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The Porter Hypothesis: Fact or Myth? - A Case Study on the EU Emissions Trading System.

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ABSTRACT

This study investigates the Porter Hypothesis in the context of the EU Emissions Trading System (EU ETS), the world's largest cap-and-trade system within environmental regulations. The Porter Hypothesis posits that environmental regulations can stimulate eco-innovation and ultimately improve the financial performance of regulated firms. To estimate the causal effects of the EU ETS on eco-innovation and firm performance, this study employs a matched Difference-in-Difference and mediation analysis. Through Propensity Score Matching, the study matches firms subject to regulation with statistically comparable non-regulated firms. The results provide support for the Weak form of the Porter Hypothesis, indicating that the EU ETS has induced eco-innovation among regulated firms. The EU ETS framework, which progressively increases in stringency across phases, has further facilitated the increased green technology innovation for all firms in regulated sectors. However, similar to previous studies on the Strong variant of the Porter Hypothesis, this study does not find support for regulation having an impact on firm performance. This thesis finds that the conditions required for the Strong variant to hold are perhaps outdated, and therefore concludes it is time to debunk this strand. Furthermore, the study provides important implications for EU policymakers concerning the prices in the carbon market and the future of the EU ETS. Overall, this study sheds light on the efficacy of the EU ETS in promoting eco-innovation and environmental regulation's role in firm performance.

Keywords: Cap-and-trade, Eco-innovation, Eco-patents, Environmental policy, EU ETS, Firm performance, Difference-in-Difference, Policy implications, Porter Hypothesis, Propensity Score Matching
JEL: E61, L51, Q50, Q54, Q55, Q56, Q58

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Key Abbreviations

EU ETS	=	European Union Emissions Trading System
EUA	=	European Union Allowances
EUTL	=	European Union Transaction Log
ERU	=	Emission Reduction Units
US SDP	=	United States Sulphur Dioxide Program
PH	=	Porter Hypothesis
PWH	=	Porter's Weak Hypothesis
PSH	=	Porter's Strong Hypothesis
DID	=	Difference-in-Differences
GLS	=	Generalized Least Squares
PSM	=	Propensity Score Matching
MAC	=	Marginal Abatement Cost
MB	=	Marginal Benefit
OHA	=	Operator Holding Account
PHA	=	Person Holding Account
R&D	=	Research and Development
ROA	=	Return on Assets
$\mathbf{CO_2}$	=	Carbon Dioxide
GHG	=	Greenhouse Gases

1 Introduction

Combating anthropogenic climate change is one of the world's most pressing issues. In 2020, the atmospheric temperature of Earth was the highest in history, and since 2005 carbon dioxide (CO_2) levels have increased by 30% (NASA, 2023). To mitigate the catastrophic damage that has befallen our planet, it is imperative that we assume responsibility for restoring global temperatures. Achieving this objective requires concerted collaborative efforts.

The 1998 Kyoto Protocol marked the first multinational endeavor to address climate change, whereby it established Greenhouse Gas (GHG) emission targets for industrialized countries (United-Nations, 1998). Subsequently, European Union (EU) launched the EU Emission Trading System (EU ETS) in 2005 with the goal of reaching carbon neutrality by 2050. Despite over 15 years having elapsed since its inception, the EU ETS remains the world's largest emission trading system and marks a cornerstone in environmental policy. Its efficacy is evident in the reduction of 42.8% in GHG emissions across ten broad industry sectors. The EU ETS currently covers close to half of the GHG emissions in the EU, encompassing significant gasses such as CO_2, nitrous oxide, and perfluorocarbons (Dechezleprêtre et al., 2018).

This thesis aims to assess the validity of the environmental policy theory known as the 'Porter Hypothesis' through an ex-post evaluation of the completed phases of the EU ETS. The Porter Hypothesis has been discussed extensively in previous literature relating to many types of environmental policy, though limited in cap-and-trade systems. Its coverage in EU ETS literature has been scarce, as researchers have not concretely connected the two areas of interest. The Porter Hypothesis encompasses three components, of which this paper will focus on two; namely the 'Weak' and 'Strong' variations. The Weak variant centers around increased innovation into carbon-reducing technology once firms become regulated. The Strong variant builds on this, by linking higher levels of innovation to enhanced firm performance in the long run. Considering the lack of consensus in prior research on the applicability of the Porter Hypothesis in earlier phases of the EU ETS, this paper seeks to undertake a comprehensive evaluation to establish whether the theory truly holds. The paper begins with a contextualization of the cap-and-trade policy framework, followed by an exposition of the two Porter Hypothesis strands that are in focus. The study proceeds to review previous literature, with the intention of highlighting gaps in current knowledge. Drawing upon the EU ETS as evidence for the paper, the research design will be presented, connecting the EU ETS to the conditions required for the Porter Hypothesis to hold. Four hypotheses will be laid out with the aim of contributing to the resolution of the main research question which seeks to investigate;

Is it time to debunk the Porter Hypothesis?
Can environmental policy really induce innovation and enhance firm performance?

Data has been gathered for the entirety of the EU ETS, though the emphasis will be on investigating the impact of Phase III, as it has not been extensively covered in previous literature. This paper utilizes Propensity Score Matching, allowing for regulated and non-regulated firms operating in the same industry, with similar characteristics, to be matched. From there, Difference-in-Difference and mediation analysis are used to determine causality. Our findings corroborate Porter's Weak Hypothesis, where eco-innovation has exhibited an upward trajectory since the EU ETS's implementation. Additionally, we find non-regulated firms are changing their innovation behavior, indicating there are spillover effects of the EU ETS. However, this thesis does not ascertain evidence relating to Porter's Strong Hypothesis, as no notable gains in firm performance could be concluded. The paper subsequently delves into the discussion of the results obtained, in the context of the Porter Hypothesis and the EU ETS. Additionally, the future of the EU ETS is discussed more generally, where policy implications and suggestions are made. Finally, limitations of this study and further research opportunities are presented prior to the concluding remarks.

2 Background

To examine the efficacy of the EU ETS with respect to the Porter Hypothesis (PH), it is first necessary to have an understanding of the mechanisms involved in the environmental policy that is being investigated, and its implementation and application within the EU. Therefore, this section provides an overview of what a cap-and-trade system is and provides a brief historical background of the EU ETS.

2.1 Environmental Regulation: Cap-and-Trade Systems

The cap-and-trade system[1] is an environmental policy involving two mechanisms working simultaneously together to reach an economic efficiency that would not have been possible with a conventional command-and-control policy.[2] Cap-and-trade is a market-oriented policy that leverages market forces to establish a carbon price, thereby driving investment decisions and innovation into carbon-mitigating technologies.[3] In the cap-and-trade system, the governing body sets a limit on the volume of emissions each year, which regulated firms must abide by. Firms can then choose whether they eco-innovate or procure emission allowances in order to meet the emission requirement. In this way, firms that have reduced their GHG emissions can sell excess allowances to firms emitting over their allocated allowance, creating a market for emission rights. This cap-and-trade system is depicted in Figure 1.

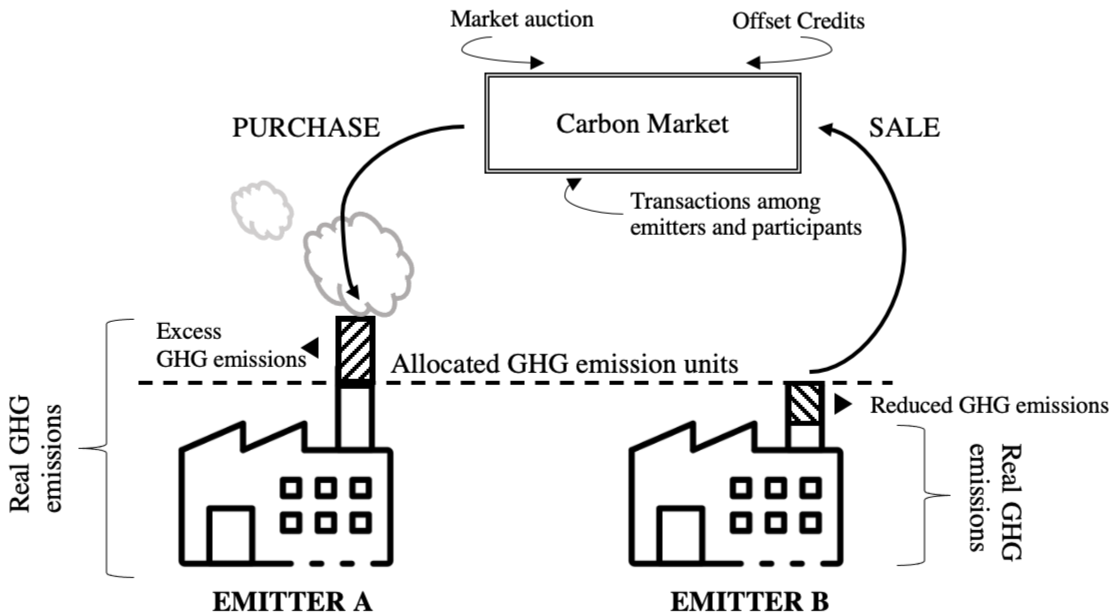

Figure 1: Cap-and-Trade Framework
Source: Authors' illustration

The underlying theory behind a cap-and-trade system helping to facilitate the lowest cost of abatement,[4] relies on the Coase Theorem. Coase (1960) argued that if property rights are clearly defined and transferable, the market [for emission rights] will set a price that creates a Pareto efficiency.[5] Therefore, an equilibrium is reached, whereby firms can buy and sell emission rights to one another whilst lowering

[1] "A system for controlling carbon emissions and other forms of pollution by setting a limit on the amount any business or organization may produce while allowing them to buy extra capacity from other organizations which have not used their full limit" (Oxford-Dictionary, 2023).

[2] "A government-based policy requiring polluters to meet specific emission-reduction targets and often requires the installation and use of specific types of equipment to reduce emissions" (European-Environmental-Agency, 2023).

[3] Referred to as eco-innovation in this paper.

[4] "The cost of securing a reduction in pollution. The abatement cost is the cost per unit or the total cost of achieving a given target" (Oxford-Reference, 2023a).

[5] "A situation where no further improvements to society's well-being can be made through a reallocation of resources that makes at least one person better off without making someone else worse off" (Science-Direct, 2023).

total emissions in the atmosphere.

Cap-and-trade systems are considered more effective than classical command-and-control policies because they incentivize firms to continuously eco-innovate. Once a command-and-control regulation is implemented, there is no additional benefit to a firm that has eco-innovated as there lacks a reward for exceeding the regulated emission standard. Furthermore, since there is no ongoing incentive to invest, command-and-control policies are more likely to yield inverse and unintended consequences (Nerudová and Dobranschi, 2016). An example of this would be if a large firm chooses to emit beyond its allowance because they realize paying fines for over-emitting are less costly than investing in changing its processes. Therefore, firms do not always internalize externalities. As a result, GHG emissions are not reduced to the intended extent, demonstrating the need for intervention that does not involve a government estimating the social cost of carbon. It is often difficult for policymakers to set a price that corresponds to the desired abatement, and therefore government failure is not a seldom occurrence.

On the contrary, cap-and-trade systems continuously incentivize firms because lower emissions levels lead to a smaller financial burden, as fewer emission allowances need to be procured. Additionally, firms will continue to invest in new technologies until their Marginal Abatement Cost (MAC) is equal to the Marginal Benefit (MB) of polluting (Kesicki and Strachan, 2011). This is the point MAC = MB, where an individual firm equilibrium is reached. Since firms are heterogeneous, the MAC is unique, creating a market for emission allowances that can be traded until a general equilibrium is reached. Therefore, a cap-and-trade system allows firms to adopt a degree of flexibility, as those who eco-innovate have the choice to continue their endeavors and later trade their emission allowances to firms who emit beyond their current allowance. The decision of whether to become a buyer or seller of allowances is dependent on the individual firm's level of internal capabilities and their MAC (Hintermann et al., 2016). Thus, since the market is driven by firms' choices (affecting the demand and supply of emission allowances), the price of the emission allowances plays a pivotal role in ensuring the cap-and-trade system works effectively.

2.2 The EU ETS

The European Commission adopted a definitive position concerning the implementation of an appropriate policy framework. From the start, they aspired to "reduce GHG emissions while producing the least overall costs to participants and the economy as a whole" (EU-Parliament, 2019).

The EU ETS is not a pioneering cap-and-trade system, and there have been other systems implemented, although on a smaller scale (Hintermann et al., 2020). One of the first larger-scale cap-and-trade policies was the US Sulphur Dioxide Programme (US SDP) which was incorporated into the 1990 Clean Air Act. The outcomes demonstrated success in reducing the pH level in acid rain as emissions had been restricted by 43% by 2007, despite increased utilization of power plants (Chan et al., 2012). Although the EU ETS will be the case study of this thesis, we must acknowledge that its incorporation and framework have been developed based on the original US SDP.

As mentioned, the demand for emission allowances in any cap-and-trade system is derived from individual firms' current level of emissions and their MAC. However, there are various factors affecting the supply of EU Allowances (EUA) in the EU ETS carbon market;[6] the two primary drivers are the number of free allowances initially allocated, and the use of carbon offsets. Offsets are international credits that work as financial instruments denoting the removal of one tonne of CO_2 from the atmosphere as a result of another certified emissions reduction project that falls outside of the EU ETS scope (EU-Commission, 2023f).[7] Offsets facilitate flexibility in the EU ETS as firms can choose in what sectors and geographical jurisdictions they wish to reduce their emissions. Thus, a firm that also has operations outside of the EU can choose to reduce carbon emissions where their MAC is the lowest, and later use these credits as Emission Reduction Units (ERU) (Tietenberg, 2010). However, this raises concerns about

[6] Other than the selling of emission allowances from a firm that has eco-innovated to one that has not.

[7] Projects qualifying for EU ETS offsets are those generated from two mechanisms in the Kyoto Protocol, namely the Clean Development Mechanism and the Joint Implementation project (EU-Commission, 2023f).

the environmental integrity of some projects as firms may attempt to circumvent the system. In response, Phase III imposed a quantitative limit of 50% ERU allowance yearly. In addition, the usage of offsets leads to an influx of EUA supply, since they are supplementary to the initial allocation allowance set out by the EU (Perman et al., 2003). Thus, offsets play a salient role in determining the market price, as an increase in supply ultimately pushes the price downwards. A lower price poses a threat to the EU ETS as it reduces the incentives for firms to eco-innovate because the action of purchasing allowances becomes less financially burdensome (Joltreau and Sommerfeld, 2019).

Carbon leakage is another threat to the EU ETS, where firms relocate their entire production to a geographical jurisdiction with less stringent emission regulations, due to fears of losing competitiveness (EU-Commission, 2023b). To mitigate this, the EU has permitted 'special treatment' to industries that are at high risk of carbon leakage, usually those in energy-intensive sectors. In this way, international competitiveness is safeguarded as firms receive a higher share of free allowances. However, the EU must be conservative as an oversupply of free allowances creates an opportunity for firms to sell any excess on the market leading to windfall profits, market arbitrage, and additional supply influx (Sijm et al., 2006). Thus, the initial allowances and use of offsets play a key role in the configuration of the supply in the EU ETS carbon market.

2.2.1 The EU ETS Design: Increasing Stringency Across Phases

As aforementioned, the ultimate goal of the EU ETS is to limit GHG emissions by implementing an annual cap (EU-Commission, 2005). For this to be sustainable, the EU laid out four phases that tighten the cap periodically between 2005-2030, enabling regulated installations to gradually adapt to the more stringent regulations. Instantly setting a stringent emissions cap would not be feasible, as firms would not have the ability to adhere to the policy - rendering the EU ETS redundant. Hence, the EU ETS incentivizes firms to engage in eco-innovation as non-compliance yields substantial fines.

It is worth noting that the regulation criteria occur at an installation level and not at the firm level. Regulation is managed through the Operating Holding Account (OHA), whereby a single firm can own several OHAs. Every regulated installation requires an OHA, as emission data and EUAs are logged via this account (EU-Commission, 2023d). This means that it is possible to detangle firms with similar characteristics, such as output potential, as some firms may oversee installations that qualify to become OHAs, whilst others do not. An example would be two power stations both operating in a EU27 country with the same total emissions, where 'Firm 1' has one large installation, and 'Firm 2' has several small installations. If Firm 1's installation exceeds a thermal input of 20 Megawatts (MW), it qualifies as regulated and is required to have an OHA, whereas Firm 2's smaller installations only have a thermal input of 5MW meaning they do not qualify. Therefore, despite Firm 1 and 2 having the same output capacity, only Firm 1 is regulated. An overview of the four phases is available in Table 1.[8]

[8] An elaboration based on the explanation provided by the EU-Commission (2015), can be found in Appendix A.

Table 1: Phases of the EU ETS

Source: Data retrieved from EU-Commission (2023)

	Phase I (2005-2007)	**Phase II (2008-2012)**	**Phase III (2013-2020)**	**Phase IV (2021-2030)**
Geography	EU27	As Phase I &: Norway, Iceland, Lichtenstein	As Phase II &: Croatia	As Phase III
Regulated installation types	Power stations & combustion plants with thermal input of > 20 MW p.a. Oil refineries, Coke ovens, Iron and steel plants with production capacity of >2.5 t per hour, Cement clinker, Glass with melting capacity of >20t daily, Lime, Bricks, Pulp, Paper and board	As Phase I &: Aviation (from 2012)	As Phase II &: Aluminum Petrochemicals Ammonia Nitric, acid, and glyoxylic acid production Carbon capture, transport in pipelines, and geological storage of CO_2	As Phase III
GHGs	CO_2	CO_2, N_2O (via opt-in)	CO_2, N_2O, PFC	As Phase III
Cap	2,058 mtCO_2	1,859 mtCO_2	2,084 mtCO_2 in 2013, decreasing linearly by 1.74% p.a.	1,858 mtCO_2 in 2018, decreasing linearly by 2.20% p.a.
Trading units	EUAs	EUAs, ERUs	All units must be converted into EUAs first	As Phase III
Fine	€40 per tCO_2	€100 per tCO_2	As Phase II	As Phase III

3 Theoretical Framework: The Porter Hypothesis

The traditional perspective among many economists concerning environmental regulation is that it may erode firm competitiveness since it imposes additional costs for firms (Nordhaus, 2007). Regulations pressure firms to divert factors of production (labor and capital) into reducing emissions, which from a profit-maximizing perspective, is unproductive. This view was challenged by Porter (1991) and together, Porter and Van der Linde (1995) formed the PH nearly three decades ago. Porter and Van der Linde (1995) have not developed a standard test to verify whether their hypothesis holds. Instead, they suggest drawing on environmental policy case studies to enhance the validity of the theory.

The PH is an adaptation of the Induced Innovation Hypothesis which was proposed by Hicks (1963). Hicks claimed an increase in real wages would stimulate firms to find alternative ways to cut their costs, specifically in the form of innovation, to enable operations to become more cost-efficient (Funk, 2002). Ceteris paribus, the theory states if one factor of production increases in price relative to others, innovation will prevail so that the increase in cost to the firm goes unnoticed. Porter and Van der Linde (1995) extended this theory by isolating the exogenous factor of environmental policy which could spur innovation.

Porter and Van der Linde (1995) argue that a stringent and well-designed environmental policy can "trigger innovation that may partially or more than fully offset the costs of complying with them". This can occur because the theoretical foundation of the PH is underpinned by the implicit assumption that pollution is a waste of resources, and therefore removing it could lead to productivity gains (Brännlund et al., 2009). Pollution is seen as an external cost, and although inevitable when producing a particular good, abating a larger proportion of pollution means that fewer resources dissipate into the atmosphere. Thus, by eliminating pollution, fewer resources are lost and can instead be used in operations elsewhere, leading to larger output in the long run. This suggests that environmental policy and economic growth go hand-in-hand, meaning there is no trade-off between the two.

Using the PH as an environmental policy tool and theoretical foundation for this paper, we evaluate the extent to which the EU ETS, particularly Phase III, promotes eco-innovation and enhances firm performance. Specifically, this paper focuses on two distinct variations of the PH,[9] namely the 'Weak' and 'Strong' forms.[10]

The first strand is Porter's Weak Hypothesis (PWH) which has a wide scope, suggesting that environmental regulation will induce certain types of eco-innovations, although it is not specified whether the rate or direction of the eco-innovation is socially beneficial (Yuan and Zhang, 2017). It does not indicate whether the innovation is helpful or detrimental to firms choosing to eco-innovate, it merely states that regulated firms will see a greater number of eco-innovations.

The second strand, Porter's Strong Hypothesis (PSH), posits that with a clearly designed policy, the induced innovation will compensate for the cost of compliance (Yuan and Zhang, 2017). This means that eco-innovation can offset the initial cost of complying with the regulation, thereby increasing firm competitiveness. This builds on PWH by adding the positive direction by including enhanced firm performance (Ambec et al., 2013).

Figure 2 presents a graphical representation of the Porter Hypothesis.

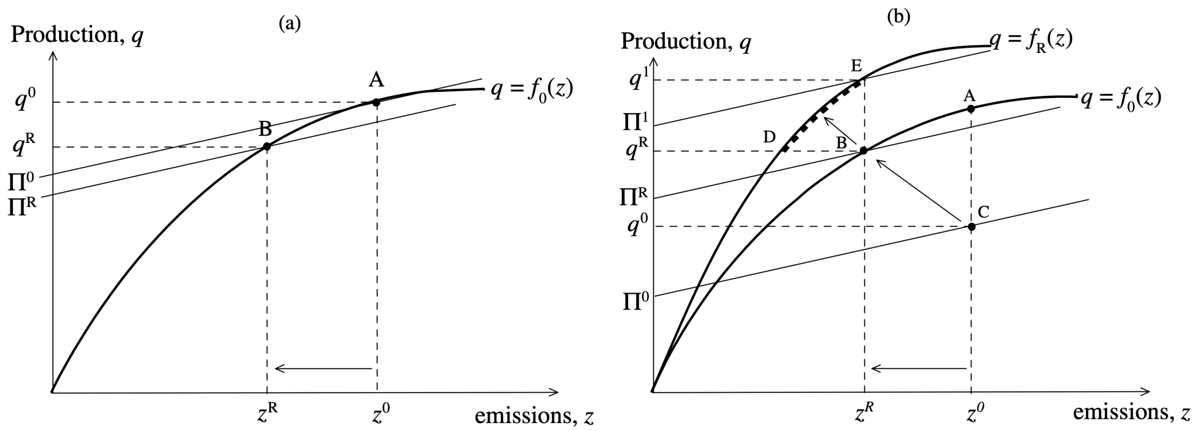

Figure 2: Graphical Representation of the Porter Hypothesis
Source: Brännlund et al. (2009)

Figure 2(a) illustrates the conventional view of an environmental policy. For simplicity, it is assumed that a good, q, is produced using only one factor of production which yields emissions of a pollutant, z. This indicates that there is a 1:1 relationship[11] between production and pollution, where an increase in production of good q leads to an increase of pollutant z. The production function f*(z)* depicts this relationship, where $f_0(z)$ represents the level of technology present at pre-regulation. This means that a profit-maximizing firm prior to being regulated will produce q^0 units, leading to emissions of z^0. Once an emission cap of z^R is imposed, the firm is forced to lower its output to q^R. We further see that profits

[9]There are three variations of the Porter Hypothesis which are; Weak, Strong, and Narrow. The Narrow form is not discussed in this paper but refers to flexible environmental policies being better than prescriptive policies with regards to innovation incentives (Ambec et al., 2013).
[10]See Appendix C for Porter Hypothesis flowchart.
[11]Assuming that firms operate on the production possibility frontier.

fall from π^O to π^R. This scenario allows for non-regulated firms to face higher competitiveness and reap larger profits.

Figure 2(b) illustrates the effects that arise as a result of the PH. As mentioned, Porter (1991) regards pollution as a waste of resources and is, therefore, an inefficiency. Thus, regulation will highlight a firm's level of emissions and thus its inefficiencies. To graphically demonstrate this inefficiency, one can assume that these firms are not operating on the Production Possibility Frontier (PPF), point C. Implementing the same emission regulation of z^0 to z^R allows firms to shift production to point B which lies on the PPF. Once operating on the PPF, inefficiencies are 'neutralized' which allows output to increase from q^0 to q^R, profits to increase from π^0 to π^R, and emissions are simultaneously reduced. The figure also depicts the "dynamic" effect that environmental policies carry, by shifting the PPF outwards further to $f_R(z)$, representing new technology. Profits are then maximized at point E, π^1, once prices have stabilized in the market. Thus, from this depiction, one can understand how the PH is implemented and leads to greater profits, given the assumption that pollution is a waste of resources.

However, this graphical depiction implicitly assumes that moving onto the PPF (from point C to B) comes without costs, and the reason for operating at point C is solely due to resource waste (Brännlund et al., 2009). Nonetheless, there could be several reasons why a firm would not be producing as efficiently as economically desired, which do not necessarily involve pollution, but could rather be attributed to a possible misallocation of factors of production.

4 Literature Review

The EU ETS has generated strong interest from researchers who have comprehensively investigated its short- and long-run effects, and this section will further connect previous findings to the PH. In this literature review, we will consider the two distinct strands of the PH and relate them to the efficacy of the EU ETS.[12]

When transitioning between phases, thereby adjusting the emissions cap, short-run effects are characterized by eco-innovation and are consistent with PWH. Conversely, long-run effects pertain to international competitiveness and firm performance which only materialize after eco-innovations have occurred, or after sufficient time has elapsed allowing firms to adapt and adhere to the policy. This aligns with PSH and is why literature in this field can be connected to this strand.

Therefore, in this section, relevant research conducted on the economic effects of the EU ETS will be presented, with the intention to investigate the potential gap in the current state of knowledge and identify any areas for development.

4.1 Short-run Effects of the EU ETS on Eco-Innovation

The first strand analyzes factors that spur eco-innovation, more specifically - how central the role of an environmental policy plays when firms choose to eco-innovate. Studies aim to disentangle the multiple layers of environmental policy that individual countries and regions are subject to and isolate the effect of the EU ETS.

Assessing the impact of the EU ETS on investment decisions has proven to be a challenging task. Studies that rely on surveys and interviews as their primary data reveal that eco-innovation is not driven by environmental policy, but rather by managerial decision-making. Therefore, a large proportion of literature finds a lack of causality in the relationship between the EU ETS implementation and eco-innovation. For example, Rogge and Hoffmann (2010) found that due to the oversupply of free EUAs in the early phases of the EU ETS, innovation into reducing CO_2 was limited. The study was carried out at the time of the global financial crisis and indicated that carbon abatement was a low priority in

[12] It should be noted that, for the purpose of this study, we are not considering the primary objective of reducing GHG emissions in the atmosphere when discussing efficacy.

the timeframe investigated. Although findings show no support for PWH, Rogge and Hoffmann (2010) acknowledge that the exogenous shock to the economy most likely shifted the agendas and priorities of many firms, leaving eco-innovation at the bottom of the list.

A similar empirical approach had previously been researched by Hoffmann (2007) where a survey was conducted to investigate corporate investment decisions. Results showed that firms were integrating carbon costs into investment decisions, indicating that companies were becoming more conscious of the social cost of carbon (Porter, 1991). The study showed that for small-scale investments with short amortization durations, the EU ETS was a significant driver. However, no evidence was found for large-scale investment decisions. The findings emphasize Phase I serving as a pilot phase as it appears the phase was most effective in raising awareness rather than changing firms' behavior, despite ∼11,000 installations being regulated. Therefore, again, there was no evidence found to endorse PWH.

A later study conducted by Martin et al. (2013) looked into innovation by investigating research and development (R&D) activity aimed at curbing emissions for 770 manufacturing firms operating in six EU countries. The study differentiates product and process innovation, and findings suggested that there was no statistical significance between regulated and non-regulated firms in product innovation, but there was a slightly positive significant effect in process innovation - therefore supporting PWH. Further results indicated a correlation between the expected increased stringency of Phase III in the EU ETS and higher levels of engagement in R&D activities. This is an interesting finding for this thesis, as it suggests that significant results might be evident after an analysis of Phase III is carried out.

During the same time period, Löfgren et al. (2013) attempted to isolate the EU ETS from the high carbon tax present in Sweden by using firm-level data to conduct an ex-post evaluation on both small and large investment decisions. Proceeding with a Difference-in-Difference (DID) estimation, there was no significant effect found on a firm's decision to eco-innovate. Nonetheless, the study does not dismiss either the EU ETS or the PH. Instead, it encourages research to be carried out at a later stage, allowing for the evaluation of potential long-run effects. This concluding remark is of particular interest to this thesis, as over 15 years have now passed since Phase I, thereby expanding the availability of data. Consequently, despite innovation being regarded as a short-term effect of the EU ETS, results may become more apparent when observing how firms have evolved during their regulated tenure.

One study that does encompass a longer timeline is by Calel and Dechezleprêtre (2016), which analyzes the number of low-carbon patents that emerge as a result of the EU ETS. Patents provide a useful proxy for technological innovation at a disaggregated level, and have been used in other studies by Popp (2002, 2006) and Johnstone et al. (2010). The study finds significant evidence that regulated installations saw 36% higher patent filings over the period 2005-2009, suggesting that induced innovation does occur. Therefore, despite the paper accrediting part of this large effect on oil prices over the time period investigated, evidence is found for PWH. To find this causal effect, Calel and Dechezleprêtre (2016) used Propensity Score Matching (PSM) on firms to ensure that prior to the EU ETS implementation, the two subsets of firms were comparable. They go on to find significant results when running a DID analysis, where the majority of patents were filed in the first five years of the EU ETS. Calel and Dechezleprêtre's (2016) study is used as a baseline for this thesis, as we aim to use a similar empirical methodology to isolate a causal effect.

Although studies are limited to the first two phases of the EU ETS, the evidence presented is a 'mixed bag', with findings often accrediting other exogenous factors having a larger impact on innovation than the EU ETS itself. However, there is a clear gap that exists; namely, whether regulated firms will continue to innovate at a similar rate to previous phases despite increasing stringency, or if non-regulated firms will now play 'catch-up'. Given the mixed support for PWH, this study seeks to investigate whether Phase III of the EU ETS yields more definitive outcomes.

4.2 Long-run Effects of the EU ETS on Firm Competitiveness

The second strand of research investigates if there is a competitive advantage for regulated firms in the EU ETS. Studies assessing the long-run competitiveness of regulated firms differ significantly depending on what variables are used for measuring economic performance and competitiveness. Therefore, varied evidence is presented when assessing whether PSH holds.

When investigating the employment effects of being regulated, Wagner et al. (2014) used panel data on manufacturing plants in France to construct a semi-parametric DID approach. Results indicated a 7% reduction in employment for regulated firms in Phase II. These findings suggest that firms are pressured to reduce labor costs to offset the expenses of transitioning to cleaner production processes, resulting in a decrease in firm performance and evidence to reject PSH. However, since Wagner et al. (2014) only looks at employment rates, it is not explicit whether firm competitiveness is affected. On the one hand, lower employment within manufacturing might lead to lower output potential. On the other hand, manufacturing is capital intensive, therefore measures enforced to comply with the regulations may have streamlined the production process.

Using a different empirical method, focusing on turnover and also employment, Anger and Oberndorfer (2008) research the German manufacturing sector. Following Balassa (1964), they define firm competitiveness as one's ability "to sell on foreign and domestic markets". The study uses an instrumental variable technique, however, does not find significant effects on firm performance being affected by the EU ETS. Given that this study was conducted not long after Phase I, the lack of findings regarding competitiveness is not unexpected as the impact may take several years to materialize after policy implementation. Moreover, the distribution of free allowances and low initial cap could have played a pivotal role in why revenues were not different between the two groups of firms (Anger and Oberndorfer, 2008).

Turning to cross-country studies, Abrell et al. (2011) finds, again, that the effects on competitiveness are negligible. Using financial data from over 2,000 firms, a matched dataset was constructed using PSM. Studying the time period 2004-2008 would show the immediate effects of the EU ETS implementation, however, they suggest a longer time period would perhaps highlight significant results as market auctioning of EUAs could yield higher financial performance (Abrell et al., 2011). The use of PSM is a well-established method for creating a comparable dataset and was also seen in the study by Calel and Dechezleprêtre (2016).

Investigating the EU ETS at a similar time period, Chan et al. (2013) analyzed a sample of firms operating in the power, cement, iron, and steel industries during the years 2001-2009. Using firm data from four years prior to the EU ETS implementation allowed the study to isolate a statistically significant impact in the power sector, where material costs increased by 5-8% during the first two phases, and turnover increased by 30% in Phase II. This study, contrary to any others mentioned, was able to find support for PSH, although only present in one sector.

In a similar approach, Marin et al. (2018) investigated the economic performance of firms with the null hypothesis that regulated firms would be negatively affected. They used several indicators including labor productivity and total factor productivity, two measures not seen in other previous literature. Rejecting their null hypothesis, results indicated no statistical difference between the two groups of firms. They also found that regulated firms reacted to the policy by passing on any costs incurred to their consumers whilst also increasing labor productivity. The time period investigated by Marin et al. (2018) is later than previous studies, and looks into the beginnings of Phase III. Although evidence to support PSH was not found, this is one of the few studies that have studied a timeline after 2012.

Thus, ex-post literature is heavily covered for Phase I and II on firm-level effects, though there have been few studies on the impact of Phase III. Furthermore, although there is limited statistical evidence that firm performance increases from regulation in the EU ETS, results obtained do not indicate a worsening of competitive position. A significant reduction in firm competitiveness would result in higher levels of carbon leakage and adverse emission effects. In this way, not finding evidence does not damage the primary goal of the EU ETS. Nevertheless, PSH has only found support in a small proportion of empirical literature. Thus, an investigation into Phase III of the EU ETS suggests, based on previous literature, firms have had sufficient time to adapt and internalize the costs of regulation into their operations - thereby potentially yielding productivity gains that are now observable.

5 Research Design

It has become apparent that the PH has not been extensively researched in the context of the EU ETS. Although a plethora of research on the EU ETS exists, there are few studies making a concrete linkage between the policy introduction and the PH. Moreover, the results around EU ETS efficacy relating to the two strands of the PH are mixed and there is no universal consensus. Furthermore, whilst the idea of eco-innovation from general environmental policies is in abundance and the phenomenon of the impact on firm performance is widely debated, there is a deficiency in analyzing the most recent phase of the EU ETS.

The objective of this section is to precisely define our research question and explain the knowledge gap we aim to fill. Finally, we present the four hypotheses investigated in this thesis.

5.1 Purpose, Contribution and Research Question

The literature review presented two significant gaps in the literature relating to the validity of the PH and the coverage of the third phase in the EU ETS. The purpose of this thesis is to address these gaps with the additional data now at hand. The first objective is to reduce the ambiguity surrounding the PH. The PH serves as the theoretical foundation for this thesis, and diving deeper into the two strands will shed more light on its validity. Secondly, this study endeavors to take a closer look into Phase III of the EU ETS, by adding to literature that exists on the previous phases.

In the choice of empirical methodology, this thesis makes contributions by analyzing a dataset that has not been previously examined. This study has chosen to construct a new dataset that follows a subset of firms over time. Since the EU ETS is now in the fourth phase, data encompassing the entirety of Phase III has become available. Although our analysis will focus on two aspects of firm behavior,[13] contributions are made as this dataset can be utilized using other variables if further research on Phase III is carried out.

Furthermore, we make general contributions that can be of benefit to a variety of stakeholders involved in the EU ETS. Firstly, investigating whether the EU ETS has had an effect on eco-innovation provides key information to policymakers on whether adjustments are necessary. Evaluating the effect of how stringency affects firms' decisions to eco-innovate, could also assist policymakers in determining structures and frameworks of future environmental regulations. Secondly, investigating whether regulated firms' financial performance changes is crucial information to uncover. The threat of carbon leakage resulting from a deterioration in firm competitiveness undermines the overarching objective of reducing emissions. Therefore contributing to the literature and relaying our findings, we aim to increase transparency to both policymakers and firms within the scope of the EU ETS.

As a result, the main research question this study hopes to answer is:

Is it time to debunk the Porter Hypothesis?
Can environmental policy really induce innovation and enhance firm performance?

In order to answer this question, this thesis lays out the conditions required for the PH to hold in theory, and evaluates them in the context of the EU ETS. We will begin by investigating PWH wherein two hypotheses are presented relating to eco-innovation. Thereafter, PSH is examined whereby an additional

[13] Investment behavior in the form of eco-innovation, and firm performance.

two hypotheses are laid out relating to firm performance. Our aim is for the four subordinate questions to serve as a means of addressing the main research question effectively.

5.2 The EU ETS and Porter's Weak Hypothesis

The PH can be tested on any environmental policy, though its coverage on cap-and-trade systems is scarce. There is, however, partial evidence of PWH in the initial US SDP (Popp, 2003). Even so, Popp (2003) finds that the spur of innovation, through increased patents, was a one-time event that occurred directly after policy introduction - rather than a continuous pattern over the regulated time period (Taylor et al., 2005).

In contrast to the US SDP, the EU ETS encompasses more suitable characteristics that Porter and Van der Linde (1995) argue are required for the PH to hold. There are three core principles that are necessary; flexibility, promoting continuous improvement, and ensuring transparency leading to regulatory certainty.

The first principle, flexibility, is fulfilled by the general cap-and-trade mechanism. The market-based policy fosters flexibility as firms have heterogeneous MACs, which renders them the economic choice of whether to innovate or to buy EUAs. With stringency increasing over time, the cap is tightened meaning the option to buy allowances becomes increasingly costly. In this way, firms have a higher incentive to innovate (Porter and Van der Linde, 1995; Ambec et al., 2013).

The second principle, continuous improvement, should (in theory) be promoted by any cap-and-trade system, although evidently, it was not observed in the US SDP. The EU ETS differentiates itself from the US SDP because there is a higher degree of eco-innovation freedom, and its clearly defined framework with progressively increasing stringency encourages continuity in eco-innovations. Regulated firms in the EU ETS are not required to innovate into a specific type of carbon-reducing technology, rather they are instigated to find several pathways to reduce emissions. This gives firms creative freedom when innovating and stimulates continuous endeavors as there is no "one correct technology". Therefore, once a firm has found a potential solution, the incentive to continue eco-innovating remains as there could be other technologies that have higher cost-saving and productivity outcomes.

The third principle considers the certainty of a policy. Regulated firms require a high level of security regarding the implementation phases and the timeline. This principle is dependent on the governing body's approach of reassuring firms operating within the scope. The EU ETS operates an EU-wide cap leading to high levels of transparency and harmonization. The latter component was ultimately missing from the US SDP because the trading market relied on regional initiatives. This made it difficult for cross-regional firms to justify changing their business operations when a more lax cap was imposed across the state border (Busse and Keohane, 2007). In contrast, the EU ETS has one single carbon market which has fostered security as it ensures the price of EUAs is equal across the EU. However, despite there being one carbon price, there has been volatility over the course of the EU ETS. During Phase I, there were policy adjustments and many firms received free EUAs. This led to a surplus of EUAs resulting in a low price of carbon, and additional uncertainty arose around whether ERUs (offset credits) could be carried forward into Phase II (Marin et al., 2018). The level of uncertainty is highlighted in the price evolution of EUAs depicted in Figure 3.

Figure 3: EU Allowance Price Evolution
Source: Data retrieved from Trading-Economics (2023)

Evidently, Phase I saw high levels of volatility in the carbon market, with prices ranging between €0-30. However, post-financial crisis during the majority of Phase III, the price stabilized, facilitating certainty in the market. The price hike at the end of Phase III can be attributed to the 'Market Stability Reserve' which was introduced in January 2019 with the aim of increasing the carbon price (EU-Commission, 2023c). This policy adjustment meant withholding a large volume of EUAs, leading to a constriction of supply and hence, an increase in price.

Although adjustments have been made in the EU ETS, the implementation approach has been clearly communicated in advance by the EU Commission. By providing firms with ample time for planning, predictability has been fostered, precluding firms from exploiting short-term solutions to circumvent the policy.

Considering the more carefully designed framework of the EU ETS, our first hypothesis will investigate whether PWH of induced innovation holds over the entirety of the EU ETS timeline.[14]

H1: The EU ETS has spurred eco-innovation in regulated firms.

5.2.1 Increasing Stringency and Certainty Across Phases

Porter and Van der Linde (1995) argue that for an environmental policy to be effective, it needs to be stringent enough to deter firms from emitting by increasing their costs significantly. In the case of the EU ETS, the costs stem from three buckets; non-compliance fines, EUAs, and eco-innovation. Ideally, the cost of eco-innovation should be less onerous than the costs incurred from paying fines and/ or procuring additional allowances, so that firms are incentivized to eco-innovate.

It is arbitrary to compare the stringency of different policies because even if both follow a cap-and-trade system, no two environmental policies are the same. However, since the EU ETS is divided into phases, we can directly compare each phase with one another. Joltreau and Sommerfeld (2019) advocate that the increased non-compliance fine is a fair estimate for the stringency tiers.[15] In addition, the tightening of the emission cap is also considered to be an indicator of stringency as each phase requires regulated firms to either engage in higher levels of eco-innovation than previously or purchase additional

[14] Although this thesis primarily focuses on Phase III of the EU ETS, the first two phases are required to reach an overview and also to serve as comparables.

[15] Reflecting back on Table 1, fines have increased from €40 to €100 for each tCO_2 emitted above the allowance. This 150% increase can be regarded as a significant and unintended cost for firms who do not plan ahead regarding their emissions.

EUAs should they want to maintain consistent production output.

Given Phase III curbs emissions more than Phase II, and additionally only allows 50% of ERUs to be converted into EUAs (Table 1), it is clear that stringency is increasing. Therefore, if PWH is true, one can expect Phase III to have a larger effect on eco-innovation than any of the previous phases. Given this thinking, our second hypothesis follows:

H2: Phase III facilitated the highest levels of eco-innovation for regulated firms since the inception of the EU ETS.

Although results have been mixed in previous literature relating to earlier phases of the EU ETS, this study believes that the EU ETS framework is sufficiently well-defined for PWH to hold. Therefore, we expect to accept **H1**. In addition, given Phase III is the most stringent to date, we believe that **H2** will also be accepted. However, it is worth noting we also expect non-regulated firms to exhibit eco-innovation behavior stemming from shifts in mindsets around climate change. Therefore, we are expecting to find evidence to support PWH, although the effect might be dampened as the difference between the subsets of firms might have converged over time.

5.3 The EU ETS and Porter's Strong Hypothesis

Firm performance and international competitiveness are highly debated topics in environmental policy economics. The fear of stunted firm productivity and revenue loss as a result of being regulated by an environmental policy is the main reason behind carbon leakage. Porter and Van der Linde (1995) make the case that there are two mechanisms why eco-innovation does not stagnate firm performance but rather enhances it.

The first mechanism is windfall profits. Heterogeneous firms are able to 'choose' their financial performance once they have eco-innovated. They are faced with the choice of selling/ leasing their technology to other firms in the market, or they can pass the cost of innovation downwards in the value chain to the end customer. In both situations, regulated firms' eco-innovation leads to windfall profits.

The selling/ leasing of new technology requires a large market size which can be achieved if it also extends across geographical jurisdictions. This requirement is fulfilled by the EU ETS, whereas the US SDP had limited geographical scope as US States had differing levels of eco-innovation requirements. For example, an eco-innovation by a Texas-based firm would only be of interest to similar firms also within the state of Texas - as firms across State borders are not willing to procure expensive technology that abates larger volumes of emissions than is required in their jurisdiction (Ellerman et al., 2010). In contrast, because the EU ETS has uniform regulations across nations, there is, therefore, a higher likelihood that firms will not only be trading EUAs amongst themselves but also eco-innovations. This generates an additional source of revenue available in the market (Bocken et al., 2014).

Furthermore, the notion of firms transferring higher production costs to the end consumer can seem counterintuitive, as this contradicts the definition of international competitiveness provided by Balassa (1964). However, this can occur because the sectors currently regulated in the EU ETS[16] have a historically low price elasticity (Joltreau and Sommerfeld, 2019). This means that with inelastic demand, firms are able to increase their prices by a proportionately larger percentage than the proceeding loss in demand, resulting in higher profits and thus, increased firm performance.

The second mechanism that Porter and Van der Linde (1995) argue facilitates increased firm performance is that there are efficiency gains from eco-innovation which can offset the initial cost of regulation. This is a long-run phenomenon as it takes time for eco-innovations to be integrated into operations once approval is given. Porter and Van der Linde (1995) acknowledge this, by noting that any productivity gains that offset the initial development cost would take several years. Therefore, for PSH to be tested,

[16]See Appendix B for regulated EU ETS sectors.

a time frame of multiple years following policy implementation is necessary.

This thesis assumes the two mechanisms facilitating enhanced firm performance, as a result of being regulated, exist in the scope of the EU ETS, given its large scale and long time frame that will be examined in the paper. Thus, the third hypotheses are as follows:

H3: The EU ETS has increased the financial performance of regulated firms.
H3.1: Phase III facilitated higher levels of firm performance for regulated entities since the inception of the EU ETS.

5.3.1 Induced Eco-innovation as a Mediating Effect for Increased Firm Performance

In H3, this paper will test whether being regulated by the EU ETS leads to higher firm performance. However, further dissecting PSH suggests it is the act of eco-innovation, and not only regulation, that drives enhanced firm performance. Consequently, this indicates that eco-innovation acts as a mediator between being regulated by an environmental policy and increased firm performance.

Regulation can prompt firms to become first movers in the market by investing in greener technology, and in doing so, obtain a competitive advantage (Mohr, 2002). In the absence of environmental regulations, firms typically refrain from becoming the first mover as it can be more profitable to wait and procure established technologies, rather than investing in R&D (Mohr, 2002). By waiting, firms avoid any learning costs that have been incurred by the first-mover. However, Porter and Van der Linde (1995) argue that this market failure can be overcome by environmental regulations that are revised or modified over time, which stands true for the EU ETS. This eliminates the burden of being a first-mover in the market and creates an incentive for regulated firms to invest and innovate in their own technologies (Mohr, 2002).

Therefore, the final hypothesis of this thesis will take a closer look at the foundation of PSH, and is presented below:

H4: The relationship between being regulated in the EU ETS and financial performance is mediated by induced eco-innovation.

With regards to **H3**, we hold the view that firm performance will not be impacted by regulation as we anticipate that non-regulated firms will have incentives to 'go green', given the importance of sustainable practices in today's society. Consequently, these firms will also be able to realize windfall profits from potential eco-innovation sales. In addition, since this study will look into comparable firms who are operating in the same industries as those regulated, we assume the inelastic nature of demand will hold for non-regulated firms too. Finally, in examining **H4**, which considers the mediating effects of eco-innovation, we posit that induced eco-innovation does not serve as a mediator for enhanced firm performance, as we do not believe there is a causal effect between regulation in the EU ETS and firm performance. Thus, although previous literature suggests that running models with data over a longer time period can highlight PSH, we hypothesize that any effect seen will be small or insignificant.

6 Data Collection

This section outlines the process of gathering and compiling the dataset used in this paper.[17]

In order to empirically assess the effects of Phase III of the EU ETS, it is necessary to collect data on installations that have been regulated during all previous phases, to enable cross-phase comparison. Furthermore, since regulation occurs at the installation level, account holder data is translated to

[17]It is worth noting that an empirical approach (Propensity Score Matching) had to be implemented before the final dataset could be compiled, and this methodology is described in the subsequent section. Thus, a description of the final dataset is available in the empirical methodology section.

firm-level data, and finally matched with non-regulated firm-level data. This facilitates the comparison between regulated and non-regulated firms that share similar characteristics. However, due to the lack of harmonization, sourcing regulated account holders proved to be a challenging identification process. Additionally, a lot of financial data from earlier phases was incomplete, making numerous observations idle. The identification process is summarized in Figure 4, and further elaboration is given below.

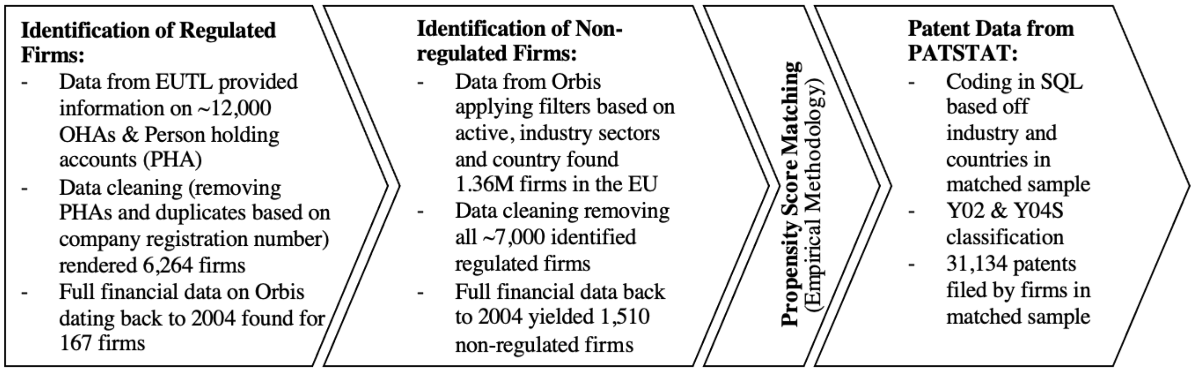

Figure 4: Data Collection Summary
Source: Includes information on data retrieved from EU-Commission (2020a), Orbis (2023), and PATSTAT (2023)

6.1 Identification Process of Regulated Firms

Following the guidance of Jaraitė et al. (2013), this section will describe the identification process of regulated firms whereby data was drawn from two databases. The first database, which contains data regarding compliance and trading at the OHA level, was found in the 2020 EU Transaction Log (EUTL) (EU-Commission, 2020a). However, the identification process poses a challenge as there are two types of account holders; Operator and Person (Jaraitė et al., 2013). Regulated installations are associated with a single OHA, but firms can own several regulated installations, resulting in multiple OHAs. Moreover, Person Holding Accounts (PHA) are those who have voluntarily opted to follow the regulations. We disregard PHAs since they could introduce selection bias as they have chosen to be part of the treatment group.[18] Although the EUTL does not directly state who the ultimate firm owner of each installation is, this information can be deciphered through a sequence of mapping.

The second database used is Bureau van Dijk: Orbis (2023), from which financial data was sourced. The data retrieved from the EUTL provided information on company registration numbers, from which we were able to match the accounts to their historical firm owner. This enabled retrieving the corresponding identification number that Orbis uses, known as the BvD ID. A dataset was generated by identifying ∼7,000 firms through string matching.[19] This highlights the harmonization issue, as a firm can have multiple regulated installations, each with its own OHA/ PHA. Consequently, on average, a firm has approximately 2 regulated installations, given that there are ∼12,000 installations that are covered in Phase III of the EU ETS.

Since our interest lies in firms that have had installations that have been part of the EU ETS since inception, we further compared our retrieved data with an older EUTL dating back to 2005.[20] Thus, removing all PHAs and any newly added installations from our dataset rendered 6,264 firms. The reason for first using a Phase III version of the EUTL is that we require all active and regulated firms, even late joiners, to be highlighted as these are later removed from the non-regulated firms' sample.

[18]These are removed once all regulated firms are identified.

[19]String matching refers to the process of searching for a particular pattern of characters within a larger string of characters (Boyer and Moore, 1977).

[20]Since 2005 was the first year of the EU ETS, a comparison to the Phase III EUTL was needed to highlight which installations were late joiners, or any that had later become non-regulated.

To retrieve financial data from Orbis, we used the 6,264 identified firms and applied filters whereby all companies were required to embody complete financial information dating back to 2004.[21] We found that this restricted our sample size significantly, reducing the number to 167 regulated firms. This paper investigates the evolution of the EU ETS and the differential impact of Phase III, and therefore financial data is required from 2004 which is the year before official policy was implemented. Nevertheless, we believe that what is lost in sample size will be regained in accuracy and robustness (Dehejia and Wahba, 1999).

6.2 Identification Process of Non-Regulated Firms

To retrieve data on non-regulated firms in the EU, Orbis (2023) was utilized and a set of conditions were implemented to ensure comparable firms were identified. The initial requirements for non-regulated firms were that they had to be founded prior to 2004, still be active, and exclude firms operating in countries that joined the EU ETS after 2005.[22] After these filters were implemented, a total of 1.3 million firms were sourced. However, this sample includes all active firms, therefore we removed the ∼7,000 previously identified regulated firms before advancing to data cleaning. Furthermore, ensuring that full financial data dating back to 2004 was available meant that 1,510 firms remained.

Therefore, after initial data gathering, a total of 167 regulated firms and 1,510 non-regulated firms were identified. These two groups of data will be used in the formation of a matched dataset, whereby a detailed process is discussed in the empirical methodology section.

6.3 Patent Data from PATSTAT

Patent filings reflect a firm's eco-innovation efforts and the use of patents to measure technological change has been used extensively within induced innovation literature (Popp, 2002; Johnstone et al., 2010; Calel and Dechezleprêtre, 2016). This thesis will also utilize patents as a proxy for eco-innovation, selecting filed patents of subclasses Y02 and Y04S,[23] since we are investigating low-carbon technological change (Martin et al., 2013; Calel and Dechezleprêtre, 2016). The subclasses have been developed by the European Patent Office (EPO) whereby any patent with this classification includes innovation for climate change mitigation technologies.

The database PATSTAT (2023) is used to source eco-patents, and the increased transparency and efforts with regard to combating climate change have made the matching of patent filings to firms less ambiguous. PATSTAT (2023) is the World Patent Statistical Database which is run by the EPO, and is a comprehensive database with patent information on over 60 million documents from over 80 unique patent offices (Calel and Dechezleprêtre, 2016). The database reports patent filings at the firm level, which is consistent with our dataset on regulated and non-regulated entities, allowing us to perform further string matching. To retrieve patent data, SQL coding was necessary as PATSTAT (2023) provides several data tables that were required to be joined and matched. Patent data was collected with restrictions in place to filter any patent filings that were not of interest. Filtering occurred on the basis of countries present in the dataset of regulated and non-regulated firms, the time period investigated (2004-2020), and the Cooperative Patent Classification of Y02 and Y04S. This yielded a total of 763,330 filed eco-patents that were linked to a firm-level application ID, and could ultimately thereafter be linked with the firms in the final matched dataset.[24]

[21] 2004 is required because this is the official pre-policy year of the EU ETS.
[22] Bulgaria, Romania, Croatia, Norway, Liechtenstein, and Iceland.
[23] Referred to as eco-patents in this paper.
[24] The matched dataset is the final data of regulated and non-regulated firms that have been 1:1 matched, generated using Propensity Score Matching. This is elaborated on in the empirical methodology section.

7 Empirical Methodology

The aim of this thesis is to identify a causal effect using a quasi-experimental design, with a matched Difference-in-Difference (DID) approach. Given that the EU ETS regulation only applies to 'large' installations, it is not considered a true stochastic event. Therefore, DID is used to estimate casual effects, where this thesis firstly utilizes Propensity Score Matching (PSM) to enhance the comparability of regulated and non-regulated firms. This is a common empirical approach for creating a matched dataset in observational data, and enables a matched DID to be performed.

Therefore, this section will elaborate on the formation of the treatment and control group in the matched dataset, the chosen methodology for causal inference, and a description of the variables, followed by a description of the final dataset. Additionally, the regressions used to test our hypotheses will also be presented.

7.1 Propensity Score Matching Method

In order to employ a DID analysis in our study, a matching method was necessary to balance the groups of firms as the identified regulated and non-regulated entities had dissimilar characteristics prior to matching.[25] Neglecting to do so could lead to a violation of the parallel trends assumption.

PSM, developed by Rosenbaum and Rubin (1983), allows for a matched control group to be constructed, by pairing each treated unit to a control unit based on a propensity score. This controls for selection bias, as well as for observed characteristics (Rosenbaum and Rubin, 1983; Caliendo and Kopeinig, 2008). In addition, PSM allows us to observe a specific subset of firms over the evolution of the EU ETS. By isolating these firms, and not including firms who have entered the EU ETS in later phases, we are able to analyze and follow how firm behavior has changed with increased stringency across phases. Below is the equation used for calculating propensity scores:

$$e_i(X_i) = P(T_i = 1|X_i)$$

The propensity score is calculated using a probit regression of the treatment on firm characteristics. The equation shows that the propensity score is the probability of a firm being in the treatment group, T, based on covariates that represent the firm's characteristics, X (Stuart, 2010). This score is used to match regulated and non-regulated firms that are statistically similar, based on the resemblance of scores.

This thesis follows the guidance of Caliendo and Kopeinig (2008) to match regulated and non-regulated firms, and simulates a similar matching methodology to previous literature investigating earlier phases of the EU ETS (e.g., Jaraite-Kažukauske and Di Maria (2016); Marin et al. (2018); Calel and Dechezleprêtre (2016)). Propensity scores are calculated on 2004 financial data, with fixed assets and operating revenue as covariates. With 2004 being the official pre-policy year, both groups of firms were devoid of regulations at this time, establishing a basis for comparability.[26] Fixed assets are widely used in EU ETS studies as it provides a good indication of the installation capacity while operating revenue evaluates the firm's financial position at an aggregate level (Joltreau and Sommerfeld, 2019). Through the incorporation of these two covariates, firms with equal resources for innovation can be identified (Osses, 2020). Moreover, matching also occurred at country and industry level,[27] to control for exogenous shocks that may impact firms operating in distinct countries and sectors differently.

[25] We conducted t-tests for operating revenue and fixed assets (on 2004 data) in the sample comprising of 167 regulated and 1,510 non-regulated firms, resulting in t = -5.354, p < 0.0001, and t = -5.939, p < 0.0001, respectively. The p-values are significant, meaning we can reject the null and conclude that there are large differences between the average means of the covariates in the two groups of firms.

[26] In our regression models, the years prior to Phase III are regarded as pre-treatment years as our interest lies in the effect of this phase.

[27] Industry based on the NACE two-digit code defined by the EU-Commission (2013).

The firms are matched based on the similarity of their propensity scores, leaving a 1:1 statistically similar pair. The matching method used is k:1 nearest neighbor matching, which is an effective method when the goal of matching is to identify groups for further analysis (Stuart and Rubin, 2008). Nearest neighbor matching on 1:1 basis searches for a control unit that has the closest distance to a treated unit. The main critique of k:1 nearest neighbor matching is that it matches all treated units to a control unit, which can provide poor matches. However, this is solved by imposing a caliper that sets the maximum tolerance level between two matched propensity scores (Caliendo and Kopeinig, 2008). Caliper matching further ensures higher quality matches when the key covariates are continuous variables (Rubin and Thomas, 2000). A caliper of 0.2 standard deviations is proven to be the most optimal level for PSM as it removes 98% of the bias in a normally distributed covariate (Austin, 2011; Stuart, 2010). After reviewing the distributions of fixed assets and operating revenue in our samples, we also concluded to implement this caliper level. The equation below describes the matching distance in our PSM:

$$D_{ij} = (e_i - e_j)$$

where e is the propensity score for each unit (Stuart, 2010).

The matching procedure was conducted without replacement, ensuring one control entity can only be matched with one treated entity. Matching with replacement could lead to a limited number of controls, causing bias, particularly with small samples (Stuart, 2010). After matching has occurred, two key aspects of PSM are to assess the covariate balance and the propensity score balance in the matched groups. Firstly, it is crucial that the treatment is unrelated to the matched groups, such that:

$$\tilde{p}(X|T = 1) = \tilde{p}(X|T = 0)$$

where $\tilde{p}$ is the empirical distribution, and the distribution on the vector of covariates (X) should be the same between the treatment group ($T = 1$) and the control group ($T = 0$) (Stuart, 2010).

Figure 5 illustrates the empirical quantile-quantile (e-QQ) plot[28] which is used to assess the covariate balance in the matched data set. The e-QQ plot compares two distributions by plotting their quantiles against each other (Gibbons and Chakraborti, 2011). If the two groups are balanced, the points will lie on the 45° line (Stuart et al., 2011). We find that prior to matching, the fixed assets and operating revenues in 2004 were unbalanced, with large differences between the two groups of firms. After matching occurs, the 1:1 matching aligns the firms on the 45° reference line, signaling that the data is balanced.

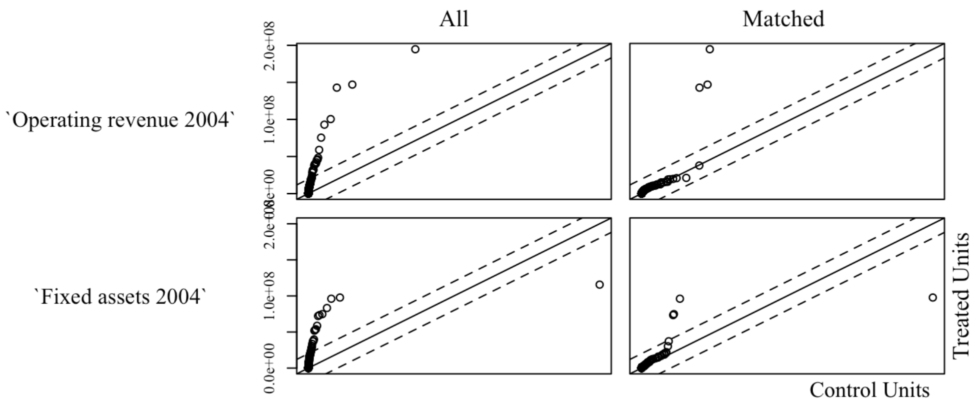

Figure 5: e-QQ Plot
Source: Authors' rendering of financial data from Orbis (2023)

[28]The e-QQ plot provides a more advanced measure of assessing balance in comparison to the following t-tests, since e-QQ plots take the entire distribution difference of the covariates into account, while t-test only accounts for differences in means.

Figure 6 additionally illustrates the balance of the propensity scores after matching. The matched treated and control units are, as visualized in the plot, balanced. They follow a similar pattern to each other, as seen through the clustering on the left side, and the similar dispersion towards the right hand side. The unmatched treated units tended to have high propensity scores, whilst the remaining unmatched control units had very low scores. Therefore, as the caliper was set to 0.2, it is understandable why not all regulated firms found matches.

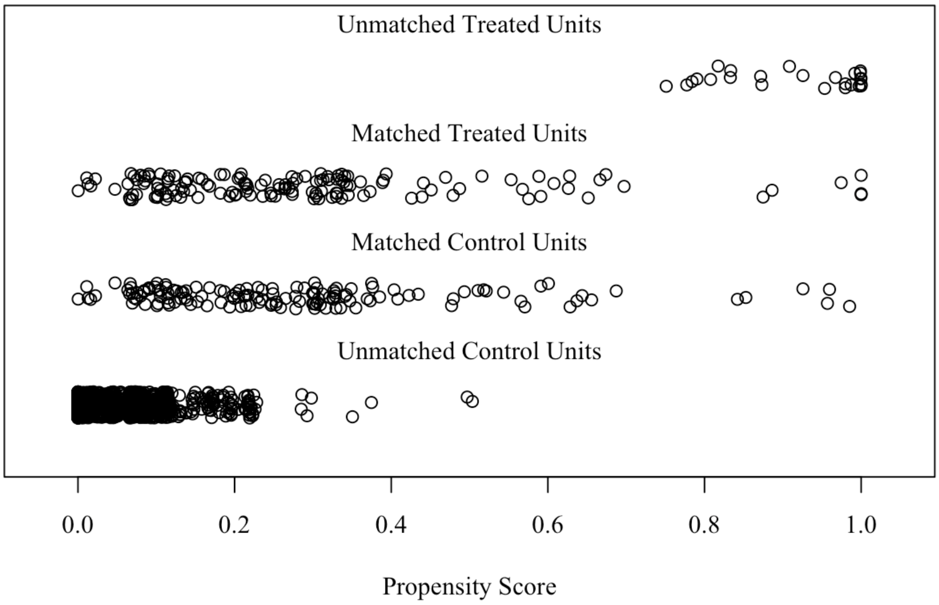

Figure 6: Distribution of Propensity Scores
Source: Authors' rendering of financial data from Orbis (2023)

Besides visual inspection of the matching, tests investigating the difference in means of the covariates between the treated and control group were conducted to evaluate whether outliers observed in the matching can be included (Caliendo and Kopeinig, 2008). Our results indicate we cannot reject the null hypothesis, meaning there is no significant difference between the means of the chosen covariates among the two groups. The t-test for operating revenue resulted in t = -1.78, p = 0.12, and for fixed assets the t-test resulted in t = -1.05, p = 0.29. These findings suggest that the two groups are balanced on these covariates after matching, thereby enhancing the validity of the PSM.

Overall, 142 pairs were computed from the 167 regulated firms and 1,510 non-regulated firms, meaning 85% of the regulated firms found a match. Looking into the excluded regulated firms, we found it was because there was no counterfactual of the same magnitude. For example, there was no non-regulated firm operating in the car manufacturing industry in Germany that could be compared to Volkswagen.

7.2 Matched Difference-in-Difference

Theoretically, after performing PSM, a suitable counterfactual is identified and should enable the average treatment effect (ATE) to be found.[29] However, in the case of regulated firms, the treatment was not random as installations were required to meet a certain threshold, violating the ignorable treatment assignment.[30] Thus, the idea of the ATE allowing for all factors influencing the probability of a firm being regulated (treated) to be observable, becomes naive (Caliendo and Kopeinig, 2008). Therefore, rather than using the ATE with the matched dataset, PSM facilitates the construction of a sample that can be assessed through a matched DID, as suggested by Abadie (2005).

[29]The ATE is the difference between the expected outcomes for firms that are regulated by the EU ETS and non-regulated firms.

[30]A key assumption of ATE is that treatment should not affect outcomes after controlling for covariates (Caliendo and Kopeinig, 2008).

The DID framework is a widely used statistical method that examines the causal effect of a policy intervention on outcome variables (Stock and Watson, 2020). By comparing changes in the outcome variable over time between the regulated and non-regulated firms, DID can account for unobservable, but temporally invariant, differences in outcomes (Caliendo and Kopeinig, 2008). However, the validity of DID relies on the parallel trends assumption, which states that any differences between the treatment and control groups prior to intervention would have remained the same in absence of intervention. In this study, the focus is on Phase III of the EU ETS, with pre-treatment and post-treatment periods of 2005-2012 and 2013-2019, respectively. Despite firms being regulated during the pre-treatment period (Phase I and II of EU ETS), we believe the parallel trends assumption will hold in our sample given the large proportion of insignificant effects of regulation from previous literature. Furthermore, a true counterfactual is facilitated by PSM, which further supports the argument to be valid.[31]

7.3 Mediation

In this thesis, mediation analysis is used to examine the pathway through which one variable has an effect on another variable. In the case of PSH, it is inferred that the induced eco-innovation from an environmental policy mediates the effect between the regulation and increased firm performance. Although, to the best of our knowledge, this empirical method has limited usage in previous literature, the mediation methodology in our study serves the purpose of comprehensively addressing the entire scope of PSH.

This thesis follows the approach outlined by Baron and Kenny (1986), Judd and Kenny (1981), and James and Brett (1984), to test for mediation which consists of the following four steps (Kenny, 2021).

(1) "The independent variable should be correlated with the outcome"
(2) "The independent variable should be correlated with the mediator"
(3) "The mediator should be correlated with the dependent variable, controlling for the independent variable"
(4) "The effect of the independent variable on the dependent variable is reduced when the mediator is included in the analysis"

By following these steps, the validity of the mediation effect in terms of the EU ETS and its effect on firm performance can be assessed.

7.4 Descriptive Variables and Final Dataset

7.4.1 Dependent Variables

To find the effect on the eco-innovation of firms, the number of filed patent applications by a firm in a given year is used as the dependent variable. Using patents is a well-established practice in research on innovations for two main reasons. Firstly, patent filings are a quantitative output measure of innovation activities, indicating the intention to monetize an invention and conveying an incentive to innovate (OECD, 2009). Secondly, patents can be disaggregated based on their purpose, allowing the collection of only patents filed for eco-innovation (Johnstone et al., 2010; Veefkind et al., 2012; Hall and Helmers, 2013).

Nevertheless, the use of patents has its drawbacks. Firstly, the filing of patents is costly, which may dissuade some firms from doing so. However, this is partially mitigated as the subclasses considered are associated with high-technology inventions, where the cost for filing a patent is relatively low in comparison to the R&D costs (Calel and Dechezleprêtre, 2016). Secondly, the data collected on eco-patents is heavily zero-inflated, as depicted in Figure 7, which can limit potential findings (Archibugi and

[31] This assumption is further elaborated in 7.6 and 8.1.

Planta, 1996). This occurs because not all innovations are patentable, and the filing of patents is not a requirement for firms. Thus, although patents indicate innovation, it does not cover all carbon mitigating R&D activities. Using R&D expenditure on low carbon technology would be a more comprehensive measure, given all endeavors into reducing carbon would be included. However, the data on this was scant as there is no harmonized reporting system on this line item.

When examining PSH, Return on Assets[32] (ROA) is used as the measure of firm performance as it offers several advantages in this context. Firstly, ROA has strong predictive power for actual market performance, particularly in industries such as manufacturing where they are heavily reliant on fixed assets (Aliabadi et al., 2013).[33] Secondly, ROA is proven to be a stable measure of firm performance compared to other financial ratios such as Return on Investment (ROI). ROI can easily be manipulated in the short term to report higher returns, while ROA takes a company's total assets over a period of time into account. Lastly, ROA is particularly relevant when assessing eco-innovations as it is typically process development which significantly impacts a company's assets, and therefore they should be accounted for (Peloza, 2009; Przychodzen and Przychodzen, 2015).

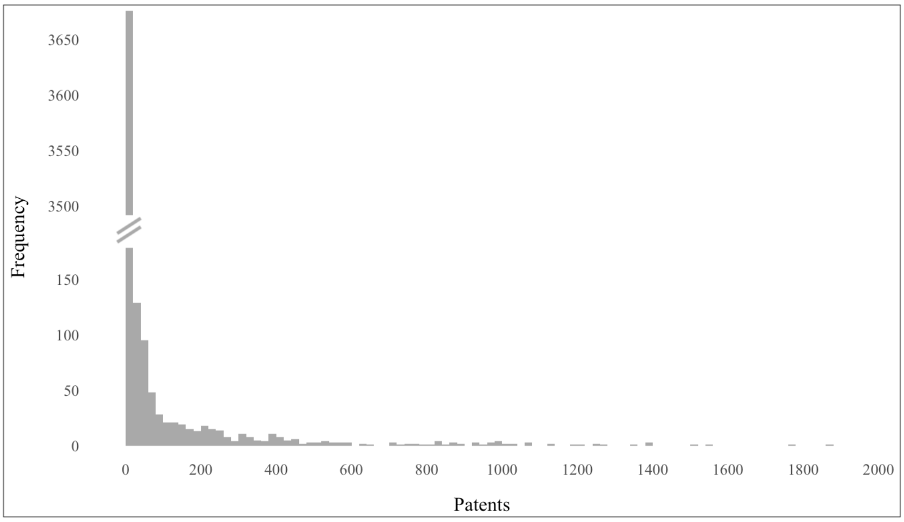

Figure 7: Eco-patent Frequency
Source: Data retrieved from PATSTAT (2023)

7.4.2 Independent Variables and Control Variables

The majority of independent variables utilized in this study will take the form of dummy variables.[34] Firstly, with regards to the EU ETS, a dummy variable taking value of *1* for regulated firms and *0* for non-regulated firms is created to distinguish between the treatment and the control group. Furthermore, in order to distinguish between phases, a categorical variable with dummies for the phases of the EU ETS are included. Furthermore, in the final model, eco-patents are included as a mediating variable.

Moreover, to account for the potential influence of country-specific and industry-specific factors on the potential to innovate or on firm performance, all models include sets of dummy variables controlling for these factors. The country fixed effects control for differences in general government regulations, institutions, cultures, and market shocks, among others. Industry fixed effects are included for similar reasoning, for example, some industries might have a faster rate of adoption of new technology and therefore see a higher rate of patent filings.

[32]ROA is defined as net income divided by total assets (Orbis, 2023).
[33]Many of which are included in the sample, ∼60%.
[34]"Qualitative or categorical variables that are introduced into regression analysis to utilize information that cannot be measured on a numerical scale" (Oxford-Reference, 2023b).

With regard to additional control variables, both operating revenue and fixed assets are included in all models. Both variables are likely to be correlated with the aforementioned independent variables on the chosen dependent variables. Fixed assets may reflect a firm's size and capacity to innovate, as firms with larger amounts of fixed assets may have greater resources to invest and be more likely to innovate (Acs and Audretsch, 1987). Similarly, operating revenue is a measure of a firm's financial resources and performance, which also may affect the firm's ability to innovate. Consequently, by including fixed effects and control variables, the possibility for omitted variable bias is reduced, and the precision of the estimates is increased, thereby improving the internal validity of the models.

7.4.3 Configuration of Final Matched Dataset

The final panel dataset consists of 48,290 observations with 10 variables. This includes data on; company name, industry, country, operating revenue, fixed assets, ROA, as well as the number of eco-patents filed,[35] for all 284 firms[36] annually between 2004 and 2020. Additionally, dummy variables stating whether a firm is regulated or not, along with a categorical variable denoting the phases, are also included.

The sample includes 18 of the original EU27 countries. Despite Great Britain representing the largest share with 14%, there is no country that dominates the sample. In addition, matches were based on the two-digit NACE industry code. General manufacturing represents 60% of the sample, followed by electricity, gas, and steam representing 10%. One may consider a 60% representation from manufacturing too prevalent in the sample. However, according to data gathered on installations from the EUTL, the dispersion in our sample is representative both in terms of country and industry. Appendix D sheds more light on the demographics of our dataset, whereas Table 2 displays the descriptive statistics.

Table 2: Sample Descriptive Statistics

Source: Data retrieved from Orbis (2023) and PATSTAT (2023)

Variables	Mean	S.D	Min	Max
Overall				
Eco-patents p.a.	31.2	135.9	0	2240
Fixed Assets (€, M)	10.3	22.3	0	308
Operating Revenue (€, M)	11.1	25.4	0	363.4
Return on Assets	4.5	7.5	-66.6	79.2
Regulated				
Eco-patents p.a.	35.3	140.7	0	2240
Fixed Assets (€, M)	11.3	26.8	0.0002	308
Operating Revenue (€, M)	12.0	33.3	0	363.4
Return on Assets	4.2	6.5	-66.6	79.2
Non-regulated				
Eco-patents p.a.	27.2	130.9	0	1871
Fixed Assets (€, M)	9.2	16.5	0	200.1
Operating Revenue (€, M)	10.2	12.8	0	111.8
Return on Assets	4.8	8.3	-48.0	61.2

7.5 Estimation Approach and Regressions

7.5.1 Estimation Approach

To determine the most appropriate estimation model for the regressions, five diagnostic checking tests are performed.[37] The results highlighted issues that need to be accounted for, as well as gave an indication on which estimation approach is most suitable for our data.

[35] Overall, 31,431 eco-patents had been filed by regulated and non-regulated firms in the final matched sample.
[36] 284 firms in the sample are made up of 142 regulated and 142 non-regulated firms.
[37] See Appendix E for a brief description of the performed tests and the results of each test.

The regressions are modeled using Generalized Least Squares (GLS) with fixed effects and cluster-robust standard errors. GLS is preferred over Ordinary Least Squares since the performed tests indicated issues with heteroskedasticity and serial correlation (Stock and Watson, 2020). In addition, cluster-robust standard errors are used to further account for these issues. Clustering is appropriate when the sampling process and the treatment assignment mechanism are clustered (Abadie et al., 2017). In line with this, industry-level clustering is conducted, as our sample comprising 41 unique industry codes is considered a large enough number to cluster. By using this estimation method, we expect unbiased and robust estimates in the parameters of interest - a necessity when drawing accurate conclusions.

Furthermore, in the regression models where the number of filed eco-patents is included, the variable is transformed to natural logarithm form due to its heavy zero-inflated count distribution (Figure 7). This transforms the variable into an approximated normal distribution, which is helpful when the data is skewed or contains extreme values (Stock and Watson, 2020).

7.5.2 Regression Models

The first two models consider PWH, whilst models three and four consider PSH. It should be noted that although Phase III extended into 2020, the regressions do not incorporate data from this year due to the disruptive impact of the Covid-19 pandemic. Therefore, data encompassing Phase III includes the years 2013-2019 to allow for a more accurate depiction of the effects of the EU ETS.

Model 1

$$lnEcoPatents_{it} = \beta_0 + \beta_1 Regulated_i + \beta_2 FixedAssets_{it} + \beta_3 OperatingRevenue_{it} + \alpha_c + \theta_j + \epsilon_{it} \quad (1)$$

Where the dependent variable is the natural logarithm of the number of filed eco-patents. The independent variable is a dummy variable named *Regulated* that takes a value of *1* if the firm owns an OHA which is regulated by the EU ETS. Furthermore, fixed assets and operating revenue are included as control variables, fixed effects for the country (α_c) and industry (θ_j), as well as the error term (ϵ_{it}).

Model 2

$$lnEcoPatents_{it} = \beta_0 + \beta_1 Regulated_i + \beta_2 Phase_t + \beta_3 Phase_t * Regulated_i + \beta_4 FixedAssets_{it}$$

$$+\beta_5 OperatingRevenue_{it} + \alpha_c + \theta_j + \epsilon_{it} \quad (2)$$

Using a DID regression model, we compare Phase II and III of the EU ETS, adding a categorical variable called *Phase* containing dummies for Phase II and III. The variable *Regulated* is the same as model (1), while this model also includes an interaction term between the variables *Phase* and *Regulated*.

Model 3a

$$ROA_{it} = \beta_0 + \beta_1 Regulated_i + \beta_2 FixedAssets_{it} + \beta_3 OperatingRevenue_{it} + \alpha_c + \theta_j + \epsilon_{it} \quad (3a)$$

To test H3, we first model a simple linear regression to examine the effect of the EU ETS on firm performance, with ROA as the proxy for firm performance.

Model 3b

$$ROA_{it} = \beta_0 + \beta_1 Regulated_i + \beta_2 Phase_t + \beta_3 Phase_t * Regulated_i + \beta_4 FixedAssets_{it}$$

$$+\beta_5 OperatingRevenue_{it} + \alpha_c + \theta_j + \epsilon_{it} \quad (3b)$$

Furthermore, to test whether the implementation of Phase III has had a more significant impact on ROA than in previous EU ETS phases, we model the regression below where *Phase* is the same categorical variable as in model (2).

Model 4

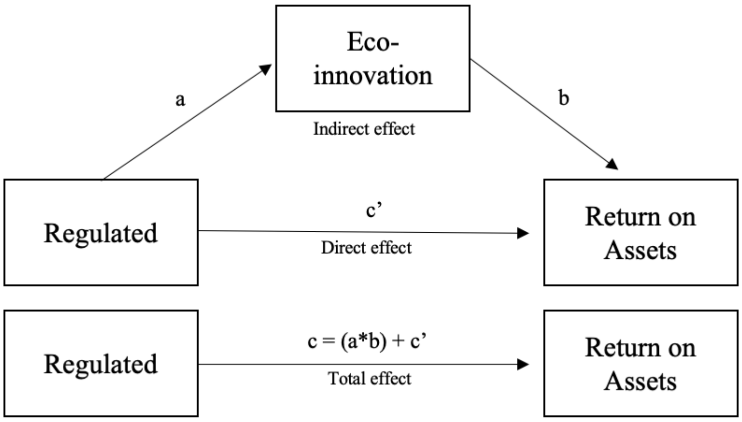

Figure 8: Mediation Pathways
Source: Authors’ illustration inspired by Kenny (2021)

To further test PSH, mediation analysis is used to see whether eco-innovation has a mediating effect between being regulated and its impact on firm performance. The outline of mediation analysis consists of four steps, requiring three regression models. The first step is to test the total effect, to establish if there is an effect to be mediated. More precisely, this tests whether the EU ETS has increased firm performance (*path c* in Figure 8), which uses the same regression as model (3a). The second step is to test whether the independent variable (being regulated by EU ETS) has an effect on the mediator (number of filed eco-patents), represented by *path a* in the figure and is the same regression model as model (1). The final step is to regress the dependent variable on both the independent variable and the mediator, this final regression model is presented below.

$$ROA_{it} = \beta_0 + \beta_1 Regulated_i + \beta_2 lnEcoPatents_{it} + \beta_3 FixedAssets_{it}$$
$$+\beta_4 OperatingRevenue_{it} + \alpha_c + \theta_j + \epsilon_{it} \quad (4)$$

With this model, one should first analyze whether the mediator has an effect on the dependent variable while controlling for the independent variable (*path b*). Thereafter, with the same regression, one should analyze the direct effect of the independent variable on the dependent variable, including the mediator as a control (*path c’*). The aim of the direct effect is to see whether the independent variable’s effect is reduced compared to when first estimating the total effect.

7.6 Model Assumptions and Limitations

There are several important assumptions and limitations to consider with the chosen empirical approach.

When dissecting the PSM methodology, there are four elements to acknowledge. Firstly, given the assumption of an ignorable treatment assignment does not hold due to the characteristics of the EU ETS regulation, the unbiased causal effect is estimated using DID which can account for time-invariant heterogeneity between the groups. Secondly, PSM assumes common support, stipulating there should be a balance between the propensity scores in the control and treatment groups. After visual analysis of Figure 6, it is concluded this assumption holds. Thirdly, PSM is unable to control for unobserved factors, and

King and Nielsen (2019) argues the main weakness of PSM is that it often fails to reduce model dependence and bias. This can be better understood by the potential overreliance on the covariate balance since PSM is bound to the matching based on observed covariates. Thus, there can be unobserved variables related to the treatment assignment or the outcome that is missing. As indicated, R&D expenditures are highly correlated with patent filings (Bronwyn et al., 1986), but could not be included due to limited data. Finally, one should consider the sensitivity of the choice of matching methodology. The selection of a matching method should prioritize the optimal balance in the groups (Stuart, 2010). With this in mind, several matching methods were tested before choosing; k:1 nearest neighbor, 1:1 matching without replacement, and a 0.2 caliper, as it gave the best balance.

To obtain unbiased estimates using DID, the parallel trends assumption is crucial. The pre-treatment years of our models include Phase I and II of the EU ETS,[38] which have been argued to show little to no effect in previous literature, hence, the control and treatment groups should not be statistically different during this period. This assumption is further elaborated on in the results section. Another point to consider is that the pre-treatment period should be sufficiently long. Considering that this study centers around Phase III of the EU ETS, the pre-treatment duration encompasses the years 2005-2012, yielding an eight-year pre-treatment timeline.

Spillover effects is another limitation to consider since the EU ETS might signal to all firms to carefully consider carbon emissions. Thus, non-regulated firms may reduce their carbon emissions voluntarily. Early researchers, such as Rubin (1974), argue that the outcomes for a particular firm must not be influenced by the treatment assignment or outcomes of other firms in the study, including the assumption that spillovers are absent in order to estimate causal effects. However, since this is hard to achieve, later researchers such as Rosenbaum (2007), argue this can be accounted for. The nature of the EU ETS regulation facilitates endeavors of smaller installations since a firm can choose to opt into the EU ETS by opening a PHA. It can be argued that conscious firms wanting to comply with the regulations have done this, and therefore these have been disregarded from the sample to minimize potential spillover effects. Furthermore, we have chosen to estimate the causal effect using matched DID, which helps account for time-invariant heterogeneity between firms and reduces the risk of spillover effects.

The final method is mediation, which relies on a few specific assumptions. Baron and Kenny (1986) argue that testing for mediation is only appropriate if the relationship between the independent variable and the dependent variable is significant. However, Hayes (2009) has strongly criticized this assumption, and suggests conducting all steps of the mediation analysis before analyzing the effect, which will serve as the approach in this paper. Furthermore, mediation analysis assumes no misspecification of the causal order,[39] no misspecification due to omitted variables, and finally no misspecification due to measurement error (James and Brett, 1984). The risk of omitted variables is present as there are likely many factors affecting firm performance, and measurement error could arise as the data available saw a lack of harmonization. However, the control variables and fixed effects were included with the aim to mitigate omitted variable bias, and the data was thoroughly cleaned to mitigate measurement error.

8 Results Analysis

This section will present the empirical results derived from the regression models. Connecting the models in the context of the EU ETS with the two strands of the PH allows the linkage between the two areas of study. Furthermore, the regressions are tested again with some new parameters, helping to validate their robustness.

[38] Although PSM matching occurred based on 2004 financial data as this is the official pre-policy year.
[39] Independent variable → Mediator → Dependent variable.

8.1 Empirical Results: The EU ETS and Porter's Weak Hypothesis

PWH is investigated in our first two hypotheses, where we find support in the first model investigating whether the EU ETS increased patent filings over the time period of 2005-2019. The results for model (1) and (2) are reported in Table 3. Figure 9 plots the number of patent filings for regulated and non-regulated firms in our sample over time.[40]

Table 3: Results - Model 1 and 2

Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Dependent Variable	**ln_Eco-patents**	
Model	**(1)**	**(2)**
Regulated	1.550** (0.5189)	1.866*** (0.4645)
Fixed Assets	2.69e-8. (1.33e-8)	2.55e-8. (1.3e-8)
Operating Revenue	2.81e-8 (1.73e-8	2.87e-8 (1.73e-8)
Phase II		0.6706** (0.2229)
Regulated x Phase II		-0.4104 (0.3574)
Phase III		0.7030* (0.2555)
Regulated x Phase III		-0.3733 (0.3365)
Fixed Effects		
Country	YES	YES
Industry	YES	YES
S.E Type	Clustered Robust	Clustered Robust
Observations	4,260	4,260
Pseudo $\mathbf{R^2}$	0.09084	0.09124
	0.0 '***' 0.001 '**'	0.01 '*' 0.05 '.'

The results from model (1) show a significant positive effect ($\beta = 1.550$, $p < 1\%$) of being regulated by the EU ETS on the number of patent filings over the entire period of 2005-2019. Therefore, regulated firms saw higher levels of eco-innovation compared to their matched non-regulated firms. The model has a Pseudo R^2 of 0.091 meaning that our variables explain $\sim$10% of why the number of filed eco-patents increased over this period. Consequently, we find enough support to accept our **H1**, indicating that PWH does hold over the course of the EU ETS's evolution. Model (1) with a natural logarithm of patents indicates a 370% increase in eco-patent filings.[41] This is explained through an example: if regulated firms have, on average, 15 more eco-patents than non-regulated firms,[42] going from 0 to 15 eco-patents is a 1500% increase, whereas going from 45 to 60 eco-patents is only a 25% increase. Given that our sample is heavily zero-inflated, the average of a 370% difference between regulated and non-regulated is therefore a natural interpretation.

Model (2) explores stringency between phases. The results show no significant effect on neither the interaction term for Phase II and being regulated,[43] nor the interaction term of Phase III and being regulated. However, the phases themselves have positive significant effects on the number of eco-patents filed for the whole sample. The coefficient on Phase II[44] has a significant effect of $\beta = 0.671$ ($p < 1\%$), and the coefficient on Phase III has a marginally higher significant effect of $\beta = 0.703$ ($p < 1\%$). The difference between regulated and non-regulated firms remains positively significant for the effect on the number of filed eco-patents ($\beta = 1.87$, $p < 1\%$).

However, the primary variable of interest, the interaction between Phase III and regulated firms, is not significant, indicating the phase did not lead to a significant increase in eco-patents specifically for

[40] See Appendix F for a time series plot over the period 2004-2020.

[41] The calculation for understanding the effect on a dummy coefficient when the dependent variable is in natural log form is: 100*($e^{1.550}$ - 1).

[42] The coefficient on *Regulated* was 14.91 when running the regression with eco-patents as a continuous variable instead.

[43] *Phase II* x *Regulated* interaction term is required for cross-phase comparison in order to draw conclusions about Phase III. The insignificance further validates the parallel trends assumption as the pre-treatment period shows no significant difference between regulated and non-regulated firms.

[44] Phase II results are reported and will also be analyzed as they serve as a direct cross-phase comparison to Phase III when evaluating the behavior and performance of regulated firms.

regulated firms. Although Figure 9 depicts a short-term spike in 2013 when Phase III was introduced, by 2019 the number of eco-patents filed annually by regulated firms was not significantly different from 2013.[45] As a result, **H2** is rejected at a 5% significance level because Phase III has not spurred significantly higher levels of eco-innovation in regulated firms compared to previous phases.

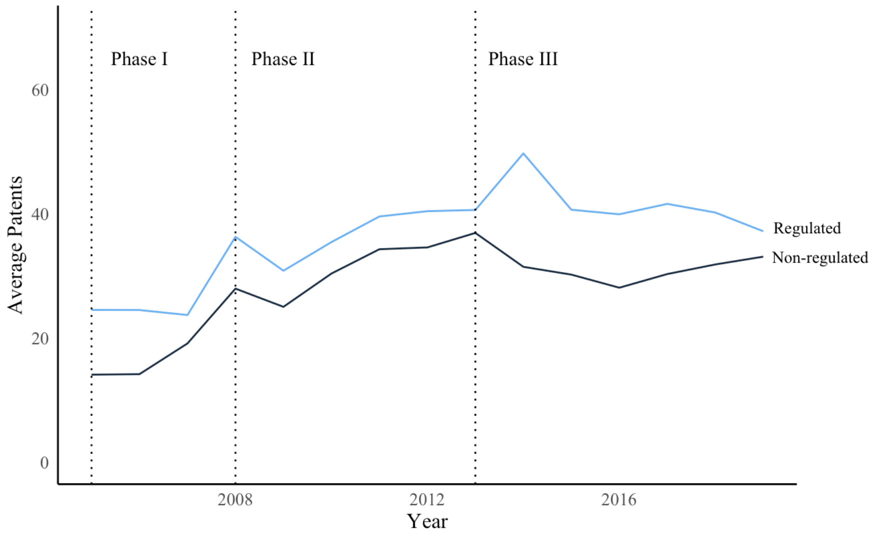

Figure 9: Eco-patent Evolution, 2005-2019
Source: Authors' rendering of data from PATSTAT (2023)

For our DID analysis to be valid in model (2), the parallel trends assumption is required to hold prior to the start of Phase III, and we see this is true upon visual inspection of Figure 9.[46] To further verify the assumption, Figure 14 showing the 95% confidence intervals can be found in Appendix G. We see that the standard errors follow the same distribution during the pre-treatment period, verifying the visual inspection in Figure 9. The lack of divergence aligns with previous literature, where little support was found for regulated firms having significantly higher induced eco-innovation than their non-regulated counterparts during the earlier phases.

8.2 Empirical Results: The EU ETS and Porter's Strong Hypothesis

The third and fourth hypotheses take a closer look at PSH. Model (3a) investigates whether there has been a difference in the financial performance of regulated and non-regulated firms over the duration of the EU ETS. The findings, presented in Table 4, show no significant effect, and therefore no support is found for the EU ETS increasing firm performance.

In model (3b), it is tested whether the implementation of Phase III has had a more significant impact on ROA than the previous phases.[47] Here, no significant results are found on the interaction terms of being regulated and the two respective phases. However, it is found that the coefficient of Phase II is significantly negative (β = -2.575, p < 1%), and similar for Phase III (β = -2.477, p < 1%). This indicates that ROA has declined for the entirety of firms in the sample. In this model, the Pseudo R^2 is low at 0.024, which means that the variables included are only responsible for ~2% of the effect on ROA. This suggests that there are multiple variables that affect firm performance which are not included in the model. Consequently, **H3** is rejected at a 5% significance level.

[45] See Appendix H for Event Study Graph where the coefficients are plotted for each year in relation to the treatment, with their respective confidence intervals.

[46] In theory, we would have expected a divergence after 2008 where Phase II was introduced with higher levels of stringency because we have not used the same datasets as previous literature. Instead, we see that both groups increased eco-innovation at a similar rate.

[47] See Appendix H for Event Study Graph where the coefficients are plotted for each year in relation to the treatment, with their respective confidence intervals.

Table 4: Results - Model 3
Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Dependent Variable	**Return on Assets**	
Model	**(3a)**	**(3b)**
Regulated	-0.738 (0.5692)	-0.1343 (0.9357)
Fixed Assets	3.11e-8** (7.87e-9)	-2.36e-8** (7.38e-9)
Operating Revenue	3.42e-8** (9.79e-9)	3.1e-8** (1e-8)
Phase II		-2.575*** (0.4826)
Regulated x Phase II		0.0547 (0.6942)
Phase III		-2.477** (0.4414)
Regulated x Phase III		-0.1855 (1.148)
Fixed Effects		
Country	YES	YES
Industry	YES	YES
S.E Type	Clustered Robust	Clustered Robust
Observations	4,260	4,260
Pseudo R^2	0.02107	0.02420
	0.0 '***' 0.001 '**'	0.01 '*' 0.05 '.'

Figure 10 shows the DID graph obtained from models (3ab).[48] Although not significant, visual inspection of the graph suggests that regulated firms had a lower ROA pre-2013. The parallel trends assumption appears to hold to a certain extent upon visual inspection, although the two groups of firms do diverge in the years following 2010.[49] After 2013, regulated firms have a lower ROA, except for the brief spike in 2015 where their ROA increased temporarily.

Figure 10: ROA Evolution, 2005-2019
Source: Authors' rendering of data from Orbis (2023)

The fourth and final model tests whether eco-innovation has a mediating effect between being regulated and ROA. The results are presented in Table 5.

The results show that the total effect is not significant, and neither is the direct effect. Following the steps by Baron and Kenny (1986), Judd and Kenny (1981), and James and Brett (1984), one can conclude that no mediating effect was found. Therefore, **H4** is rejected at a 5% significance level.

[48] See Appendix F for a time series plot over the period 2004-2020.
[49] See Figure 15 in Appendix G for the ROA time series plot with confidence intervals.

Table 5: Results - Model 4

Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Dependent Variable	**Return on Assets**	**ln_Eco-patents**	**Return on Assets**
Model	**Total Effect**	**Mediator**	**Direct Effect**
Regulated	-0.1738 (0.0.5692)	1.550** (0.5189)	-0.0008 (0.0415)
ln_Eco-patents			-0.1726 (0.5558)
Fixed Assets	3.11e-8** (7.97e-9)	2.69e-8. (1.33e-8)	3.11e-8** (8.78e-9)
Operating Revenue	3.42e-8** (9.79e-9)	2.81e-8 (1.73e-8)	3.42e-8** (9.86e-9)
Fixed effects			
Country	YES	YES	YES
Industry	YES	YES	YES
S.E Type	Clustered Robust	Clustered Robust	Clustered Robust
Observations	4,260	4,260	4,260
Pseudo R^2	0.02107	0.09084	0.02107

0.0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

8.3 Robustness Tests

The results indicate that PWH could be supported to a certain extent. To verify this, tests of robustness are conducted on both model (1) and model (2).[50]

Firstly, model (1) showed a significant effect of being regulated in the EU ETS on the number of filed eco-patents. In the sample, there are three countries that represent ∼10% of the data points each: Great Britain (GB), Spain (ES), and France (FR). Therefore, model (1) Excluding GB, model (1) Excluding ES, and model (1) Excluding FR are tested excluding the respective countries. Besides testing the validity of the significant effect of model (1), these models can further provide insights of the EU ETS in the domestic economies. The effect of being regulated in the EU ETS on eco-patent filings is still significant when excluding the respective countries. However, the effect varies in terms of magnitude; when excluding ES and FR, the effects are larger and $\beta = 1.876$ and $\beta = 1.759$ respectively, compared to the original model ($\beta = 1.550$). This indicates that these countries do not file as many eco-patents, and their presence in the original model dampens the effect.

Secondly, tests of excluding countries are conducted on model (2) as well. This thesis continues to not find significance on the interaction terms between the phases and the EU ETS. The original model has a $\beta = 1.866$ on the general effect of being regulated on patent filings. This effect is still significant when excluding the respective countries, however, differs in magnitude. When excluding GB, ES, and FR, the coefficients become $\beta = 1.684$, $\beta = 2.161$, and $\beta = 1.986$, respectively. Again, the coefficient on being regulated is highest when excluding ES, indicating ES files fewer eco-patents than the rest of the countries in the sample.

Thirdly, model (1) is tested with a 2-year lag on fixed assets and operating revenue. This test is conducted because, whilst there exist varying views among researchers regarding innovation timelines, there is a general consensus that it takes at least two years for R&D to convert into a granted patent (Bronwyn et al., 1986; Hall and Helmers, 2013). In the original model, lags were excluded because we are investigating filed patents, which do not exhibit the same timeline discussion as granted patents. In this test, the coefficient on being regulated is still positively significant, with the number of filed eco-patents as the dependent variable ($\beta = 1.496$). The effect is now slightly smaller compared to model (1) ($\beta = 1.550$), and the Pseudo R^2 has also decreased, indicating that when lags are introduced the independent variables explain even less of the variation in eco-patent filings. When introducing lags to the model, a time shift occurs because the lags create a delay between the cause and the effect. Therefore, approximately 13% of the total sample's observations are disregarded, which can be one explanation for the model's reduced ability to explain the variation in the dependent variable.

[50]See Appendix I for test results.

Fourthly, the last robustness test for PWH includes introducing similar lags on model (2). The effect is reduced again from $\beta = 1.866$ in the original model (2), to $\beta = 1.589$ in 'model (2) with 2-year lag'. Pseudo R^2 has again slightly decreased, which once more can be partly explained by the reduced sample size.

Finally, despite our models on PSH being insignificant, one robustness test is made on model (3b). We assume the time from R&D to affect firm performance is approximately four years.[51] Therefore, to conclude that the model is not insignificant because of the choice to not include lags, a model of robustness introducing a 4-year lag is conducted on fixed assets and operating revenue. However, this reduces the sample size by approximately 27%, and the coefficients of the interaction terms remain insignificant.

In conclusion, the robustness checks conducted do not provide new insights but rather reassure that there is internal validity in our models. The significance and sign of the coefficients remained the same for all models on PWH, indicating the chosen models provided robust results.

9 Discussion

This section provides a qualitative discussion of the results that have been found using our dataset. We will begin by linking our findings to interpretations and implications for both the Weak and Strong strands of the PH, leading us to answer our research question. Thereafter, we turn to a broader scope where we consider additional implications of our study, in the context of the future of the EU ETS and the PH. Finally, we consider the limitations of our study and introduce recommendations for further research.

9.1 Results Discussion

9.1.1 The EU ETS and Porter's Weak Hypothesis

Given Phase I and II of the EU ETS have been investigated in previous literature, this paper aims to serve as an extension by analyzing the policy effect of Phase III given more time has elapsed. According to the results from model (1), the first hypothesis can be accepted as we find evidence to support that regulated firms file more eco-patents than those who are non-regulated. The significance highlights that the EU ETS has spurred regulated firms to eco-innovate more, which is also reflected in Figure 9. With this in mind, we find support for PWH, however, model (2) dampens this support to a certain extent. We found that the increase in stringency between phases did not have a significant effect on eco-patent filings for regulated firms.

Phase III was considered as a large 'ramp up' from Phase II, by setting the emissions cap to decrease by 1.74% per annum. In addition, the EU tried to curb the supply of EUAs by setting the default to the auction market and further limiting the number of offsets one could credit. However, it appears as these changes, which endured over 7 years, were too lenient as firms did not drastically change their investment behavior. This paper can therefore make no inference from Porter's assumption that having stringent rules will lead to higher levels of eco-innovation for regulated firms. We believe that the 1.74% decreasing cap was not strict enough to spur ongoing innovation, as firms could calculate the total emission reduction required over the duration of the phase and choose to only innovate once. This raises the question of how stringent does an environmental policy have to be for PWH to fully hold? Perhaps it would be better to have shorter phases that pressure regulated firms to innovate more frequently, thereby putting eco-innovation higher on the agenda. This paper does not dive deep into this question, however, we do provide some policy implications the EU Commission could think about implementing, yielding greater intensities of filed eco-patents.

However, although we do not find support that increasing stringency of the EU ETS affected regulated

[51] There is no consensus on the number of years, however, it takes at least two years for an idea to materialize into a patent, and from here we assume an additional two years for the patent to be commercialized and incorporated into operations.

firms' eco-innovation behavior, there is nonetheless support for PWH arising in model (2). Both Phases II and III are significant in the number of eco-patents filed, meaning that both groups of firms have contributed to the total increase in eco-patents filings. We see that the magnitude of the coefficient in Phase III is marginally larger than in Phase II, which is in line with the increased stringency of the EU ETS. This is an interesting observation because it indicates that non-regulated firms are also choosing to eco-innovate, highlighting the spillover effects present and the social pressures of modern society. With increased awareness about the damage and role GHG emissions play in contributing to climate change, it is perhaps not surprising that non-regulated firms also choose to invest in cleaner and greener processes. We believe there are two motives for this, if we disregard environmental altruism.

Firstly, non-regulated firms are competing with regulated firms in the same industries. Therefore, they have had to adapt to the changes in consumer preferences and cater to what conscious customers are demanding. If they do not, they risk losing key accounts and damaging their reputation for not doing their part to help the environment. Secondly, innovation is a driver of growth. Experimenting with new technologies and processes could lead to streamlining the production of a particular product. Therefore if regulated firms are innovating, non-regulated firms do not want to risk falling behind and thus, competition prevailing in the markets could be an important driver of eco-innovation.

This reasoning provides an explanation as to why the interaction terms in model (2) were not significant, as the changes in behavior between regulated and non-regulated firms were not significantly different, as both groups increased eco-innovation when moving between phases. We believe that non-regulated firms who are not required to spend resources on eco-innovation are evidently doing so, and this is a testament to how aware and conscious the markets are becoming. Therefore, there is an element of PWH that is supported as the individual phases have had a significant impact on the filing of eco-patents. This makes it clear that environmental policy does not only affect regulated firms, rather it extends to all firms operating in sectors covered by the EU ETS. Perhaps a detail that should be incorporated in PWH is that environmental policies increase awareness and therefore stimulates firms in regulated sectors to innovate, regardless if they meet the individual installation threshold or not. As a result, in terms of the absolute number of eco-patents evolving over the course of the EU ETS, we observe evidence for PWH that stringency can have an effect on eco-innovation - disregarding whether the firms are regulated or not.

Overall, the findings from model (1) and (2) show support for the PWH. With regard to our research question, we do not find evidence to debunk PH. It is clear that the EU ETS framework has been carefully designed with a gradual increase in stringency, thereby yielding positive effects in regulated sectors. However, it would be naive to accredit the increase in eco-innovation purely to the EU ETS. We believe that the change in mindset regarding the climate change crisis has played a pivotal role in how firms are choosing to operate.

9.1.2 The EU ETS and Porter's Strong Hypothesis

The debate on whether environmental policy stunts economic growth by hindering firm competitiveness has been deliberated for years, "particularly in a world that is characterized by the rise in global value chains and the fragmentation and interdependence of production across multiple jurisdictions" (OECD, 2021). This has made the implementation of any environmental policy politically challenging. As aforementioned, results have been mixed with regard to previous phases of the EU ETS and firm competitiveness. This paper finds evidence that a well-designed policy, the EU ETS, has no negative consequences on the economy with regard to firm performance. In model (3ab), we found no significant difference in ROA between the two groups of firms, meaning regulated firms face neither a competitive advantage nor disadvantage. We therefore find a lack of support for PSH. Although regulated firms were not found to perform better than their counterparts, our results highlight a critical finding as firms who are subject to the EU ETS perform, in our sample, equal to those who are free to emit without having to adhere to a policy. For policymakers, this has important implications as this evidence is key to ensuring minimal carbon leakage occurs. If the EU Commission can relay evidence that deflates concerns regarding productivity slowdowns, more firms might be willing to opt into the EU ETS in the form of a PHA.

While the two mechanisms argued by Porter and Van der Linde (1995) for PSH are plausible, we believe that they have become outdated due to shifts in mindset around climate change. With global temperatures rising, GHGs are now considered a serious threat to the environment, and firms operating in energy-intensive (regulated) industries are becoming more conscious due to changes in consumer preferences. Therefore, as we saw in models (1) and (2), non-regulated firms are also eco-innovating and trying to find alternate processes to minimize total emissions. Thus, non-regulated firms face equal opportunities with regards to selling/ leasing new technology, and so, are also able to collect windfall profits. Hence, both regulated and non-regulated firms are able to capitalize on the additional revenue stream in the market, meaning this is not a distinguishable factor that enhances the performance of regulated firms.

Additionally, we begin to question whether the action of selling/ leasing innovations is utility maximizing in the framework of the EU ETS. The filing of patents, naturally, can only occur once R&D has been conducted (Gittelman, 2008). Summing the time for innovation research and the years until patent issuance leads to a substantial period of time before innovation can be sold on the market. Although the phases of the EU ETS have a long duration, with Phase III having the longest tenure, investing in own R&D is perhaps still the utility maximizing option - rather than waiting for other firms to create and sell their innovations. This is because, in the meantime, firms that are not eco-innovating must turn to the market and buy additional EUAs. Therefore, by the time innovations are put out on the market, the time horizon remaining until a new phase starts might be too short for a firm to justify the procurement of costly technologies. This, therefore, results in a market that is characterized by many sellers and few buyers, thereby making the notion of an additional source of revenue no longer a defining factor in influencing regulated firms' performance.

Furthermore, it is clear the inelastic nature of demand in the regulated sectors did not affect the ROA of regulated firms in our sample. Joltreau and Sommerfeld (2019) propose that additional profits gained from transferring eco-innovation costs onto the consumer are likely to only appear under specific market structures. Firms, therefore, require a certain degree of market power to collect windfall profits. An example where this is prevalent is the electricity sector because the distribution is reliant on national grid structures and guidance. This creates barriers for international firms to compete, hence this sector has been known to have a monopoly market structure (Clò, 2010). Joltreau and Sommerfeld (2019) show this evidence in the electricity sector compared to the manufacturing sector. Given the manufacturing sector makes up ∼60% of the firms in our sample, this is perhaps another reason why we do not find a significant difference in regulated ROA.

Moreover, we also concede that the outcomes in model (3ab) might have been influenced by the macroeconomic environment. We saw that for both Phase II and III the effect on ROA was negative and significant,[52] yielding lower financial performance across the board. The past decade has been turbulent, with the financial crisis hitting at the start of Phase II, and Brexit falling in the midst of Phase III. These two large events have likely, among others, had a significant impact on firm behavior and performance. The passing of the Brexit referendum introduced uncertainty within the EU, as trade agreements took four years to draft and this is a key pillar for firm competitiveness. This impacted the EU ETS because the trade in goods, including EUAs, were involved in discussions concerning tariffs given the United Kingdom decided to leave the EU single market. This could therefore have had an effect on ROA for all firms in the industries covered in the EU ETS as there are spillover effects such as supply chain disruptions.

In addition, PSH argues that it is eco-innovations that increase productivity, resulting in higher returns in the long run. This was tested in model (4), where we found no mediating effect, and in model

[52]The coefficient for Phase III was still negative, but less so compared to Phase II, suggesting an improvement over the time period.

(3b) where we found no significant results on the interaction terms. Despite previous literature alluding to analyzing data from Phase III being a sufficiently long time period to gauge the long-run effects on firm performance, it seems that this time horizon is still not long enough to find support for PSH. This paper collected over 15 years worth of firm performance data, yet no causal effect could be identified. It has become evident that this paper aligns with previous literature stating that "the relation between sustainable practices and altered financial performance might only hold in the long-term" (McWilliams and Siegel, 2000). Therefore, we further question how long of a time horizon is required to provide evidence to show whether the PSH truly holds in practice.

Henceforth, PSH is not supported in models (3ab) or (4), meaning either; the EU ETS framework is not well suited for the two mechanisms that Porter and Van der Linde (1995) argue facilitate enhanced firm performance, or, the PH is outdated given it has been almost three decades since its founding. This thesis believes that a lot has happened in the last three decades, and the rise of climate change activists has had an influential role in firms' decision-making. Therefore, we do not find additional sources of competitive advantage for regulated firms since non-regulated firms are behaving in a similar way. They too will reap potential long-term productivity gains, and therefore regulated firms do not realize any competitive edge. Thus, in light of the results presented and discussion regarding the mechanisms required for the hypothesis to hold, this thesis is inclined to, and will be, debunking PSH in the context of the EU ETS.

9.2 General Discussion - EU ETS Policy Implications

This paper acknowledges the primary goal of the EU ETS is to reduce GHG emissions, however, one must also recognize that innovation is the key driver contributing to the curbing of emissions in the atmosphere (Grubb, 2004). Thus, the findings of this study do have important implications for policymakers who design and implement environmental regulations. This section will therefore discuss what the EU can do to ensure that the 2050 net-zero target is reached.

To enhance ongoing eco-innovation among regulated firms, the EU could reconsider its approach to how they set their emission cap and influence the price of EUAs in the market. One policy recommendation is to implement a price floor,[53] building on the experience of the 'Californian Cap-and-Trade Program', where a price floor was introduced (Narassimhan et al., 2018). The Californian program used the EU ETS as a baseline but implemented a price floor to ensure a "reserve auction price" where the State set a reserve price to mitigate the shortcomings seen in the EAU price (Borghesi et al., 2016). If the EU were to implement this, it would ensure the price of EUAs never dropped below a specified value, providing more certainty and predictability to regulated firms. The implementation of a price floor, however, does not come without risks. Finding the social cost of carbon has been proven difficult, and a price floor set too high may lead to market distortion or increase the cost of compliance of regulated firms (EU-Commission, 2020b). Such factors may have negative implications for their competitiveness and result in government failure.

Another strategy to fuel an ongoing innovation stream could be through increasing the frequency of policy adjustments in the total emissions cap. Our analysis suggests that the long duration of the phases may have contributed to the lack of significant results for regulated firms' eco-patent filings, despite new adjustments in Phase III. Phase II and III spanned over 4 and 7 years respectively. This might be too long of a time period for there to be an incentive to continuously innovate, and instead, regulated firms may choose to innovate once during each phase due to the costly nature of R&D. However, if the EU Commission were to notify firms in advance that the cap will be progressively curbed at regular and more frequent intervals, such as every two years, then firms are pressured to eco-innovate more. They would no longer be able to utilize the same innovation (without further development) from the beginning of a phase until the end. However, this policy recommendation does not come without faults. The EU would

[53]In addition to the aforementioned Market Stability Reserve, implemented in January 2019, to facilitate a higher EUA price.

be required to communicate all adjustments several years ahead of time, to ensure certainty and provide firms with enough time to plan accordingly. Certainty is one of the three assumptions outlined by Porter and Van der Linde (1995), and is one that is crucial to maintain in order to keep trust and transparency in the EU ETS.

One of the major concerns previously discussed is the fear of carbon leakage because of potential competitive disadvantages faced by regulated firms compared to their competitors in non-EU countries. Although our findings show that the EU ETS has not had a negative impact on firm performance, the risk of carbon leakage remains significant and should be considered in future policymaking. It is critical for the EU to reassure and incentivize regulated firms, to avoid relocation of production to less regulated countries. This has previously been addressed through the allocation of free allowances to high-risk industries, such as steel and cement. Considering the impact this had on the price of EUAs, the EU is currently working on an alternative solution, which centers around implementing a carbon price on imports from countries with less stringent environmental regulations. The EU has decided to gradually introduce the Carbon Border Adjustment Mechanism (CBAM) starting in the fall of 2023, which will replace free allowances and set a fair price on the emissions from the production of imported carbon-intensive goods (EU-Commission, 2023a). The CBAM, therefore, ensures equal treatment of EU production and imported production.

Looking ahead, there is a possibility of linking several ETSs, or even creating a global ETS. In the Paris Agreement, a possible creation of a global carbon market is stated (EU-Commission, 2023e). Our research findings stipulating that regulation induces eco-innovation and does not harm firm competitiveness reinforces this possibility. We have observed that linking is possible, for example between the EU ETS and the Swiss ETS. Linking could provide greater flexibility in trading allowances and a larger market will both increase liquidity and decrease the cost of compliance (ICAP, 2023). However, to facilitate the encouragement of eco-innovation, it is important to provide clear and consistent regulations across the ETSs, requiring dedicated collaboration between governing bodies. Nonetheless, the linking of ETSs creates a global effort to develop and establish carbon markets. This could play a salient role in reaching carbon neutrality and promoting sustainable practices.

9.3 Limitations of this Study

Despite this study only finding significant results for regulated firms in model (1), with supporting evidence in model (2), it could be rash to make a conclusive statement regarding the impact of Phase III, as we have only modeled a single sample dataset. Our final matched dataset can be considered small in sample size with 284 firms, however prior studies applying the PSM method in the EU ETS context have also noted financial availability as a factor for the sample size reduction (e.g., Jaraite-Kažukauske and Di Maria (2016); Marin et al. (2018)). After reviewing the results tables, it is apparent that the coefficients have relatively large standard errors, which we believe can be attributed to considerable variations in the smaller sample size.

One limitation of this study was the complex task of sourcing input data. This involved string-matching data from multiple databases to access financial and patent data for each company owning an OHA, resulting in a larger margin for error (Jaraitė et al., 2013). Another limitation regarding the input data is the choice of covariates in the matching process and the control variables in the regression models. It would have been preferable to incorporate an additional covariate and control variable proxying innovation activity, such as R&D expenditures (Caliendo and Kopeinig, 2008). However, the limited data availability hindered this endeavor.

Moreover, this paper uses patents as a proxy for eco-innovation. This has previously been criticized as all innovations are not patentable, and the patented technology differs highly in terms of quality (Griliches, 1990). Furthermore, this thesis has aggregated all filed patents of subclasses Y02 and Y04S, in order to consider all patents related to GHG emissions, and not only specific minor classes.[54] In this way, it captures the degree of freedom and flexibility in the EU ETS, since they do not require firms to innovate in a particular way. However, Calel and Dechezleprêtre (2016) suggest that not examining minor classes separately could result in overlooking the potential policy effects. Their study found that the EU ETS had positive and significant results on specific minor classes, such as renewable energy, which would not be evident when analyzing at an aggregated level.

9.4 Further Research

This study offers valuable insights and serves as inspiration for future research on environmental policies. To further research the EU ETS, our newly developed dataset of firms can be utilized in several ways. Firstly, researchers could build on our study by examining the PH through the share of eco-patents within the total number of filed patents, to gain insights into firms' integration of green technology in their overall innovation strategy. Secondly, future research could examine the EU ETS's impact in comparison or conjunction with other policy interventions, as it could provide insights into which policy designs are counteracting or complementing each other (IETA, 2015). Thirdly, since the EU implements multiple environmental adjustments to achieve carbon neutrality, such as the CBAM, it will be essential to study the efficacy of newly developed sub-policies and their impact on firms in the context of the PH. However, if possible, we do recommend future researchers to aim to achieve a larger sample size, for example by attempting to use national databases in combination with EU databases.

Moreover, it is our aim that this study will serve as inspiration for further research into environmental regulations in general. One promising subject would be the exploration of the potential linkage between ETSs and its effect on firms. Such research has the potential to yield valuable insights, as there are discussions surrounding the potential linkage of the EU ETS with the newly developed UK ETS.[55] Finally, we highly encourage additional research into the PH. To enhance the external validity of the PH, future research could apply the same methodology of this paper in another environmental setting, such as the newly developed China National ETS.

10 Conclusion

The Porter Hypothesis is an environmental policy theory stating regulation induces eco-innovation, which in turn enhances firm performance and productivity. To better be able to understand whether the Porter Hypothesis holds, the theory is tested on an environmental policy encompassing the desirable characteristics (stringent and well-designed) outlined by Porter and Van der Linde (1995). This study has examined the EU Emissions Trading System, the largest cap-and-trade system in the world, with the objective to test the validity of the Porter Hypothesis and shed more light on the most recent EU ETS phase. The identification methodology adopted was Propensity Score Matching. This constructed a counterfactual group of non-regulated firms operating in regulated industries, who had similar eco-innovation resources during the pre-policy year of 2004. Furthermore, the empirical methodology included two Difference-in-Difference analyses for each strand of the Porter Hypothesis investigated, as well as a mediation analysis to further evaluate the Strong variant of the Porter Hypothesis.

Recall the research question:

Is it time to debunk the Porter Hypothesis?
Can environmental policy really induce innovation and enhance firm performance?

[54] Y02 and Y04S have further subclasses within their classification. Therefore, minor subclasses represent specific types of innovation within the classification.
[55] The UK ETS replaced UK's participation in the EU ETS in January 2021 (UK-Government, 2023).

Our results suggest Porter's Weak Hypothesis holds. Over the entirety of the EU ETS, eco-innovation has increased for regulated firms, and we have found that the increase in stringency across phases also had a significant impact on the total number of eco-patents filed - irrespective if a firm was regulated or not. With Phase III being the most stringent over the time period investigated, it was found that this phase had the largest effect on eco-innovation with a $\beta = 0.7030$ at a <1% significance level. Furthermore, our results for Porter's Weak Hypothesis are robust in that they are neither driven by specific EU countries nor by any exclusion of countries from the sample. This evidence supports the short-run effects of environmental regulation and Porter's Weak Hypothesis, rendering this strand of the hypothesis valid and still relevant.

However, turning to the long-run effects on firm performance, our results were insignificant, but highlighted that environmental regulation has no adverse effects on firm performance. The lack of significant results suggests that regulated firms are not better off than their non-regulated counterparts. Furthermore, eco-innovation was found not to have a mediating effect on firm performance, suggesting it is not a significant driver of productivity and output of firms. Therefore, this study finds no evidence of Porter's Strong Hypothesis in the context of the EU ETS, leading us to debunk this strand. This thesis provides additional insights as to why the Strong variant of the Porter Hypothesis is not valid for the EU ETS and credits the shift in mindsets around climate change as a large contributing factor. This factor has progressively evolved over the last decade, alluding to the fact that Porter's Strong Hypothesis is outdated given the mechanisms involved for the strand to hold are no longer distinct or solely confined to regulated firms.

This thesis has further provided policy implications and discusses potential adjustments that the EU could implement to ensure the 2050 net-zero target can be reached. Firstly, drawing on the success of the Californian Cap-and-Trade Program, the implementation of a price floor could improve price stability in the EUA carbon market and hence, increase certainty among firms operating in the scope. Additionally, increasing the frequency of policy adjustments could spur higher levels of eco-innovation, the driving force behind reducing emissions. Furthermore, we discuss measures the EU Commission has expressed, such as the CBAM and the potential linking of other ETSs around the world.

Lastly, this thesis has provided recommendations to encourage further research. The first suggestion is to utilize the newly developed dataset for further research on the EU ETS and the Porter Hypothesis, including; examining the integration of eco-patents into firms' overall innovation strategy, studying the interaction between the EU ETS and other policies, and assessing the effectiveness of newly developed sub-policies. We also encourage achieving a larger sample size and recommend combining national databases with the EU databases to achieve greater access to financial data such as R&D into carbon mitigating technology. Furthermore, we call for ongoing endeavors into examining the Porter Hypothesis, but in other cap-and-trade systems to enhance the external validity of the theory. Finally, we encourage researchers and economists to continue analyzing general environmental policy and its effect on firm performance. This is key as firms need to realize the strain they are putting on the planet, and we see environmental policies having the potential to make our world more sustainable, and revert the anthropogenic climate change that has already occurred.

To conclude, we hope this thesis inspires more research to be conducted into the inconclusive Porter Hypothesis, as well as additional case studies on the third phase of the EU ETS. Given the severity of climate change and political challenges related to implementing environmental policies, this is a topical field leaving room for more research.

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12 Appendix

12.1 Appendix A: EU ETS Phases (Elaborated)

Phase I: The three-year pilot ran between 2005-2007 and is said to be 'the cornerstone for environmental policy', and was regarded as a kinaesthetic 'learning by doing' phase. Initially, the only GHG regulated was CO_2, with power generators and energy intensive industries being covered. As previously mentioned, to mitigate carbon leakage all EUAs were provided by the EU for free. However, this proved to be ineffective as the EU had overestimated emissions resulting in excess supply of allowances in the market. By 2007, the price of carbon had fallen to zero as supply far exceeded the demand. Thus, it was decided no allowances were to be carried forward into Phase II. Overall, $\sim$11,000 installations in the EU27 met the threshold for regulation, and the total emission cap was set to 2,058 million tCO_2 per annum. The cap was based on the National Allocation Plans (NAPs) that each account holder submitted to their residing country.

Phase II: Lasting between 2008-2012, the second phase implemented a 6.5% lower cap on emissions at 1,859 million tCO_2 per annum and saw the addition of three new countries. Nonetheless, despite reducing the free allowance allocation to 90% and further curbing the cap, there continued to be an oversupply of EUAs. Emissions fell more than expected in 2008-2009 due to the financial crisis which weighed heavily on the market price of carbon throughout the phase. Further changes from the first phase included an increase in the fine from €40 to €100 per tCO_2.

Phase III: With a reign over the period 2013-2020, new countries and sectors were included and more stringent regulations put into place. Firstly, to aid harmonization between member states, the NAPs were abolished and replaced with an EU-wide cap. This cap was set to decrease linearly by 1.74% per annum which is equivalent to reducing 38 megatons of CO_2 every year. In addition, rather than free allowance allocation, the default method for allocating allowances turned to market auctioning. Furthermore, a cap of 50% allowance in offset crediting was implemented. These policy adjustments helped to curb supply and stimulate the trading of EUAs among countries, as well as stabilizing the price of carbon.

Phase IV: It was agreed in 2018 that the fourth phase would operate between 2021-2030. The primary adjustment to phase three would be the emission cap, which now declines at 2.2% per annum. Although not decided, there were also talks about linking the EU ETS with other emission trading systems, for example with Australia.

12.2 Appendix B: EU ETS Sectors

Table 6: Sectors present in the EU ETS

Source: Data retrieved from EU-Commission (2020a)

Activities	**Sector**	**No. of Installations**
Combustion of fuels	Combustion	7662
Refining of mineral oil	Refineries	140
Production of Coke	Iron and Steel, coke, metal ore	20
Metal Ore roasting or sintering		10
Production of pig iron or steel		244
Production/ Processing of ferrous metals	Other metals	257
Production of primary aluminium		33
Production of secondary aluminium		36
Production/ Processing of non-ferrous metals		86
Production of cement clinker	Cement and Lime	263
Production of Lime		293
Manufacture of glass	Other non-metallic minerals	371
Manufacture of ceramics		1093
Manufacture of mineral wool		54
Production/ Processing of plasterboard		40
Production of pulp	Pulp and paper	181
Production of paper or cardboard		594
Production of carbon black	Chemicals	18
Production of nitric acid		36
Production of adipic acid		3
Production of glyoxal and glyoxylic acid		1
Production of ammonia		29
Production of bulk chemicals		366
Production of hydrogen and synthesis gas		43
Production of soda ash and sodium bicarbonate		15
Aviation	Aviation	376
Capture of GHG	Other	3
Other Activity		249
Total		**12,516**

12.3 Appendix C: The Porter Hypothesis - Flowchart

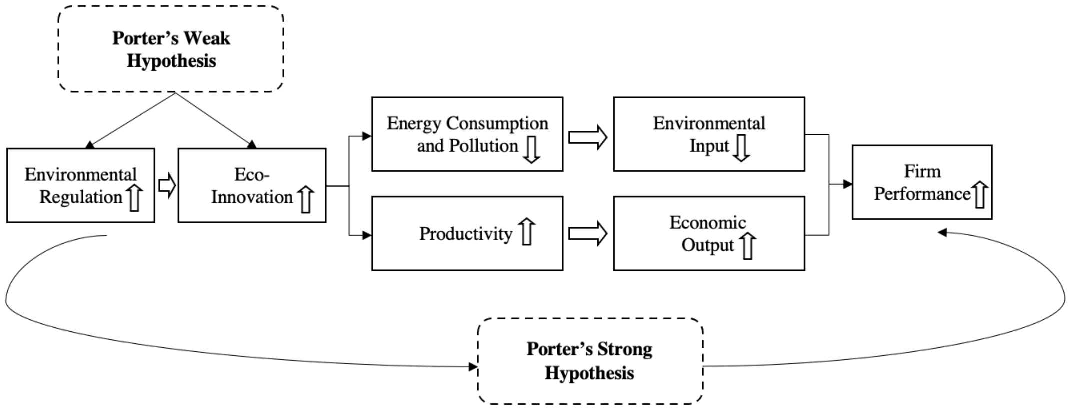

Figure 11: Porter Hypothesis Flowchart
Source: Authors' illustration

12.4 Appendix D: Final Dataset Demographics

Table 7: Demographics of Firms in sample
Source: Data retrieved from EU-Commission (2020a) and Orbis (2023)

Code	**Name**	**N**	
AT	Austria	8	(3%)
BE	Belgium	18	(6%)
CZ	Czech Republic	8	(3%)
DE	Germany	26	(9%)
DK	Denmark	10	(4%)
ES	Spain	38	(13%)
FI	Finland	15	(5%)
FR	France	31	(11%)
GB	Great Britain	39	(14%)
GR	Greece	5	(2%)
HU	Hungary	2	(1%)
IE	Ireland	7	(2%)
IT	Italy	19	(7%)
NL	The Netherlands	7	(2%)
PL	Poland	21	(7%)
PT	Portugal	3	(1%)
SE	Sweden	24	(8%)
SI	Slovenia	3	(1%)

Table 8: Sectors according to two-digit NACE classification in sample

Source: Data retrieved from EU-Commission (2020a) and Orbis (2023)

Code	**Sector description**	**N**	
05	Mining of coal and lignite	3	(1%)
06	Extraction of crude petroleum and natural gas	4	(1%)
07	Mining of metal ores	10	(4%)
08	Other mining and quarrying	5	(2%)
09	Mining support service activities	8	(3%)
10	Manufacture of food products	18	(6%)
11	Manufacture of beverages	7	(2%)
12	Manufacture of tobacco products	2	(1%)
13	Manufacture of textiles	2	(1%)
14	Manufacture of wearing apparel	7	(2%)
15	Manufacture of leather and related products	2	(1%)
16	Manufacture of wood and products of wood and cork	4	(1%)
17	Manufacture of paper and paper products	11	(4%)
18	Printing and reproduction of recorded media	5	(2%)
19	Manufacture of coke and refined petroleum products	4	(1%)
20	Manufacture of chemicals and chemical products	20	(7%)
21	Manufacture of basic pharmaceuticals and pharmaceutical preparations	15	(5%)
22	Manufacture of rubber and plastic products	7	(2%)
23	Manufacture of other non-metallic mineral products	17	(6%)
24	Manufacture of basic materials	11	(4%)
25	Manufacture of fabricated metal products, excluding machinery & equipment	8	(3%)
26	Manufacture of computer, electronic and optical products	17	(6%)
27	Manufacture of electrical equipment	7	(2%)
28	Manufacture of machinery and equipment	9	(3%)
29	Manufacture of motor vehicles and trailers	8	(3%)
30	Manufacture of other transport equipment	6	(2%)
31	Manufacture of furniture	2	(1%)
32	Other manufacturing	3	(1%)
35	Electricity, gas, steam and air conditioning supply	29	(10%)
41	Construction of buildings	10	(4%)
42	Civil engineering	7	(2%)
50	Water transport	1	(0%)
51	Air transport	3	(1%)
52	Warehousing and support activities for transportation	4	(1%)
53	Postal and courier activities	1	(0%)
58	Publishing activities	1	(0%)
61	Telecommunications	1	(0%)
62	Computer programming, consultancy and related activities	1	(0%)
64	Financial service activities, excluding insurance and pension funding	1	(0%)
68	Real estate activities	2	(1%)
74	Other professional, scientific and technical activities	1	(0%)

12.5 Appendix E: Diagnostic Check Results

1. **The Breusch Pagan Test**: The Breusch and Pagan (1980) test is conducted to detect potential heteroskedasticity in the error terms that can cause biased standard errors. The results showed a significant p-value, indicating issues with heteroscedasticity.
2. **The Hausman Test**: The Hausman (1978) test is performed to determine whether fixed effects or random effects are most appropriate for the model (Zulfikar and STp, 2018), in which the low p-value indicates fixed effects are most suitable.
3. **The Wooldridge Test**: Wooldridge (1990) F-statistic is undertaken to test for serial correlation. The null hypothesis was rejected, indicating presence of serial correlation.
4. **The Pesaran Test**: The Pesaran (2015) test is conducted to address issues with cross-sectional dependence that can occur in large panel datasets. For this test, the null hypothesis was rejected, thus cross-sectional dependence is present.
5. **The VIF Test**: The Variance Inflation Factor (VIF) test is conducted to ensure that the results are not affected by multicollinearity, which is recommended when using multiple regression models (O'brien, 2007). In all regression models, year dummies are excluded due to multicollinearity. Nevertheless, the VIF value is below the threshold at 10 for the explanatory variables.

Model (1) and (2)

Table 9: Diagnostic check results on Eco-patents as a dependent variable
Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Test	BP	df	Chi-Squared	z value	P-value
Breusch-Pagan	552.5	60			<2.2e-16
Hausman		2	24.12		5.787e-6
Wooldridge		1	420.86		<2.2e-16
Pesaran				414.54	<2.2e-16

	GVIF*	df	GVIF(^1/(2*df))
Regulated	1.5247	1	1.2347
Phase	1.014	1	1.0071

Model (3) and (4)

Table 10: Diagnostic check results on ROA as a dependent variable
Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Test	BP	df	Chi-Squared	z value	P-value
Breusch-Pagan	267.19	60			<2.2e-16
Hausman		2	11.604		0.003022
Wooldridge		1	310.71		<2.2e-16
Pesaran				13.531	<2.2e-16

	GVIF*	df	GVIF(^1/(2*df))
Regulated	1.5247	1	1.2347
Phase	1.014	1	1.0071

*Where GVIF stands for Generalized Variance Inflation Factor. The GVIF value are the same for both regression models as the same independent variables are used (Investopedia, 2023).

12.6 Appendix F: Difference-in-Difference Graphs for 2004-2020

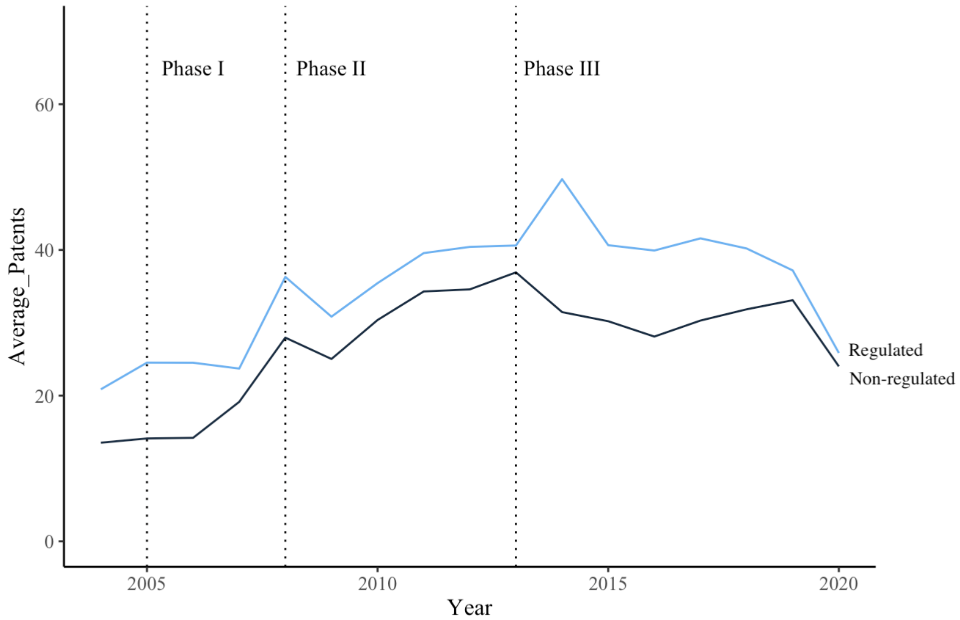

Figure 12: Eco-patent Evolution, 2004-2020
Source: Authors' rendering of data from PATSTAT (2023)

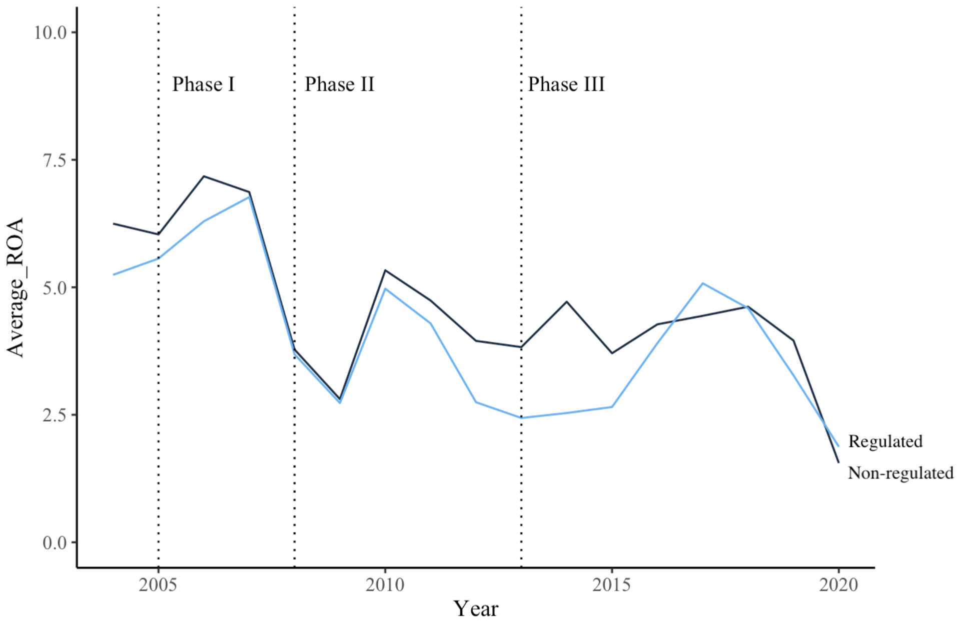

Figure 13: ROA Evolution, 2004-2020
Source: Authors' rendering of data from Orbis (2023)

12.7 Appendix G: Difference-in-Difference Graphs with Confidence Intervals

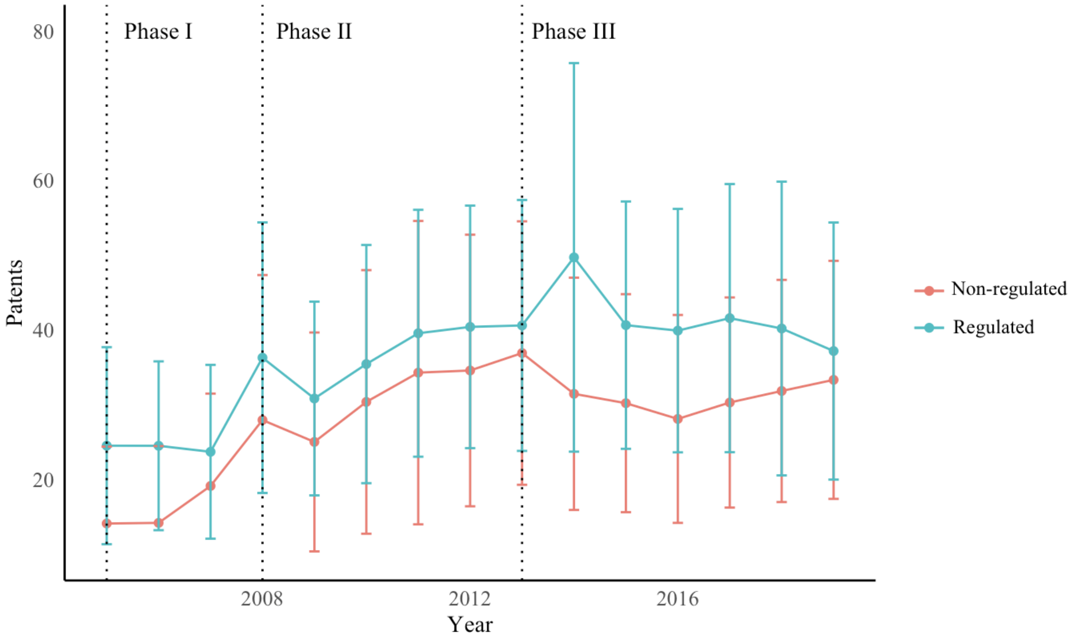

Figure 14: 95% Confidence Interval, Eco-patents
Source: Authors' rendering of data from PATSTAT (2023)

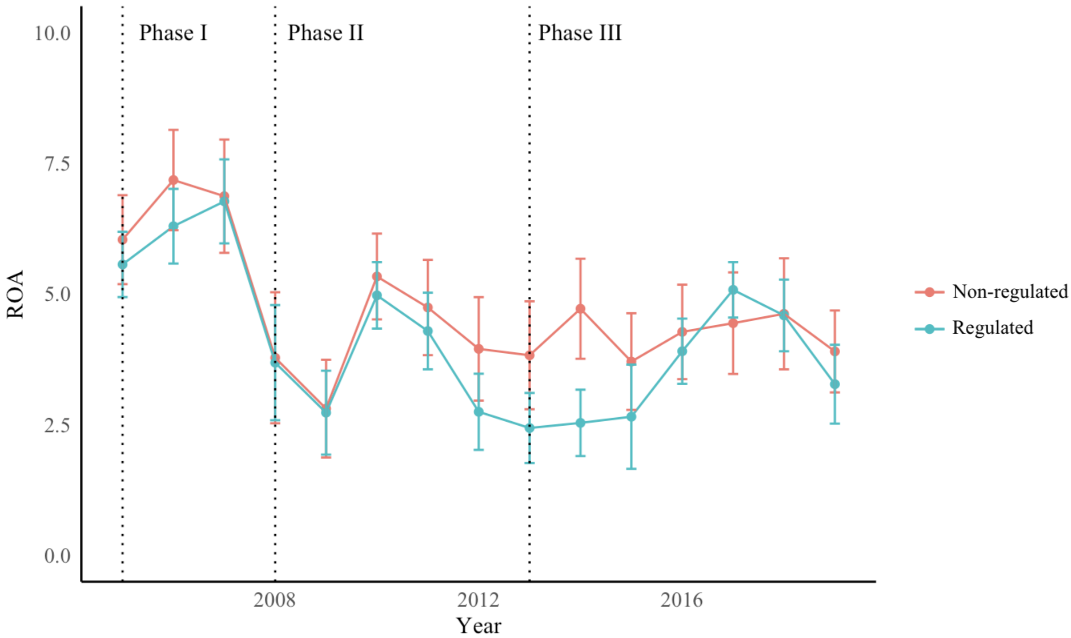

Figure 15: 95% Confidence Interval, ROA
Source: Authors' rendering of data from Orbis (2023)

12.8 Appendix H: Event Study Plots

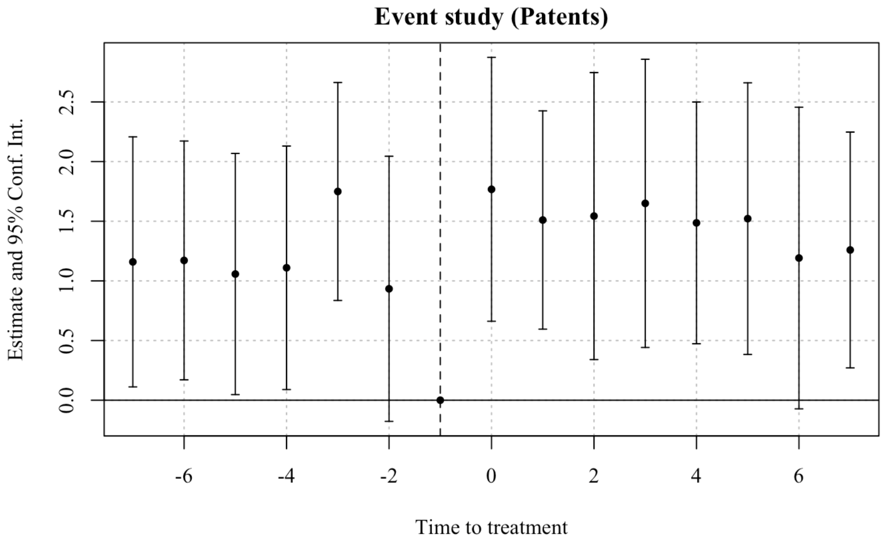

Figure 16: Event Study Plot, Eco-patents
Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

This figure plots the event study lead and lag estimates of the regressions with their 95% confidence intervals (Hansen and Shapiro, 2019). On the y-axis, the interaction between time to treatment and the treatment variable is plotted, and on the x-axis, the years, with the year before treatment (2012) as the baseline year (the vertical dotted line), are plotted. From this graph, it is clear that the number of patents filed is positively significant for almost every separate year, both before and after the increasing stringency of Phase III. However, the coefficients are slightly higher after 2013, indicating more patents are filed after Phase III. This is in line with our aggregated results from the models.

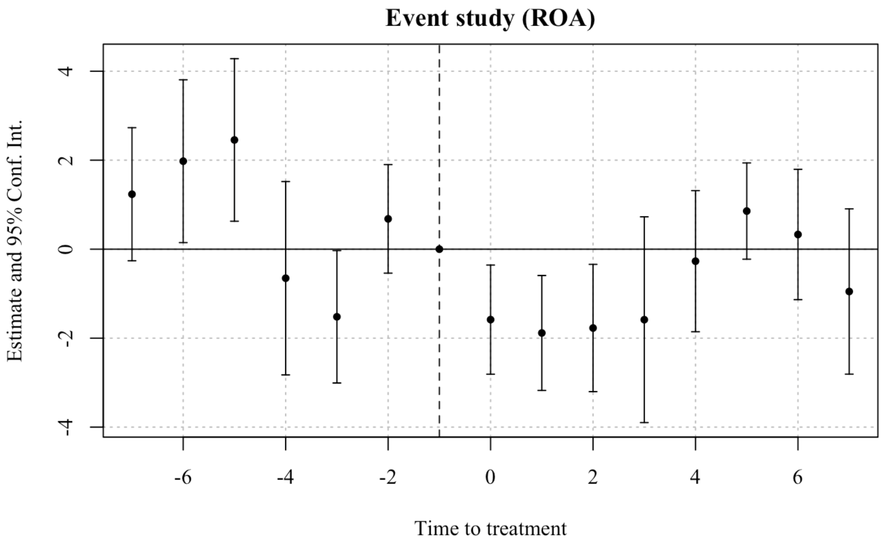

Figure 17: Event Study Plot, ROA
Source: Authors' rendering of data from Orbis (2023)

The event study plot for ROA shows both significant and insignificant effects. The three years following the treatment year are significant and negative, indicating a drop in ROA for the aggregated firms in the separate years. However, the effect becomes insignificant and close to zero after three years. Therefore, given that the post-Phase III coefficients are varied, this provides an explanation as to why the interaction term in model (3b) was not significant.

12.9 Appendix I: Robustness Test Results

Table 11: Robustness test excluding countries on model (1)

Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Dependent Variable	**ln_Eco-patents**			
Model	**(1)**	**(Excluding GB)**	**(Excluding ES)**	**(Excluding FR)**
Regulated	1.550** (0.5189)	1.493* (0.6398)	1.876** (0.5181)	1.759** (0.4595)
Fixed Assets	2.69e-8. (1.33e-8)	9.16e-9 (2.26e-8)	1.85e-8 (1.23e-8)	2.8e-8. (1.43e-8)
Operating Revenue	2.81e-8 (1.73e-8)	1.18e-7* (4.43e-8)	3.38e-8 (1.97e-8)	2.96e-8 (1.85e-8)
Fixed effects				
Country	YES	YES	YES	YES
Industry	YES	YES	YES	YES
S.E Type	Clustered Robust	Clustered Robust	Clustered Robust	Clustered Robust
Observations	4,260	3,675	3,690	3,795
Pseudo R^2	0.09084	0.09438	0.09219	0.09337

0.0 '***' 0.001'**' 0.01'*' 0.05'.'

Table 12: Robustness test excluding countries on model (2)

Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Dependent Variable	**ln_Eco-patents**			
Model	**(2)**	**(Excluding GB)**	**(Excluding ES)**	**(Excluding FR)**
Regulated	1.866*** (0.4645)	1.684** (0.5540)	2.161*** (0.4501)	1.986** (0.5976)
Fixed Assets	2.55e-8. (1.3e-8)	7.96e-9 (2.29e-8)	1.72e-8 (1.21e-8)	2.67e-8. (1.39e-8)
Operating Revenue	2.87e-8 (1.73e-8)	1.18e-7* (4.44e-8)	3.43e-8 (1.97e-8)	3.01e-8 (1.84e-8)
Phase II	0.6706** (0.2229)	0.5628* (0.2299)	0.6432* (0.2551)	0.6374* (0.2419)
Regulated x Phase II	-0.4104 (0.3574)	-0.2797 (0.2984)	-0.4101 (0.3234)	-0.3148 (0.2957)
Phase III	0.7030* (0.2555)	0.5431. (0.2786)	0.5856* (0.2750)	0.6120* (0.2847)
Regulated x Phase III	-0.3733 (0.3365)	-0.1842 (0.5043)	-0.3099 (0.4890)	-0.2506 (0.5108)
Fixed effects				
Country	YES	YES	YES	YES
Industry	YES	YES	YES	YES
S.E Type	Clustered Robust	Clustered Robust	Clustered Robust	Clustered Robust
Observations	4,260	3,675	3,690	3,795
Pseudo R^2	0.09084	0.09438	0.09219	0.09337

0.0 '***' 0.001'**' 0.01'*' 0.05'.'

Table 13: Robustness test with two-year lag on Fixed Assets and Operating Revenue, model (1)

Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Dependent Variable	**ln_Eco-patents**	
Model	**(1)**	**(With 2 year lag)**
Regulated	1.550** (0.5189)	1.496** (0.5547)
Fixed Assets	2.69e-8. (1.33e-8)	2.87e-8* (1.35e-8)
Operating Revenue	2.81e-8 (1.73e-8)	2.7e-8 (1.88e-8)
Fixed effects		
Country	YES	YES
Industry	YES	YES
S.E Type	Clustered Robust	Clustered Robust
Observations	4,260	3,692
Pseudo R^2	0.09084	0.08967

0.0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

Table 14: Robustness test with two-year lag on Fixed Assets and Operating Revenue, model (2)
Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Dependent Variable	**ln_Eco-patents**	
Model	**(2)**	**(With 2 year lag)**
Regulated	1.866*** (0.4645)	1.589** (0.4757)
Fixed Assets	2.55e-8. (1.3e-8)	2.81e-8* (1.3e-8)
Operating Revenue	2.87e-8 (1.73e-8)	2.72e-8 (1.3e-8)
Phase II	0.6706** (0.2229)	0.4332 (0.2625)
Regulated x Phase II	-0.4104 (0.3574)	-0.1009 (0.3646)
Phase III	0.7030* (0.2555)	0.4581 (0.2967)
Regulated x Phase III	-0.3733 (0.3365)	-0.0967 (0.5210)
Fixed effects		
Country	YES	YES
Industry	YES	YES
S.E Type	Clustered Robust	Clustered Robust
Observations	4,260	3,692
Pseudo R^2	0.09084	0.08977
	0.0 '***' 0.001'**'	0.01'*' 0.05'.'

Table 15: Robustness test with four-year lag on Fixed Assets and Operating Revenue, model (3b)
Source: Authors' rendering of data from Orbis (2023) and PATSTAT (2023)

Dependent Variable	**Return on Assets**	
Model	**(3b)**	**(With 4 year lag)**
Regulated	-0.1343 (0.9357)	0.2769 (0.9340)
Fixed Assets	-2.36e-8** (7.38e-9)	8.95e-9 (6.71e-9)
Operating Revenue	3.1e-8** (1e-8)	1.52e-8 (9.55e-9)
Phase II	-2.575*** (0.4826)	-2.755*** (0.5719)
Regulated x Phase II	0.0547 (0.6942)	0.3246 (0.6399)
Phase III	-2.477** (0.4414)	-2.670** (0.9124)
Regulated x Phase III	-0.1855 (1.148)	-0.6010 (1.078)
Fixed Effects		
Country	YES	YES
Industry	YES	YES
S.E Type	Clustered Robust	Clustered Robust
Observations	4,260	3,124
Pseudo R^2	0.02420	0.02265
	0.0 '***' 0.001 '**'	0.01 '*' 0.05 '.'