us understand the impact of the EU ETS on innovation. Therefore, before delving further into the previous empirical evidence therefore, it is constructive to start by investigating four of the main ways that innovation itself is commonly measured, which can be seen in table 1.

***Table 1**: Summary of common ways of studying innovation and related indicator, adapted from Sjöö et al. (2014, pp. 3-9).*

Inputs	Amount of R&D or total innovation expenditure measured as the share of labour or investments devoted to it. Indicates that new knowledge is being applied and produced.
Intermediary outputs	Number of patents or patent citations. Indicates that new knowledge has been produced, i.e. invented, as well as a perceived level of novelty from the innovator.
Subject-based outputs	Interviews or surveys of the innovator, measured as the degree of novelty of the actual innovation from the firm perspective. Indicates that the innovating agent perceives the innovation to have a certain degree of novelty.
Object-based outputs	Periodicals or interviews with industry experts, measured as the degree of novelty of the actual innovation from the market perspective. Indicates that the market perceives the innovation to have a certain degree of novelty.

The two indicators that appear to be most commonly used to study the impact of the EU ETS are inputs (e.g. Löfgren et al. 2014; Laing et al., 2014; Rogge et al., 2011a; Rogge et al., 2011b) and intermediary outputs (e.g. Calel & Dechezleprêtre, 2016; Bel & Joseph, 2018). The main issue with studying innovation based on inputs is that it does not "show the efficiency of the process by which inputs are transformed into outputs, or into innovative products." (Coombs et al., 1996, p. 404). A problem with patents then, is that they primarily measure invention, which despite indicating new knowledge does not necessarily indicate that it, is or will become, of economic use on the market (Coombs et al., 1996). This leads one to ask: how do we interpret the findings of previous studies about the impact of the EU ETS on innovation?

The most common finding of the previous research is that the EU ETS have had either no (e.g. Löfgren et al., 2014; Martin et al., 2012), low to moderate (e.g. Lundgren et al., 2015) or an inconclusive (Laing et al., 2014) impact on innovation. Some studies have also found that the policy have had more of an impact (e.g. Calel & Dechezleprêtre, 2016), but such findings are relatively scarcer. Since none of these studies, or any other that the author of this thesis have found for that matter, have based their findings of innovation that are evidence of economic use, this represents a gap in the previous literature.

2.2 Theoretical Framework

In order for the study to contribute to what we already know about the EU ETS and innovation, this study will use a theoretical framework that indeed focuses primarily on the theoretical aspects of the link between these two, as opposed to the specific design features of the policy. Such features could for example be the impact of grandfathering or allowances prices, but the review of the previous research suggests the impact of this is known. Specifically, the common view appears to be that a lack of stringency and large share of free allocation in the EU ETS have hampered innovation.

Instead, the study aims to draw from the straightforward economic theory that seems to fairly well agreed upon in the research about environmental policy and innovation. The same mechanisms are also what seems to be view of the EC, as the system is based on the market-based cap-and-trade principles. This relative "simplicity" of the theoretical framework is conducive as it also allows the author to spend more time constructing the dataset needed in order to study if the EU ETS have been associated with increased innovation from a new light. The theoretical framework to be applied is visualised in Figure 3:

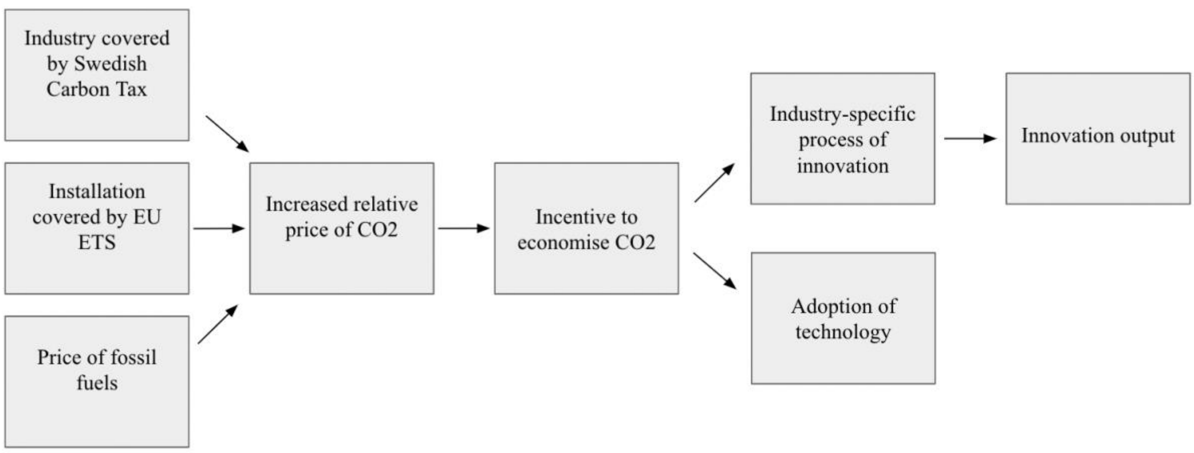

Figure 3: Own illustration of theoretical framework.

The first part of the theoretical framework refers to the three main factors that have been identified for inducing changes in the relative price of CO_2 for the Swedish PPI, which may incentivise the firms to economise CO_2 to different extents over time. Through the incentive, firms may either adopt existing technology (which is not defined as innovation in the thesis), or engage in a process of innovation, e.g. through R&D, which might lead to innovation output.

2.2.1 Limitations

The main limitation of microeconomic approaches to study innovation, which would be a reasonable characterisation of the theoretical framework that is used here, is that

> its internal mechanism - the learning, searching and formal R & D processes - remains inside a black box. The model is driven by exogenous changes in the economic environment in which the firm (or public research agency) finds itself (Ruttan, 1997, p.1521).

In the theoretical framework, this limitation is clear as it is based on the notion that the exogenous change of the CO_2 price leads to the incentives to engage in a process of innovation, which may be followed by output. Thus, the study will not be able to encapsulate internal mechanisms or mechanisms between firms, which are sometimes accounted for to study the innovation (see e.g. Gullbrandsen & Stenqvist, 2013).

3 Data

3.1 Innovation

The main source of the thesis is the SWINNO database (the reference source to which is Sjöö et al. (2014), which have been updated by Kander et al. (2019)) contains the data about innovation that is used in the empirical analysis. This data plays a crucial role in the dataset that is constructed in this study, as it is used to identify a treatment and a control group and the innovations that these have commercialized over time, which forms the dependent variable of the regression model.

The SWINNO database was constructed using the Literature-Based Innovation Output (LBIO) method (Sjöö et al., 2014). This method essentially entails systematically covering product announcements of trade journals over a long period of time (Coombs et al., 1996), which have the below main strengths and weaknesses:

Table 2*: The LBIO method (adapted from Coombs et al., 1996, p.405)*

Strengths	Weaknesses
Evidence of innovation with economic significance, which is independent from the researcher.	Does not capture process innovation.
Often captures more innovations from small firms than alternative methods.	Possibly fewer innovations captured from larger firms as they have a lower incentive to report them, and more from firms seeking to increase perceived innovativeness.
Timely when it comes to identifying year of commercialization.	Potentially problems with identifying and selecting the right trade journals.

The trade journals from which the data for this study derives were selected "based on the following criteria: (a) inclusion of an independent editorial board; (b) a mission to report on innovation and technological development; and (c) a focus on either Finland or Sweden" (Kander et al. 2019, p.52). They also chose to include a specific pulp and paper journal due to the importance of the industry in the two countries. This makes the data especially relevant for this study, while the timely identification of the year of commercialization is beneficial as the regression is performed on an annual basis and it is highly reliable as it is direct, primary data of innovation.

3.2 EU ETS

In order to identify which of the innovating firms from the SWINNO database that had received a treatment, i.e. have been regulated by the EU ETS, the thesis have used publicly available data from the Swedish Environmental Protection Agency (EPA). This is the government authority that is responsible for the allocation of EU allowances to Swedish installations and following up on their emissions reporting every year (Swedish EPA, n.d.c.), which is then published at Swedish EPA (n.d.a). This published data stipulates the name of every installations, what firm operates it, where it is located (both county and municipality), what industry it belongs to, as well as allocated EUAs and reported emissions for every installation (Swedish EPA, n.d.a). Since the firms are legally required to supply this information according to certain standards after which it needs to verified by the (Swedish EPA, n.d.d) this data can be seen as reliable, while being relevant to the study.

3.3 Firm level

The most important data that is used at the firm level are the various online sources that are used to ensure that the firms meet the selection criteria B and C, as well as D when applicable, which are outlined in section 4.1.3. When possible, the data sources that are used have been the firm's own websites, which more often than not contains the relevant information needed for the criteria. The firm's own website can be seen as primary sources and whereas firms could potentially have an incentive to exaggerate e.g. their year of founding, this risk is seen as low. Nevertheless, when found, data on e.g. years of founding were triangulated with the data from Allabolag and the Company database from Statista (n.d.). Allabolag is a private company that provides firms with credit information such as years of founding and corporate structure, which bases its information of the firm's own annual reports (Allabolag, 2022f; 2022g). Therefore, it is reliable and contains valid information for the study. Statista (n.d.) is also used for both firm level data such as the number of employees of the firms and their revenue. This data however, is only provided for either 2020 or 2021, and is therefore used a proxy of the annual firm size between 1991-2018.

4 Methods

4.1 Difference-in-Differences

4.1.1 Research design

In an experimental design, the experimenter typically assigns participants to different conditions where independent variables are manipulated with the aim of measuring the impact or effect of these on a dependent variable, while using control variables (Robson & McCartan, 2016, p.113). In a quasi-experimental design, which is used in this thesis, Robson & McCartan (2016, p.127) describe that elements of the experimental design are maintained with the defining difference that the treatment and control group is not randomly assigned. As the two groups of firms to be studied are chosen based on a number of selection criteria, which is elaborated on in section 4.1.3., this an appropriate description of the research design.

The design is suitable for studying the impact of the EU ETS on innovation for two main reasons. First, the treatment of the policy is deliberately, i.e. not randomly, assigned to certain installations. Second, by combining the data from SWINNO and the Swedish EPA, the thesis has data from both before and after the EU ETS was implemented, as already mentioned. Having such data is required for a Difference-in-Difference (DiD) regression, which is a quantitative method that can be used to estimate the impact of a given policy on a dependent variable when the treatment is not randomly assigned (Fredriksson & Oliviera, 2019). The method has also been used in multiple studies that are similar to this thesis (see e.g. Calel & Dechezleprêtre, 2016; Löfgren et al., 2014) and it is a method that is increasingly used to study innovation (Fredriksson & Oliviera, 2019). Therefore, this is an appropriate method for answering the research question.

4.1.2 Assumptions

In this type of regression model where the treatment group is deliberately assigned, Fredriksson & Oliviera (2019) describe that identifying a suitable control group is crucial. They explain that the most important assumption that needs to be validated in a DiD model is that the control group follows the same trend over time as the treatment group would have, in this case, if the EU ETS would not have been implemented. In order to validate this assumption, the model will first use a set of selection criteria that are outlined in the following section and after that apply control variables to control for both endogenous and exogenous factors to the firm that are relevant based on the theoretical framework.

The second main assumption of the regression model is the stable unit treatment value assumption, which "implies that there should be no spillover effects between the treatment and control groups, as the treatment effect would then not be identified" (Fredriksson & Oliviera, 2019, p. 523). This assumption is arguably more problematic in this study. This is because innovation in theory can spread across firms, e.g. through imitation (Gullbrandsen & Stenqvist, 2013). This is a limitation of the theoretical framework and hence the overall regression model.

4.1.3 Construction of dataset

In order to estimate the impact using the DiD regression model, a central aim of the thesis is to construct a suitable dataset over a long time period. This was also seen as beneficial for being able to describe the trends of both innovation and the broader economisation of CO2 over time. Whereas the data sources on innovation contains data all the way back to 1970 (Kander et al. 2019; Sjöö et al. 2014), it was decided that the start year of the dataset would be in 1991. The main reasons were that data on other important factors became available close to that year (e.g. in 1990 for industrial carbon emissions from the Swedish EPA, n.d.b) and that the Swedish Carbon Tax was implemented in 1991 (Hammar & Åkerfeldt, 2011), the rate of which needs to be controlled for following the theoretical framework. Another reason was that looking even further back in time was likely going to increase difficulties in ensuring that the firms have been operating over the entire period, as well as controlling for mergers and acquisitions. The end year of the dataset was then set to 2018, since this was the last year that a pulp and/or paper innovation had been commercialized in the SWINNO database.

Having set the time period to 1991-2018, the next step was about ensuring that the firms included in the dataset could have commercialized an innovation over the entire time period and that the groups that they belonged to were comparable to the extent that their trends were likely to be parallel, absent the EU ETS. This motivated the use of selection criteria, which are defined in Table 3 and 4 below.

Table 3*: Selection criteria of the treatment and control group*

A	The firm needs to have commercialized at least one pulp and/or paper innovation between 1991-2018 according to SWINNO.
B	The firm needs to have been founded or registered the year of 1991, at the latest, and remained in operation until at least 2018. It needs to be possible to identify this following a qualitative investigation of online sources.
C	If the innovating firm as it is written in SWINNO have merged with, or been acquired by, another firm, then the output is counted as belonging to the latter.

Table 4: *Selection criteria specific to the treatment group*

D	The literal name of the innovating firm and its location in SWINNO needs to be related to at least one installation that is regulated by the EU ETS over the entire period of 2005-2018 by name and geographical location. If data on the location of the innovating firm is missing in SWINNO, the relationship to a regulated installation needs to be clear following a qualitative investigation.
E	At least one of the related regulated installations of the matched regulated firm needs to have been allocated EU allowances every year between 2005-2018.

Having identified firms that meet the selection criteria, the dependent variable was constructed with the reasoning and methods outlined in table 5.

Table 5*: Construction of the dependent variable*

1	The firms that meet the selection criteria are assumed to have been able to commercialise innovation over the entire time period. Thus, for example if it can be observed that a firm only commercialised one innovation over the time period in the year 1991, it can also be observed that it *has not* commercialised innovation any other years.
2	In addition to the pulp and/or paper innovations that the firms have commercialized, all other types of innovations that they have commercialized are included. This follows the reasoning that e.g. an energy-efficiency innovation of a pulp and paper firm is not a pulp or paper innovation. This was done by manually going through the literal names of the innovating firms of all innovations in the SWINNO database, after which the ones found were included.

A clear benefit of criteria A is that it helps the study validate the parallel trend assumption, as it is likely to control for some potential differences in the innovation characteristics of the pulp and paper industry. This is based on the notion that the patterns of innovation have previously been found to differ based on the technology that is dominant in the specific industry (Malerba & Orsenigo, 1996). Moreover, Criteria B was used to ensure that the firms indeed could have commercialized innovation over the entire time period, which is fundamental to step one of constructing the dependent variable. Furthermore, Criteria C was included as it was found to be common during the construction of the database and necessary to control for. In addition, Criteria D was used to identify the treatment group, i.e. was regulated by the EU ETS. Here, a similar assignment of the treatment group based on having had a regulated installation have previously been done in Calel & Dechezleprêtre (2016) and therefore seemed reasonable, since it was possible to do with the data.

4.1.4 DiD regression model

Having constructed the dataset, it was applied to a Difference-in-Differences regression model that is described in Table 6 and through the following theoretical equation:

$$Y^{Innovation} = \beta_0 + \beta_1 D^{post} + \beta_2 D^{Treatment} + \beta_3 D^{Post} * D^{Treatment} + \beta_4{}^{Revenue} + \beta_5{}^{Employees} + \beta_6{}^{Carbon\ Tax} + \beta_7{}^{Oil\ Price}$$

Table 6: *Regression model*

Variable	Description
$Y^{Innovation}$	Number of annual innovation outputs observed per firm, which is a dependent count variable to indicate a decrease or increase of innovation.
$\beta_1 D^{post}$	Dummy variable stipulating the time before and after the EU ETS implementation in 2005.
$\beta_2 D^{Treatment}$	Treatment group dummy stipulating if the firm was or would become regulated by EU ETS.
$\beta_3 D^{Post} * D^{Treatment}$	Interaction variable, which is the DiD estimate of the impact of EU ETS on innovation.
$\beta_4^{Revenue}$	Proxy control variable of firm level differences between 1991-2018 in the process of innovation, measured as the revenue of the firm, million USD, in 2020 or 2021.
$\beta_5^{Employees}$	Proxy control variable for firm level differences in the process of innovation between 1991-2018, measured as the number of employees, in 2020 or 2021.
$\beta_6^{Carbon\ Tax}$	Control for firm level difference in the relative price of CO2, measured as the annual nominal carbon tax rate, SEK per tCO2e.
$\beta_7^{Oil\ Price}$	Control for changes in fossil fuel price, annual OPEC crude oil price from (in U.S. dollars per barrel).

The inclusion of control variables for firm size was based on the notion that it was likely to have an influence on innovation (Malerba & Orsenigom 1996). Since some previous evidence suggests that innovation is proportionate to the firm's size (Symeonidis, 1996), this was therefore included. However, longitudinal data was not available to control for this, hence why the value from 2020 or 2021 from Statista (n.d.) is used as a proxy for the size between 1991-2018.

Moreover, the carbon tax rate was also a variable that was clearly going to have an influence on the outcome based on the theoretical framework. In order for this to be as accurate as possible to the observations, the industry-specific rates and exemptions outlined in Hammar & Åkerfeldt (2011, p.6) and National Institute of Economic Research (2022, pp. 25-26) were used. From 1991 until 30/6 2008, the rate for industry installations inside and outside of the EU ETS was the same and varied between 25-50% of the general rate (Hammar & Åkerfeldt 2011, p.6; National Institute of Economic Research, 2022, pp. 25-26). Then, the rate was lowered to 15% for installations inside the EU ETS, until 2011 when they were completely exempted from the tax (National Institute of Economic Research, 2022, p. 25). At the same time, industrial firms outside the EU ETS payed 21% of the general rate until 2011 when the rate was set to 30%, which have remained until today (National Institute of Economic Research, 2022, p.26).

In addition, as Lundgren & Marklund et al. (2015) had previously found fossil fuel prices to be a significant predictor of innovation while it follows the theoretical framework, this variable was included. It is important to note here that because the carbon tax is levied on oil prices in Sweden and therefore increases in the price of oil for the producers relative to the price of oil that is set on the world market (Hammar & Åkerfeldt, 2011), that the crude oil price of the OPEC producers is assumed to reasonably mirror the world market price.

5 Empirical Analysis

5.1 Results

Based on the selection criteria, the analysis found 37 innovating firms that had commercialized at least one pulp and/or paper innovation between 1991-2018, out of which 17 did not meet the criteria and was therefore not included in the analysis. The explicit motivation and specific criteria for those that do not meet the criteria is outlined in Appendix A.

Based on this, a multiple linear Difference-in-Differences regression model was applied to test if the EU ETS is associated with increased innovation in the Swedish PPI. The overall regression model was statistically significant (R^2 = .025, df = 7, 496, *p = .089). Under the model, the Difference-in-Difference estimate (β_3 = .091) was not found to be statistically significant (p = .107), which can be seen in Table 7 below. These findings confirm the main finding of the previous research on the topic (e.g. Löfgren et al., 2014; Martin et al., 2012; Lundgren et al., 2015; Laing et al., 2014) by suggesting that the EU ETS is not associated, or possibly has a weak positive association with innovation.

Table 7: *Regression output*

Model	Unstandardized B	Coeff. Std. error	Standardized Coefficient Beta	t	Sig.
(Constant)	.093	.034		2.738	***.006
$\beta_1 D^{post}$	.023	.051	.045	-.442	.659
$\beta_2 D^{Treatment}$	-0.80	.034	-.158	-2.342	**.020
$\beta_3 D^{Post} * D^{Treatment}$	.091	.056	.150	1.614	.107
$\beta_4^{Revenue}$	-9.122E-6	.000	-.175	-1.711	*.088
$\beta_5^{Employees}$	7.583E-5	.000	.243	2.225	**.027
$\beta_6^{Carbon\ Tax}$	-5.888E-5	.000	-.018	-.277	.782
$\beta_7^{Oil\ Price}$	-.001	.001	-.105	-1.251	.211

Note: **p<0,1, **p<0,05,***p<0,01*

It was found that the size of the firm, both in terms of revenue (*p = .088) and employees (**p = .027) significantly predicts innovation. Moreover, while neither the carbon tax (p = .782) or oil price (p = .211) were found to significantly predict innovation, the findings indicate that the latter is relatively more important in predicting innovation. This is in line with the findings by Lundgren et al. (2015) who suggests that fossil fuels have been a more significant predictor of innovation than the Swedish Carbon Tax policy.

In addition, in table 7, the nature of the data can be observed. First, we can see that two was the highest number of innovations commercialized by a firm in the same year. Second, we can see a considerable range in firm size between the firms both in terms of revenue and employees. It can also be seen that 56 observations are missing for these two variables, which is because data was not available for two of the firms included in the model. Third, it can be seen that the minimum value of the carbon tax is zero, which is because the firms covered by the EU ETS were exempted from the tax in 2011 (National Institute of Economic Research, 2022, p. 25).

Table 8*: Descriptive statistics*

Variable	N	Minimum	Maximum	Mean	Std. Deviation
$Y^{Innovation}$	560	0	2	.07	.259
$\beta_1 D^{post}$	560	0	1	.50	.500
$\beta_2 D^{Treatment}$	560	0	1	.50	.500
$\beta_3 D^{Post} * D^{Treatment}$	560	0	1	.25	.433
$\beta_4{}^{Revenue}$	504	11	21471	1704.78	4842.603
$\beta_5{}^{Employees}$	504	12	3373	496.89	806.362
$\beta_6{}^{Carbon\ Tax}$	560	.000	362.670	159.778	101.767
$\beta_7{}^{Oil\ Price}$	560	12.28	109.45	47.8021	31.672
Valid N (listwise)	504				

5.2 Discussion

Having found that the EU ETS, at most, had a weak positive association with innovation under the regression model, the remains of the analysis is dedicated to answering the sub-question: How can the association be explained?

Underlying this answer is the previous research that suggests that the EU ETS have been inefficient in spurring innovation due to design features of the policy, primarily a lack of stringency (see e.g. Rogge et al., 2011b; Bel & Joseph, 2018; Lundgren et al., 2015) as well as the generally high level of grandfathering (e.g. Martin et al., 2012; Bel & Joseph, 2018), which have been seen as hampering the induced innovation in the Swedish PPI particularly in Phase 3 (2013-2020) of the policy (see Stenqvist & Åhman, 2014; Gullbrandsen & Stenqvist, 2013). The association found in the regression model is in line with this research.

Now, following the theoretical framework, the first trends that need to be analysed are the factors that have implications for the relative price of CO2, which are not related to the aforementioned design features of the EU ETS. Below, therefore, is the oil price that serves as a proxy for the actual price of fossil fuel as an input factor of production, which is followed by the estimated industry-specific carbon tax rates.

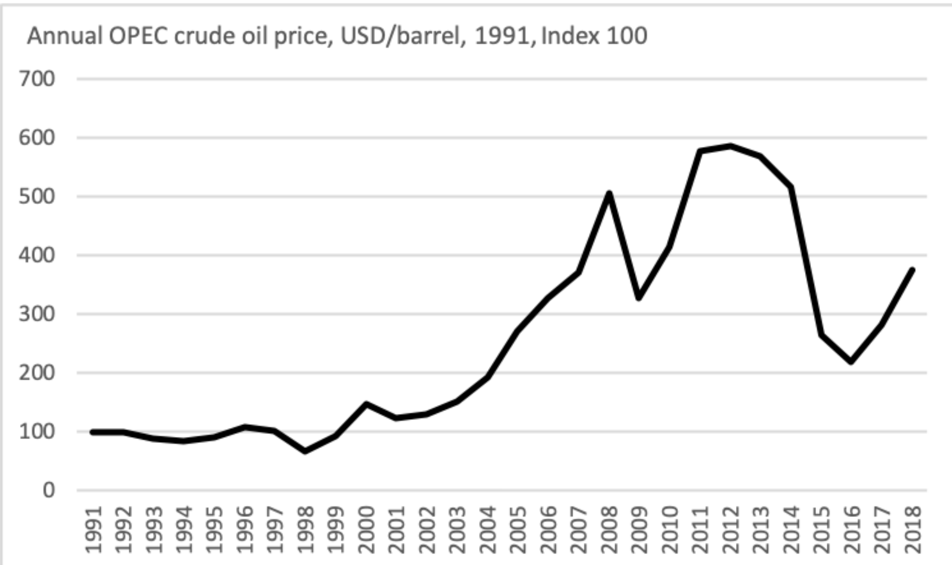

Figure 4: Oil price (Statista, 2022).

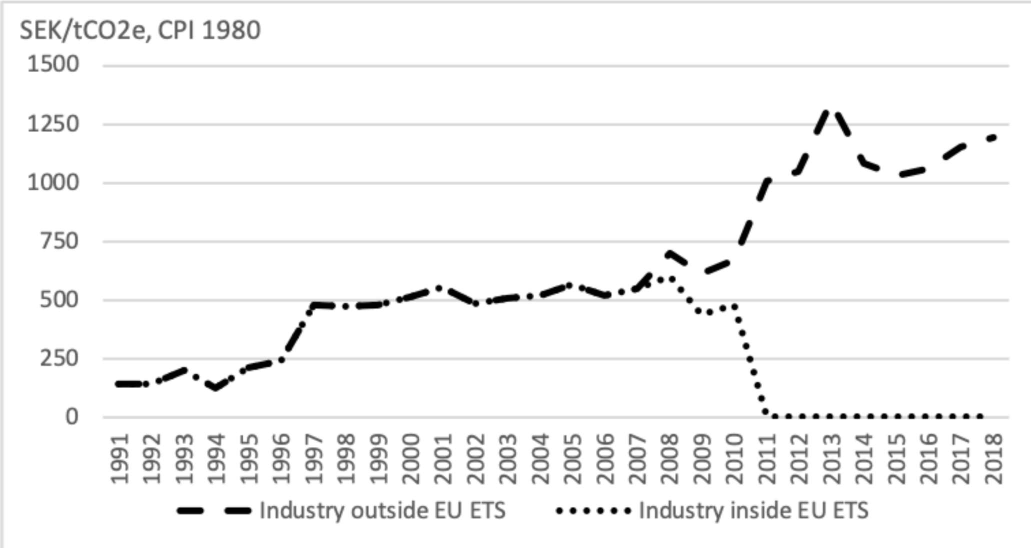

Figure 5: Estimated industry-specific carbon tax rates. Own calculation based on data of the nominal rate (WB, 2022b), development of the annual nominal level of the rate for areas of use (Hammar & Åkerfeldt, 2011, p.6; National Institute of Economic Research, 2022, pp.25-26), exchange rates from Eurostat (2022) and adjusted for inflation with 1980 as the base year (Statistics Sweden, 2022).

Regarding the oil price, it can be observed that it has increased dramatically over the time period, starting most noticeably around year 1999, which continued until a short drop from 2008 but had recovered in 2011, to then fall back down in 2014. Regarding the estimated industry-specific carbon tax rates, we can see that the same rate was applicable to industry outside EU ETS, which is generally seen as the control group, and the treatment group followed the same pattern until the middle of 2008 when industry covered by EU ETS were given additional exemptions. What is most noticeable over the long-term for both groups, is the increase in the carbon tax rate between 1996-1997, which was due to increase of the industry rate from 25 to 50% of the general (see Hammar & Åkerfeldt, 2011, p.6).

As per the theoretical framework, these changes should have led to incentives to economize CO2, which may occur either through adoption (including fuel switching) or innovation. This leads one to ask whether such an economization can be observed and is therefore illustrated in Figure 6.

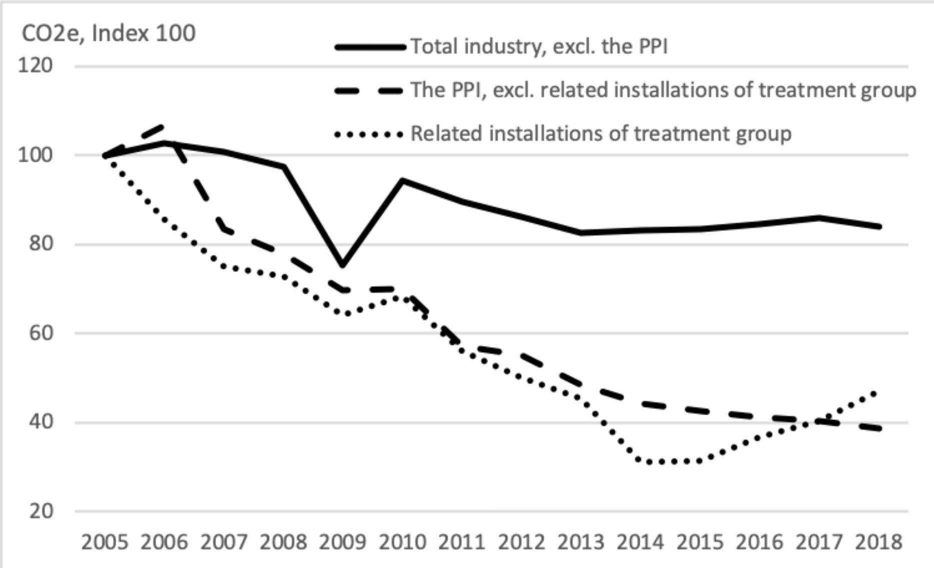

Figure 6*: Trend of emissions reduction after EU ETS implementation (Swedish EPA, n.d.a; n.d.b).*

Based on figure 6, it can be observed that relatively more emissions reduction has occurred in the PPI and in the related installations of the treatment group than it has in total industry, which happened concurrently with the EU ETS. However, whether the emissions reduction can be explained with the implementation of the EU ETS is another matter, which requires one to extend the time perspective to 1991. Since the related installations of the treatment group follows the same general trend as the broader PPI between 2005-2018, while accounting for around 44% of total emissions from the broader PPI (including printing works) in 2018 (Swedish EPA, n.d.a; n.d.b), it is assumed to encapsulate the general long-term trend of the treatment as well. This trend from 1991-2018 can therefore be observed in Figure 7 in relation to total industry.

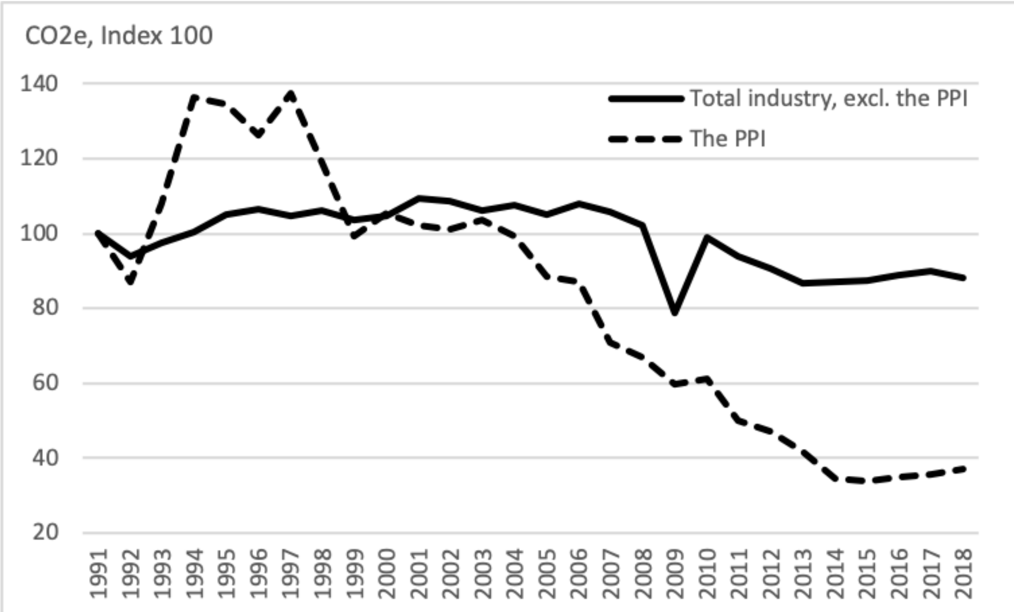

Figure 7: Trend of emissions reduction before and after EU ETS implementation (Swedish EPA, n.d.b).

Figure 7 provides a more accurate view of the long-term emissions reduction trend before and after the EU ETS was implemented. It can be observed that the largest relative increase of emissions occurred from 1992 to 1994, while the largest relative decrease occurred between 1997 and 1999. Despite that the reduction plateaued between 1999 to 2003, the overall trend of emissions trend since 1997 until 2014 appears to be fairly linear on average. Thus, it can be observed that the general emissions reduction of the PPI started eight years prior to the implementation of the EU ETS.

Assuming that a change in the relative price of CO2 is the main driver of economisation of carbon, an explanation to the weak positive association of the EU ETS could be that the price change had already been induced by something else. While it is beyond the scope of the study to *determine* what induced this, the increase in the oil price between 1998 to 2000 and/or the increase of the carbon tax rate from between 1996 and 1997 are two reasonable explanations based on theory. The previous research by Lundgren et al. (2015) is highly relevant here, as their study of the EU ETS and the Swedish Carbon Tax between 1998-2008 in the very case of the Swedish PPI found fossil fuel prices to have a significant impact on technical development, while it was only moderate for the two policies. Moreover, since the EU ETS would then turn out to have a generally low level of stringency and high level of grandfathering of EUAs, as the previous research suggests, a plausible explanation is that the relative price change of CO2 was not high enough, compared to the already high price, in order to create additional incentive to economise the use of CO2. Furthermore, since the oil price ($p = .211$) in the regression model was found to be a relatively stronger predictor of innovation than the Swedish Carbon Tax rate (p = .782), the price of the former appears to be the main explanation for the weak positive association.

Accordingly, the firms that are included in the regression model may have responded to primarily the oil price either through adoption of existing technology or innovation. It is important to note here that the innovation data that are studied in this thesis is unlikely to capture process innovations, as previously defined. Specifically, only three of the 36 innovations that were observed were defined as process innovations in SWINNO. Hence, an alternative explanation than what is offered by this study could be that the emissions reductions was enabled through in-house innovations. Having said that, it is still relevant to study the long-term innovation trend of the ones that were observed, primarily as these are of economic use and could therefore at least in theory have implications for economisations of CO2. The trend is illustrated in figure 8.

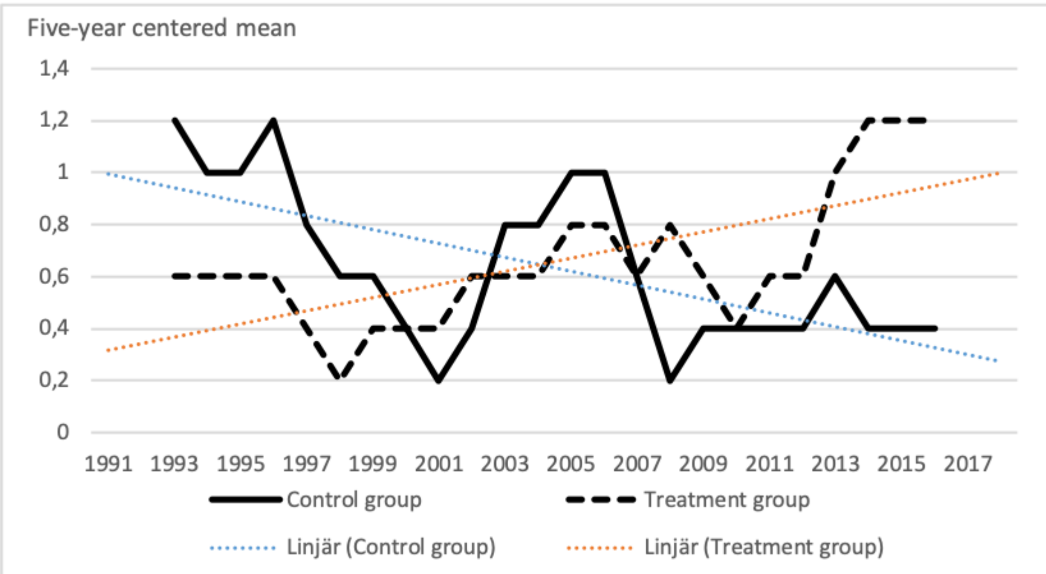

Figure 8: Long-term innovation trend (own dataset, based on Sjöö et al., 2014; Kander et al., 2019).

In the long-term innovation trend, it should first of all be noted that the level of innovation output between the two groups is not strictly comparable, as it does not include the control variables of the regression model, where firm size both in terms of revenue (*.088) and employees (**.027) were found to be significant predictors. Moreover, as this trend does not control for the carbon tax or the oil price, this trend does not isolate the association of the EU ETS in the same way as the regression model.

Figure 8 is, however, relevant for describing the trends that might be related to the explanation of the association that is proposed. The main aspect that can be observed is that the treatment group seems to have a positive linear innovation trend, while the control group appears to have a negative linear trend. This implies that their different paths meet right around the time the EU ETS was implemented in 2005. Based on the theoretical framework, this is slightly conflicting since the two groups received the same treatment in terms of the Swedish Carbon Tax while the same oil prices were applicable to their production processes. Thus, one would expect them to follow the same trends before the policy was implemented, after which the treatment group would diverge from the parallel trend as per the assumption made in the difference-in-differences method. A simple, potential explanation to this could be that the oil price was relatively more important of an input factor in the production process of the treatment group, hence causing it to economize it to a further extent through innovation. While this would be a reasonable contention based on the theory, empirically studying this is beyond the data access and scope of the study.

Furthermore, despite that the emissions reductions trend appear to have already been induced when the EU ETS was implemented, it has nonetheless reduced emissions fairly rapidly compared to the total industry. Thus, both because of the finding of a weak positive association of the EU ETS and innovation, as well as what could be interpreted as a weak positive innovation trend of the treatment group as seen in figure 8, this indicates that *adoption*, e.g. fuel-switching, and/or process innovations, have been more important responses to the changes in the relative price of CO2 over the time period. In turn, this could potentially explain the broader emissions reduction of the Swedish Pulp and Paper Industry between 1991-2018.

6 Conclusion

After constructing the dataset of regulated and unregulated firms of the PPI between 1991-2018, the thesis has found that the EU ETS have no association, or possibly a weak positive association with innovation in the Swedish PPI, in a statistically significant DiD regression model. Thus, the study has answered the research question and fulfilled the main aims of the study, while confirming the main findings of the previous research from a new light.

Moreover, the it is proposed that the association likely can be explained by the low additional price increase of emitting carbon dioxide for the pulp and paper firms after the EU ETS was implemented, compared to the price before. First, a relatively linear emissions reduction trend is observed between 1997-2014, implying that economisation of CO2 started eight years before and continued nine years after the EU ETS was implemented in 2005. Since considerable relative price increases occurred in proximity to the start of the negative emissions trend through the industry-specific Swedish Carbon Tax Rate and the oil price, it is proposed that this could explain the start of the economisation of CO2. As the price of CO2 would then be low after the EU ETS was implemented, due to a high level of grandfathering and lack of stringency, the additional price increase was likely too low to increase innovation. Instead, it is suggested that the overall economisation of CO2 in the Swedish PPI can be explained by adoption of existing technologies, and/or process innovations, which was captured to a low extent in the data of innovation.

6.1 Future research

Since this study likely was the hitherto first estimate of the impact of the EU ETS on innovation that uses LBIO data, there is arguably great scope for future research on the topic. Through refined and more advanced approaches to constructing the dataset needed, which were beyond the scope of the thesis, research that covers more industries than the Swedish PPI, such as Iron and Steel, Chemical Industries and Refineries, could be opened up. In turn, enabling a more robust and greater contribution of the ability of the policy at increasing innovation at a general level. Here, detailed data of innovating firms from the SWINNO database together with the data of regulated installations (see Swedish EPA, n.d.a) is useful.

What is more, since the dependent variable was based on the innovation count of the innovating firms with low values of the annual observations, more advanced statistical methods for dealing with this may be used for strengthening the empirical analysis. For example, a Poisson Regression might have been more suitable to this data (Lovett & Flowerdew, 1989), but ultimately beyond the scope of the thesis.

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Appendix A

***Table 9**: firms that did not meet the selection criteria*

No.	Literal name of firm as written in SWINNO	Qualitative motivation	Related criteria(s)
1	Rottneros Board ; Rottneros Board ; 8484002	Production at the installation, which is located in Vrena according to SWINNO, stopped in 1992 and moved to Bolivia the same year (TT, 1992).	B
2	LättPallen Sverige AB ; LättPallen Sverige ; 8889002	Founded in 1995 (LitePaq, n.d.).	B
3	Wellboard AB ; Wellboard ; 6544002 and Wellboard Scandinavia AB ; Wellboard Scandinavia ; 6578002	According to SWINNO, both are located in Söråker and due to the similarity of the names they are likely the same firms. The only information found states that "Wellboard in Sweden" was newly founded when it was published in 2003 (Sveriges Radio, 2003).	A, B
4	Addmarkable ; Addmarkable ; 8536002	Newly founded in 2005 (Edström, 2005).	B
5	Accon ; Accon ; 6360002	Registered in 2000 (Allabolag, 2022a)	B
6	Byggmatek ; Byggmatek ; 6564002	Subsidiary of BS Utveckling AB that was registered in 2006, the location (Mullsjö) matches with the one according to SWINNO (Allabolag, 2022b).	B
7	2 Stand ; 2 Stand ; 5001002	Subsidiary of X2 Nordic AB, which was registered in 2004, and is described as the part of the operation that sells advertising stands (Allabolag, 2022c). This matches with the description of the innovation in SWINNO as a Point-of-Purchase Display.	B
8	Design Force ; Design Force ; 8108002	Founded in 2002 where ReBoard was developed (Green Lite, 2018), which matches with the innovation name in Swedish according to SWINNO.	B
9	Organoclick ; Organoclick ; 8050002	Founded in 2006 (OrganoClick, 2022).	B
10	Anoto ; Anoto ; 10169002	Founded in 1996 (Anoto, 2022).	B
11	Whitelines ; Whitelines ; 10750002	Founded in 2006 (Whitelines, n.d.)	B
12	Aircontainer Package Systems ; Aircontainer Package Systems ; 10515002	Registred in 2006 and liquidated in 2020 (Allabolag, 2022d).	B
13	Peepoople ; Peepoople ; 11143002	Founded in 2006 and the description of the innovation as a type of toilet (Peepoople, n.d.), matches with the one in SWINNO.	B
14	Hysch ; Hysch ; 11103002	Recently founded in 2013 (Mittuniversitet, 2013), which was a collaborator of the innovation according to SWINNO.	B
15	Collimated Chipping Technology CCT AB ; Collimated Chipping Technology ; 11073002	Registered in 2010 (Allabolag 2022e), and the location Sundsvall matches with the one according to SWINNO.	B
16	Ifoodbag ; Ifoodbag ; 12751002	Founded in 2013 (Ifoodbag, 2022) and the description of the innovation as a type of cooling and packing solution matches with SWINNO.	B
17	SCA Display ; SCA Display ; 11446002	The location in SWINNO is Norrköping and no regulated installation could be identified there in Swedish EPA (n.d.a). No information was found to confirm that the firm existed over the time period.	B, D