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Competitive Carbon Reductions?

Firm-level Analysis of Emission Abatement and Competitiveness in the EU Emission Trading System

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Abstract

The impact of EU ETS Phase III on firm-level GHG emissions and competitiveness is examined in this study utilizing a Difference-in-Differences empirical method supplemented by Propensity Score Matching. It finds a significant and increasing reduction in emissions among regulated firms, indicating the regulation's effectiveness. Firms classified as underallocated experience more substantial emissions reductions, challenging the Coase theorem. Surprisingly, regulated companies exhibit a significant and growing positive effect on competitiveness, aligning with the Porter hypothesis. Regional and sectoral analyses reveal nuanced results, emphasizing the importance of tailored support for regions with unique characteristics. This study highlights the potential of market-based mechanisms to promote environmental and economic sustainability in global efforts to combat climate change.

Keywords: Environmental regulation, Emission trading system, GHG, Porter hypothesis, Coase theorem, Competitiveness, Difference-in-Differences, Propensity Score Matching

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1. Introduction

In recent years, there has been a growing recognition of the need to address climate change on a global scale. Environmental negotiations and policymaking have increasingly focused on the urgent threats posed by rising greenhouse gas (GHG) emissions. Within the realm of environmental policymaking, both at the global and European Union (EU) levels, there has been a shift toward introducing more ambitious and comprehensive objectives and policies. Launched in 2005, the EU Emissions Trading System (EU ETS) is a prime example of such environmental policies covering more than 10,000 stationary installations and accounting for roughly 40% of GHG emissions in EEA-EFTA states (European Commission, 2023a). This emission reduction scheme establishes emissions caps for specific sectors, and creates a market for emission trading among companies. This framework establishes a transparent carbon price, motivating emissions reductions and cleaner technology investments (ICAP, 2021).

However, questions have emerged about the trade-off between stringent regulations and firm competitiveness which were particularly accentuated at the beginning of Phase III of EU ETS (2013-2020). This phase saw significant regulatory changes such as a substantially reduced overall cap, a significant shift towards auctioning as the default allocation method and new benchmark-based free allocation mechanisms (European Commission, 2023a). This transition presents an empirical opportunity to assess the effectiveness of the EU ETS in incentivizing regulated firms to reduce their emissions and to test whether there is a trade-off between the stringency of environmental regulation and the competitive performance of affected firms.

Past research in this domain has not provided a straightforward answer to the question of how EU ETS incentivizes firm-level emission abatement and what are the system’s effects on the competitiveness of regulated companies. Furthermore, existing studies have primarily focused on the early trading periods, Phase I and Phase II, potentially missing the long-term effects that may emerge as abatement requirements become more ambitious (Joltreau & Sommerfeld, 2018). This study aims to contribute valuable insights into this ongoing debate by examining the emission abatement efforts of companies and the competitiveness effects in Phase III compared to Phase II by utilizing four financial performance indicators as proxies for competitiveness (Value added, EBITDA, ROE, and Profit Margin).

A comprehensive dataset is created by combining and analyzing the EU Transaction Log (European Commission, 2023c) and the Orbis database (Bureau van Dijk, 2023) with application of Simon (2021) in connecting the two sources of data. A first-differences methodology is applied to estimate the effects of the more stringent regulation of Phase III on GHG emissions compared to Phase II. Subsequently, for the examination of the effects on the competitiveness indicators, a Propensity Score Matching (PSM) method is utilized to create a comparable control group to reduce selection bias and a Difference-in-Differences (DiD) method is applied to reduce endogeneity concerns. The research offers a valuable addition to the discourse on environmental policy and corporate behavior.

The core of this study revolves around two overarching research questions. Research Question 1 (RQ1): What was the effect of Phase III of the EU ETS on firm level emissions among regulated companies? Research Question 2 (RQ2): How did the increased regulatory stringency in EU ETS Phase III impact regulated companies' competitiveness? We will examine these questions through a set of hypotheses, each addressing distinct aspects of firm-level effects of EU ETS Phase III on emissions and competitiveness.

Hypothesis 1a postulates a significant and increasing reduction in GHG emissions at the firm level throughout Phase III for those companies subjected to EU ETS regulations. This hypothesis was supported by our analysis. *Hypothesis 1b* takes a closer look at the allocation of emission allowances, suggesting that firms classified as underallocated, receiving fewer allowances than their verified emissions, experience more pronounced reductions. Our findings reinforced this hypothesis. *Hypothesis 1c* explores the influence of an abrupt decrease in Allocation Factor (AF) on emissions by firms, specifically between the transition from Phase II to Phase III and this hypothesis was also substantiated. Building upon these firm-level analyses, Hypotheses 1d and 1e expand the scope to examine whether similar patterns can be observed when comparing firms in different sectors and regions, examining sectoral and regional dynamics. Our results revealed that at the regional level, Hypotheses 1d and 1e was not supported, but the sectoral analysis provided partial support.

Shifting the focus to the competitive landscape, *Hypothesis 2a* investigates whether regulated companies under EU ETS Phase III faced a significant negative impact on their competitiveness indicators compared to non-regulated counterparts, examining the potential repercussions of stringent environmental regulation on business performance. However, this hypothesis was rejected, and instead, our findings indicated a positive competitiveness effect which is the most intriguing finding of our analysis. *Hypothesis 2b* extends this inquiry by scrutinizing firms in sectors and regions that did not significantly adjust their emission paths, aiming to uncover any correlations between regulatory stringency and competitiveness effects. *Hypothesis 2b* was partially supported by our analysis. These hypotheses are grounded in existing literature and theoretical frameworks, serve as the foundation for our in-depth analysis of the EU ETS during Phase III.

The remainder of this paper is structured as follows. Section 2 introduces the theoretical framework that explores the potential competitiveness effects of environmental regulation, examines carbon offsetting cap-and-trade systems with a particular focus on allocation methods, and introduces the EU ETS in detail. Section 3’s literature review delves into empirical assessments of allocation methods in the EU ETS, and formulates the hypotheses of this paper derived from the existing body of research. In section 4, the main data sources and the empirical methodology is introduced, expanding on the application of PSM and the DiD approach. The results of the empirical investigation follow in section 5, presenting and interpreting the research findings. Section 6’s Conclusion & Limitations section summarizes the key insights and contributions of the study in advancing our understanding of the EU ETS and its impact on environmental outcomes and competitiveness. Furthermore, the last section also highlights the limitations of the study, providing future research directions and opportunities for improvement of the empirical design.

2. Theoretical framework

2.1. Competitiveness & Carbon leakage effects of environmental regulations

The debate surrounding the impact of environmental regulations on business competitiveness has been a persistent and evolving discourse since the 1970s. According to neoclassical economic theory stringent environmental regulations hinder the competitiveness of domestic firms by imposing additional costs and restrictions on their operations. The Pollution Haven Hypothesis specifically states that more stringent environmental regulations can elevate compliance costs, potentially driving pollution-intensive production to regions with lower abatement expenses, effectively creating what are termed "pollution havens” (Jaffe et al., 1995). This process is also known as carbon leakage.

Competitiveness holds vital significance in the discourse surrounding environmental regulation. The notion of competitiveness generally encompasses three levels, ranging from firm-level competitiveness to sectoral and national competitiveness. This research primarily focuses on firm-level competitiveness in its empirical investigations. At this micro level, competitiveness refers a firm's ability to manufacture high-quality, distinct products at minimal costs while maintaining market shares and profitability (Arlinghaus, 2015). There are two basic measurement approaches to firm-level competitiveness: the analysis of the drivers of competitiveness, such as resource productivity and internationalization; and the assessment of competitive success, measured by market performance, financial outcomes, and overall economic well-being (Ellerman et al., 2010).

Disparities in regulatory stringency across countries can lead to asymmetric impacts on firms competing within the same market. The resulting changes in relative production costs, arising from both direct and indirect regulatory expenses, can affect businesses differently, potentially decreasing the competitiveness of those located under the more stringent regulatory regime. The second-order effect of these disparities are the firm's responses such as changing the production volume, prices or the volume and focus of their investments. Third-order effects may include changes in economic, technological, environmental and trade-related outcomes as well (Dechezlepretre & Sato, 2017). The economic outcomes are what Ellerman et al. (2010) refers to as the competitive success of companies. This perceived threat to the competitiveness and the risk of carbon leakage have emerged as significant obstacles to the implementation of ambitious climate policies globally and has prompted policymakers to make compromises in the environmental ambition of climate policies in order to address these concerns (Branger et al., 2015).

The Porter Hypothesis, which is based on the dynamic competitiveness theory developed by Porter & van der Linde (1995), states that rigorous regulations can, in fact, bolster the competitiveness of firms by encouraging efficiency enhancements that reduce costs, fostering innovation. In the short term, industries may experience increased compliance costs that could potentially challenge their competitiveness. However, in the long run, if these regulations are rigorously enforced, they can create strong incentives for domestic companies to innovate and adapt, which could ultimately enhance their competitiveness (Peuckert, 2014). Further potential competitive advantages of rigorously enforced environmental legislation on a country level include benefits to sectors involved in providing environmental services, such as manufacturers of pollution control equipment. Additionally, in some cases, stringent regulations may result in the closure of exceptionally inefficient plants, leading to overall productivity enhancing industry restructuring (Jaffe et al., 1995).

This revisionist perspective on environmental regulation, views regulatory frameworks not as impediments but as industrial policy instruments that can actually enhance the competitiveness of firms. This perspective diverges from neoclassical economics by challenging the static mindset and making two critical assumptions: first, that the private sector may systematically overlook profitable innovation opportunities, and second, that regulatory authorities have the capacity to correct this perceived market failure by providing incentives for innovation through effective regulation (Testa et al., 2011). The Porter hypothesis has faced skepticism among economists. They question the assumption imbedded in the Porter hypothesis that firms are systematically ignorant of profitable production improvements due to regulations. They raise concerns about the knowledge gap between regulators and firms regarding these improvements and whether continuously escalating regulatory standards will consistently lead to the development of new clean and profitable technologies (Jaffe et al., 1995). Additionally, environmental regulations often represent a substantial net cost to firms rather than a source of innovation-driven profit (Jaffe & Palmer, 1997).

One of the primary objectives of this study is to provide a comprehensive exploration of the complex dynamics and influential determinants that underlie the impacts of stringent multilateral environmental regulations on firm-level competitiveness. The overarching aim is to empirically investigate and substantiate the theoretical frameworks of neoclassical economic theory and the Porter hypothesis. By focusing on the competitiveness outcomes resulting from the EU ETS, a large-scale environmental regulatory framework that spans an entire continent, this research establishes a robust foundation for such inquiries.

2.2. Emission trading systems

In this section, the mechanisms of the emission trading system (ETS) is examined to better understand the operation of such schemes before our empirical investigation of their effects on firm-level outcomes. ETS is a market-based environmental regulatory framework to control and reduce GHG emissions. The system operates on the principle of 'cap and trade’. It involves the governmental imposition of a cap, which sets a maximum limit on total emissions within specific economic sectors. Companies operating in these sectors are required to hold permits equivalent to the volume of emissions they release into the environment. Companies can acquire these permits through some kind of allocation method facilitated by the government. Subsequently, firms have the opportunity to participate in a market where permits can be traded among companies. The fundamental concept is to incentivize emissions reductions while allowing flexibility for businesses to adapt to evolving emission targets and conditions.

The cap established by the government usually declines progressively over time. This approach provides a clear and long-term signal to companies, allowing them to strategize and invest accordingly (ICAP, 2021). To ensure the environmental effectiveness of an ETS, stringent monitoring, reporting, and verification procedures should be implemented, with penalties in place to enforce compliance and uphold the integrity of the system. In response to the higher marginal costs incurred by ETS compliance, companies fundamentally have three options: adjust output prices, optimize production processes to minimize carbon allowance usage, adopt less carbon-intensive technologies, or a combination of these approaches (Oestreich & Tsiakas, 2015).

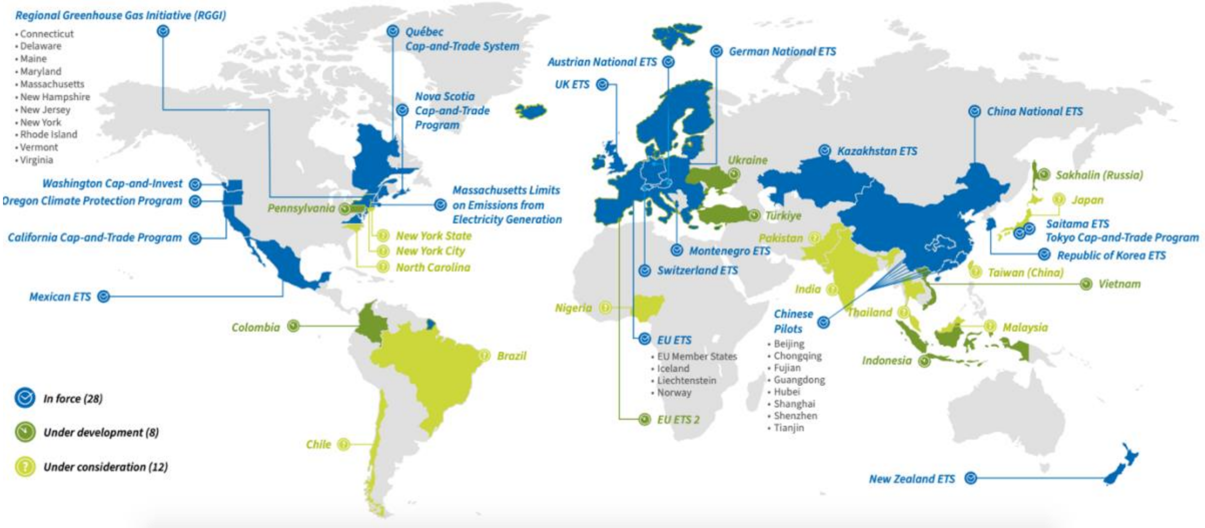

Figure 1, Emission trading wordwide. Source: ICAP, 2023.

This dynamic market-driven approach contrasts with traditional regulatory methods, such as command-and-control measures or carbon taxes, providing businesses with the freedom to identify and implement the most cost-efficient strategies for reducing emissions within a predetermined cap (European Commission, 2015). This approach encourages innovation and flexibility, as businesses strive to reduce emissions while minimizing operational costs (ICAP, 2021). Furthermore, ETS establishes a clear price for carbon emissions by creating a market for GHG permits. This pricing mechanism makes the societal costs of emissions integrated into the prices of goods and services (ICAP, 2021).

The landscape of carbon markets internationally has undergone significant transformations over the past two decades, from a predominantly top-down approach led by UN institutions to a bottom-up paradigm where national and regional governments play a more central role (Meadows et al., 2019). Currently, there are 24 ETSs in operation across five continents, as depicted in Figure 1, collectively covering GHG emissions of countries representing nearly 54% of global GDP (ICAP, 2021). Bilateral collaborations and international programs, such as the World Bank's Partnership for Market Readiness and the

International Carbon Action Partnership (ICAP), have played instrumental roles in facilitating the development and harmonization of carbon markets across different regions (Meadows et al., 2019). Moreover, the concept of linking carbon markets has gained traction as a means of enhancing their efficiency and impact (ICAP, 2021).

2.2.1. Allowance Allocation

As the structural break in the EU ETS between Phase II and Phase III was primarily driven by the dramatic overhauling of the allowance allocation mechanisms, it is of vital significance for the analysis to examine the theoretical foundations of these mechanisms in ETSs. The government, after setting the emissions cap, faces a crucial decision regarding how to distribute permits among companies. These permits, that usually represent one ton of GHG emissions, can be either allocated for free based on past emissions or performance standards, or alternatively, they can be auctioned off to the highest bidder (ICAP, 2021). The decision involves balancing economic competitiveness, environmental effectiveness, and fairness, as well as determining who benefits from the value created by emission constraints (Ellerman et al., 2010).

British economist, Ronald Coase's analysis provides valuable insights about the efficiency of resource allocation. According to the Coase theorem, whether or not the damaging party is not held liable for any damage, the final allocation of resources remains the same, assuming costless market transactions (Coase, 1960). In other words, without transaction costs, the initial allocation of resources, and the allocation method does not influence the final outcome. Translating this to emission trading, according to the theorem, the upfront assignment of emission allowances should have no effect on the supply and demand for emissions. Trade would continue until the equilibrium i.e. when marginal valuations and marginal costs are balanced, provided the basic assumptions such as rationality, perfect information, and the absence of transaction costs are met (Venmans, 2016). This implies that under ideal circumstances, the initial distribution of emission permits should not affect investments in emissions abatement either.

However, the practical implementation of carbon markets can be influenced by various real-world factors, including transaction costs, asymmetric information, and behavioral anomalies. Some examples for transaction costs in ETSs are administrative costs, compliance costs, trading costs, etc. Regarding asymmetric information, an example could be firms' superior knowledge about their exact emissions data, compared to the regulator. In Venmans' (2016) research, the behavioral anomalies are in focus. He identifies two systematic biases described by behavioral economics as the core reasons for managers to behave irrationally. The first is the endowment effect i.e. the concept that individuals tend to place higher value on items or assets they already possess (Kahneman et al., 1990), which can lead to a reluctance among firms to sell permits they have been allocated, even if selling them would be economically advantageous. The second bias is reference dependence, as managers often rely on baselines including the pre-ETS situation, their endowment of free allowances, and the actions of competitors, when assessing the incentives for investment that influence their behavior and decision-making within emissions trading systems (Venmans, 2016). As a result of these market failures, real-world cap-and-trade systems may experience distortions in emission outcomes that deviate from the theoretical predictions of independence between allocations and emissions. Therefore, choosing the allocation method can have long-term consequences on the efficiency, and the fairness of the system.

2.2.1.1. Auctioning

From an economic perspective, auctioning is considered a straightforward and effective means of distributing permits to those entities that place the highest value on them. This approach rewards early action to reduce emissions, serves as a revenue-generating tool for governments and reveals a transparent and market-driven carbon price which fosters a competitive carbon market (ICAP, 2021). Further key motivations for auctioning include the absence of windfall profits, which occur when companies receive a surplus of free permits without making substantial emission reductions (Ellerman et al., 2010). However, there are scenarios where free allocation becomes a warranted strategy, particularly during the initial phases of an ETS (Branger et al., 2015).

2.2.1.2. Free allocation

The primary rationale for free allocation is to compensate entities for their existing carbon-intensive infrastructure and processes, as free allocation significantly reduces compliance costs for industries operating within the ETS. This allocation method also preserves capital that can be redirected toward investments in emissions reduction technologies and energy efficiency measures (European Commission, 2015). Free allocation serves to compensate vulnerable sectors for their carbon-related costs, enabling them to remain competitive while complying with emissions reduction targets (Branger et al., 2015). Allocating permits for free can act as a transitional measure, mitigating the economic shock of transitioning into an ETS and helping industries adapt to new emission reduction requirements (ICAP, 2021). Despite receiving permits for free, entities may remain incentivized to invest in low-carbon technologies, as they have potential to sell surplus permits should they reduce emissions, while an increase in emissions would entail additional costs (ICAP, 2021).

However, when companies receive more free allowances than their emissions i.e. they are overallocated, they may perceive reduced pressure to invest in emission reduction measures, as compliance with EU ETS obligations requires less capital (European Commission, 2015). Furthermore, free allocation strategies can give rise to windfall profits, particularly in sectors that pass on the cost of allowances to consumers. These profits result from the opportunity cost of using freely allocated allowances for compliance instead of trading them on the market. The issue of windfall profits introduces equity concerns, as it effectively transfers wealth from consumers to producers (Verde et al., 2018). To address these concerns, the allocation of free allowances, ideally, should be tailored to a firm's capacity to pass on regulatory costs i.e. their elasticity of supply which is unobservable in most cases.

Let us examine how the free allocation of allowances may lead to windfall profits and why the cost-pass-through rate of firms is a crucial in its determination, using a simple supply-demand graph (Figure 2). The introduction of the ETS leads to an increase in production costs via the following channels: I. higher marginal cost associated with the actual or opportunity cost of carbon allowances (r); II. higher marginal cost linked to adopting less carbon-intensive technologies, i.e. fuel-switching costs (c). These elevated marginal costs result in an upward shift of the supply curve, i.e. firms reduce their production levels, driving up the equilibrium output price. In the new equilibrium with reduced production level (X_1), consumers face a new price (p_c), that is larger than the original marginal supply cost by ($c + r$). The increase in producer surplus is graphically represented by the shaded green area *A*. If these allowances had been sold through auctions, area *A* would represent government revenue. The loss in produced surplus, due to the new fuel-switching costs borne by the companies is depicted as the shaded blue area *B*. If the difference between area *A* and area *B* is positive, it indicates that the free allocation of carbon allowances provides firms with increased profits. The size of areas *A* and *B* depends on the elasticity of supply curve i.e. to the extent to which firms can transfer the rise in marginal cost to consumers through higher output prices i.e. the firms' cost-pass-through rate (Oestreich & Tsiakas, 2015, Koch & Mama, 2019).

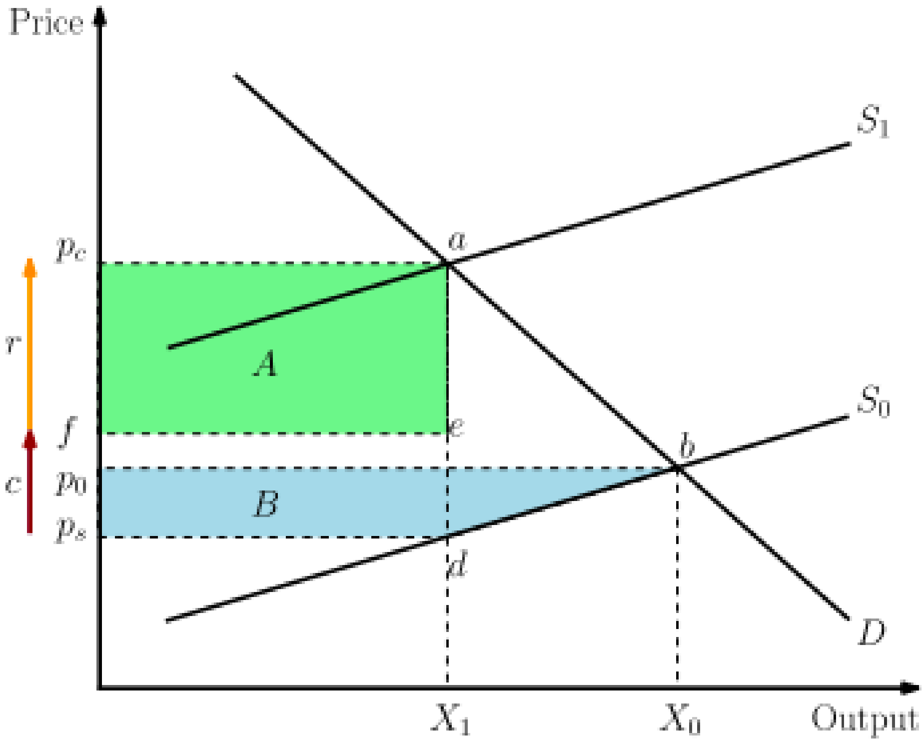

Figure 2, The effect of free carbon emission allowances on firm profits. Source: Oestreich & Tsiakas, 2015.

The evaluation of the causal impact of free allocation mechanisms on emissions represents a vital aspect of assessing the potential for carbon leakage and its impact on competitiveness. Therefore, assessing how much regulated companies transfer carbon-related expenses into product prices is crucial (Laing et al., 2014). However, a significant challenge lies in accurately quantifying and differentiating country-level and sectoral variations in the cost-pass-through rate (Verde et al., 2019). This challenge emerges as a central obstacle to the effective implementation of free allocation strategies.

The allocation of free allowances within an ETS can take on two distinct approaches: ex-ante and ex-post allocation. They are or often referred to as “grandfathering” and “benchmarking”, respectively. Grandfathering is based on historical emissions or output levels as a basis for awarding allowances. This approach incentivizes firms to enhance the efficiency of their operations, as greater efficiency leads to the accumulation of unused allowances. However, firms retain these unused allowances regardless of whether emission reductions result from efficiency improvements or external factors like reduced demand or competitive challenges (Macantonini et al., 2017). The simplicity and moderate data requirements of grandfathering make it an attractive option, but it has notable drawbacks. For instance, it may reduce the need for early trading and potentially penalize companies that proactively invest in emission reductions. Such investments could effectively lower their "historical emissions baseline," resulting in fewer permits allocated to them in subsequent phases (ICAP, 2021). Grandfathering tends to favor incumbent firms, affording them a cost advantage over newcomers who must purchase their allowances. Moreover, if an industry anticipates grandfathering, it creates an incentive to intensify polluting activities to secure a larger allocation.

Benchmarking, also commonly referred to as "output-based allocation" or OBA introduces a dynamic and performance-driven dimension to the allocation of allowances within an ETS. Under benchmarking, companies receive free allowances based on a set of predefined performance standards that assess emissions intensity at either the product level or across an entire sector (Macantonini et al., 2017). In contrast to grandfathering, benchmarking allocates allowances according to the production performance of installations. This rewards installations that demonstrate higher efficiency and place fewer emissions demands, while incentivizing less efficient installations to take more substantial measures to compensate for their excess emissions (European Commission, 2015). Moreover, free allocations under benchmarking significantly reduces surplus allocations that may lead to windfall profits (Sartor et al, 2014). However, the implementation of benchmarking requires high-quality data and a comprehensive understanding of industrial processes (ICAP, 2021).

All in all, the government's ultimate choice between allocation methods encompasses various trade-offs. Auctioning is the most straightforward, market-based approach that allocated allowances to companies that place the highest marginal value on them, therefore effectively internalizing the social costs of carbon emissions into companies' optimization decisions. However, some considerations potentially warrant the application of free allocations as well: the protection of vulnerable, carbon-intensive industries within the regulation from losing their relative competitive position and relocating their production facilities into a less stringent regulatory environment. This mechanism harms companies' competitive position under the jurisdiction of the government compared to other regions which invokes protectionist motives, and renders the efforts of the environmental regulation less efficient, as emissions are not abated but simply shifted elsewhere. The choice of the free allocation mechanism between grandfathering and benchmarking includes further trade-offs between the effectiveness and fairness of benchmarking, and the moderate data requirements and implementability of grandfathering.

2.3. The EU ETS

The European Union Emissions Trading System (EU ETS) is a prime example of a well-established, long-functioning ETS, operating since 2005. It stands as a cornerstone instrument of the European Union's strategy to address climate change effectively and reaching climate targets set out in the Green New Deal (European Commission, 2023b**)**, as the world's pioneering and largest carbon. Covering emissions from more than 10,000 installations in the energy sector, manufacturing industry, aviation operators, and more, the EU ETS accounts for around 40% of all EU GHG emissions (European Commission, 2023a). In this section, the brief history of this environmental regulatory scheme will be outlined, as well as the evolution of the overall emission cap and the allocation mechanism throughout its phases of operation. These are crucial aspects in describing and understanding the operation of an ETS.

2.3.1. History of the EU ETS

The EU ETS has its origins deeply rooted in the Kyoto Protocol, a significant international agreement established in 1997, that introduced legally-binding emission reduction targets for industrialized nations during its initial commitment period from 2008 to 2012. In March 2000, the European Commission introduced a Green Paper to make efforts in reaching the emission reduction targets set out in the Kyoto Protocol, outlining initial concepts for the EU ETS, which laid the foundation for extensive stakeholder discussions (European Commission, 2023a). During this period, certain EU member states, including the United Kingdom, Denmark, and the Netherlands, took proactive steps by implementing their own environmental taxation and trading schemes. Concerns about regulatory fragmentation and its potential impact on the EU's common market played an important role in driving the development of a comprehensive, pan-European trading system (Ellerman et al., 2010). The EU ETS Directive was officially adopted in 2003, leading to the system's launch in 2005. The legal framework of the EU ETS is established in Directive 2003/87/EC (European Commission, 2023a). The final design of EU ETS Phase I involved a clear emissions limit, transparent data disclosure, member state-level allocation, and a mandatory pilot period to identify and address any shortcomings (Ellerman et al., 2010).

Phase I of EU ETS (2005-2007) was primarily designed as a pilot phase. Its key objectives were to assess and refine the mechanisms for carbon price formation within the emerging carbon market and to establish the essential infrastructure for effective monitoring, reporting, and verification of emissions (European Commission, 2015). During this pilot phase, the scope of the system was limited to only carbon dioxide (CO2) emissions originating from power generation and energy-intensive industries. The vast majority of emission allowances were allocated to businesses at no cost during this phase. Additionally, the penalty for non-compliance with the established emissions limits was set at only €40 per ton of excess emissions (European Commission, 2023a). Phase II (2008-2012), marked a significant expansion and harmonization of the program. During this phase, the EU ETS aligned closely with the first commitment period of the Kyoto Protocol (European Commission, 2015). Notable features of this phase included a reduction in the cap on emission allowances by approximately 6.5% compared to the 2005 level, the introduction of auctions in several countries and the increase in the penalty for non-compliance to €100 per ton. The establishment of the Union registry, replacing national registries, and the adoption of the European Union Transaction Log (EUTL) made the administration of the system fully harmonized as well (European Commission, 2023a).

Phase III (2013-2020) was in alignment with the second commitment period of the Kyoto Protocol. This phase marked several significant changes aimed at enhancing the system's efficiency and impact (Meadows et al., 2019). These changes included the adoption of a single, EU-wide cap on emissions, replacing the previous system of national caps. Another crucial change was the shift from free allocation to auctioning as the default method for allocating allowances, emphasizing a market-oriented approach to emissions management. Moreover, harmonized benchmarking was introduced for the allowances still provided for free (European Commission, 2023a). Phase IV of EU ETS (2021-2030) continues the progresses of the third phase in terms of the stringency of the overall cap level and the shifting of the allocation method of allowances towards full auctioning (Meadows et al., 2019).

2.3.2. Evolution of the overall cap level

The EU ETS operates under the principle of placing a progressively decreasing cap on the total volume of greenhouse gases that can be emitted by covered entities, which include power plants, industrial factories, and the aviation sector (European Commission, 2023a). During Phases I and II, the cap was determined through a bottom-up approach, aggregating the national allocation plans of individual EU Member States. Phase I began with a cap of 2,096 million metric tons of CO2 equivalent (MtCO2e) in 2005, while Phase II commenced with a cap of 2,049 MtCO2e in 2008 (ICAP, 2022).

In Phase III, for stationary installations, a unified EU-wide cap was established at 2,084 MtCO2e in 2013, with an annual reduction rate of 1.74% applied to the 2008-2012 baseline emissions. This reduction factor led to a consistent year-on-year decrease in the cap, ultimately resulting in a cap of 1,816 MtCO2e in 2020. Phase Four continues the trajectory of emissions reduction with even greater ambition. For stationary installations, a single EU-wide cap of 1,572 MtCO2e was introduced in 2021, subject to an annual linear reduction factor of 2.2% based on the 2008-2012 baseline emissions. This stringent reduction approach translates into a yearly decrease of approximately 43 million allowances. There is no predetermined end date for the linear reduction factor, signaling a commitment to ongoing emissions reductions beyond 2030 (ICAP, 2022). Figure 3 depicts the overall cap reduction in the EU ETS throughout the Phases of its operation.

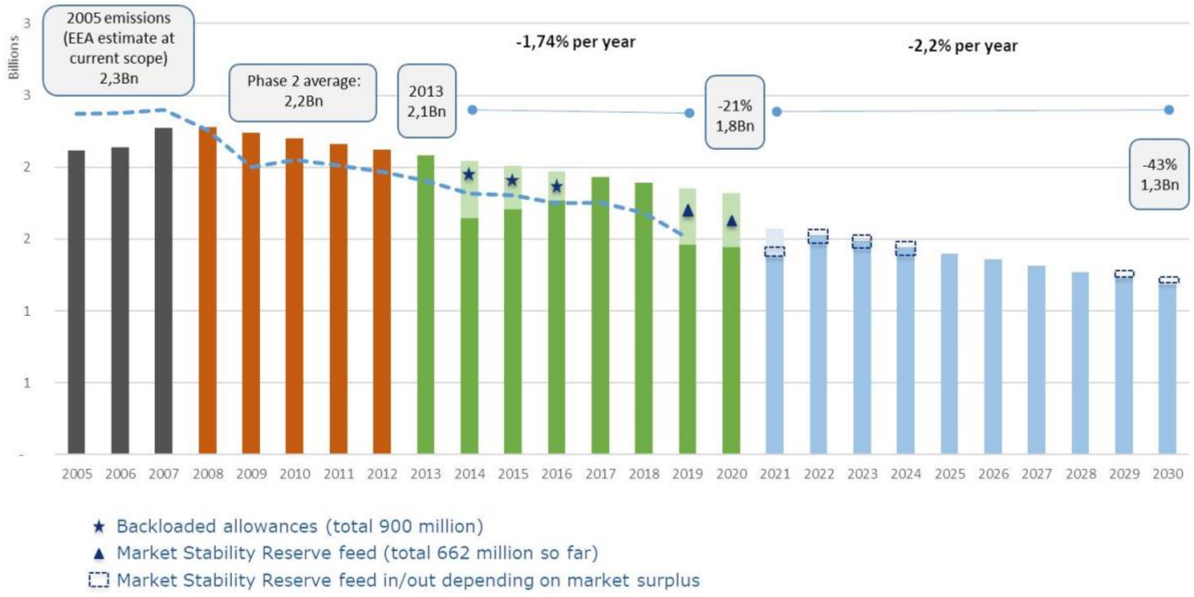

Figure 3, Overall cap reduction in the EU ETS. Source: European Comission, 2020.

2.3.3. Evolution of the allocation methods

During Phase I, allocation of allowances was determined based on the national allocation plans of individual Member States, with some employing grandparenting methods. Phase II followed a similar pattern, with approximately 90% of allowances allocated for free. However, Phase II also introduced benchmark-based free allocation and auctioning in several Member States, although it accounted only for 3% of the total allowance allocation (European Commission, 2023a) Phase III introduced several significant changes in the allocation and auctioning of emission allowances. During this phase, approximately 57% of allowances were auctioned, with the remaining portion allocated for free based on benchmarking criteria (European Commision, 2020). In the electricity production sector 100% auctioning was introduced. Within the industrial sectors, free allocation was determined by benchmarks set at the average of the 10% most efficient installations, with the share of free allocation incrementally decreasings from 80% in 2013 to 30% in 2020. Sectors considered at risk of carbon leakage received 100% free allocation at the relevant benchmark throughout the Phase(European Commission, 2023a).

In Phase IV of the EU ETS, the allocation of emission allowances for the industrial sector undergoes significant changes. To accommodate technological progress, the benchmark values are adjusted annually, with each benchmark assigned a specific annual reduction rate, ranging from 0.2% to 1.6%. Furthermore, Phase IV introduced an adjustment mechanism for free allocation that is triggered when industrial production experiences a 15% increase or decrease, ensuring that allocation levels align closely with actual production levels (ICAP, 2022). Figure 4 summarizes graphically the changes in the allocation method over the Phases.

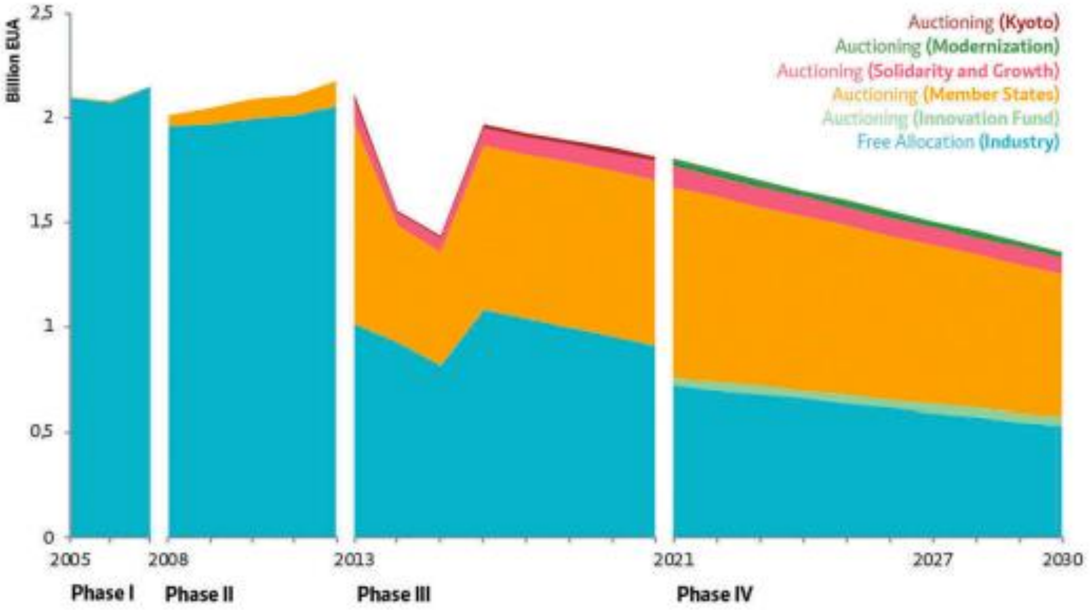

Figure 4, Changes in the composition of allocation methods over phases of EU ETS. Source: Dorsch et al., 2019.

3. Literature review & Hypotheses

3.1. Previous literature on firm-level impacts of EU ETS

Competitive performance indicators or proxies, which focus on firm-level assessments, are a key area of investigation in the assessment of the EU ETS's competitiveness, with an emphasis on market share, profits, revenues, employment, and productivity. In investigating carbon leakage, research has examined changes in trade balance and investment diversion to regions with less stringent regulations, although establishing causal relationships remains challenging. Few studies delve into direct evidence of carbon leakage, examining whether the policy has led to increased emissions outside the EU. Furthermore, a subset of studies investigates the relationship between carbon prices within the EU ETS and company stock returns, shedding light on competitiveness perceptions from an investor's standpoint (Verde, 2020).

The non-random allocation of firms into the system poses challenges of selection bias that enhance the complexity of establishing causality between the treatment and the outcomes (Martin et al., 2012). Furthermore, endogeneity concerns are also present in these analyses in the form of reverse causality that stem from the possibility that changes in firm revenues and employment could influence the allocation factor (Ander & Oberndorfer, 2008). Therefore, sophisticated empirical methods are usually applied in order to determine the policy's direct impact on emissions and competitive performance. Considering the most popular approaches to the empirical design, difference-in-differences (DiD) method is widely favored due to the structural breaks in the system across phases in the overall cap as well as the allocation method. Additionally, researchers utilize multi-factor models (MFM) to analyze the impact of carbon price changes on company stock returns. Time-series and panel-data models, including gravity-type models from international trade theory, are also often employed (Verde, 2020).

Researchers most frequently employ dynamic panel data approaches to analyze firm-level data over time. DiD for analyzing this type of data is often combined with Propensity Score Matching (PSM) which allows researchers to match treated and control firms based on observable characteristics, mitigating selection bias and endogeneity issues (Abrell et al., 2011; Petrick & Wagner, 2014; Marin et al., 2018). A recurring trend in the literature is the unexpected absence of the EU ETS's anticipated negative impact on firm-level economic performance. Contrary to conventional expectations, numerous studies consistently report limited adverse effects on various economic indicators such as revenue, employment, and competitiveness (Ander & Obeerndorfer, 2008; Abrell et al., 2011; Chan et al., 2013; Petrick & Wagner, 2014; Marin et al., 2018). While results may vary somewhat across studies and economic indicators, the overall consensus suggests that the EU ETS has had limited negative economic consequences for the companies affected. Furthermore, empirical studies examining carbon leakage have generally also failed to find statistical evidence of such phenomena occurring in sectors covered by the EU ETS (Branger et al., 2016).

Another notable trend is the sector-specific variation in the EU ETS's impact. Different industries experience distinct effects, with some sectors, like the power industry, facing increased compliance costs due to the purchase of allowances and a shift towards lower-emission fuels. In contrast, industries such as cement and steel do not exhibit statistically significant impacts on material costs, employment, or turnover, indicating limited evidence of production shifts to other regions (Chan et al., 2013; Petrick & Wagner, 2014). The literature commonly covers Phase I and Phase II of the EU ETS. These phases are well-documented, and studies have explored their effects on firms' economic performance, with Phase II often associated with more nuanced outcomes, including both positive and negative impacts. However, there is a lack of firm-level data analysis for Phase III of the EU ETS.

In conclusion, the body of literature on the EU ETS consistently challenges the expectation of negative economic impacts on firms. Sector-specific variations in the effects of the EU ETS and the utilization of dynamic panel data approaches, Propensity Score Matching (PSM), and Difference-in-Differences (DiD) frameworks are common trends in the literature. While Phases I and II are well-studied, a critical research gap exists concerning the analysis of firm-level data in Phase III.

3.2. Hypotheses of the paper

After establishing the theoretical framework and conducting a review of the literature concerning the firm-level effects of the EU ETS, a set of hypotheses has been formulated, drawing from established theoretical principles and well-documented empirical findings. The first group of hypotheses (1a-d) revolves around the impact of EU ETS Phase III on GHG emissions at the firm level, compared to that of Phase II. With the gradual reduction of the overall emissions cap within regulated sectors, a decline in total emissions in regulated industries is certain. However, the precise distribution in which this reduction occurs remains uncertain. It is possible that substantial reductions may be achieved by a select few firms, or that the burden is evenly distributed among all participating firms. As discussed in the literature review, substantial sectoral variations exist in this context. This study advances the exploration further by examining not only sectoral disparities but also regional distinctions. The second set of hypotheses (2a, 2b) centers on the competitive dynamics concerning companies subject to the EU ETS in comparison to their non-EU ETS counterparts in Phase III. This assessment uses four competitiveness indicators (Added value, EBITDA, Return on

Equity, and Profit margin). As with the investigation into emissions, this analysis also accounts for sectoral and regional subgroup effects.

Hypothesis 1a: There was a significant and increasing reduction in greenhouse gas (GHG) emissions at the firm level over the years of Phase III for regulated companies. This hypothesis is founded on prior research, such as Abrell et al. (2011), which has explored the implications of the EU ETS on firm-level emissions, and also on the intertemporal mechanisms inherent to Phase III, wherein the overall emissions cap progressively decreases by 1.74% annually.

Hypothesis 1b: The reduction of GHG emissions is more pronounced for firms that have been underallocated, meaning they have been distributed free allowances below their verified emissions. This hypothesis challenges the assumptions of the Coase (1960) theorem, highlighting that the allocation method of emission allowances does matter due to existing market failures and transaction costs. Firms that fall into the underallocated category face elevated compliance costs as they must either reduce their emissions or acquire additional emission permits, thereby increasing their marginal production costs. On the contrary, overallocated firms need not reduce their emissions to comply with regulations and may even reap windfall profits from the surplus allowances allocated above their actual emission levels, particularly when they possess a high cost-pass-through rate.

Hypothesis 1c: GHG emissions are more substantially reduced in firms that experienced a considerable decrease in their Allocation Factor (AF = Allocated allowances / Verified Emissions) between 2012 and 2013, marking the transition from Phase II to Phase III. This hypothesis also challenges the validity of the Coase theorem with respect to emission allowance allocation methods. This hypothesis also draws from Venmans' (2016) observations, suggesting that managers often base their decisions on reference points, including their previous endowment of free allowances and their allocations from preceding phases of the ETS. Consequently, firms facing a significant and abrupt reduction in their AF may have overreacted by making more substantial emissions reductions. Additionally, these companies are more likely to operate within the Electricity production sector, where free allocation was entirely revoked, creating a heightened incentive for emission reduction.

Hypothesis 1d and *Hypothesis 1e* further extend the examination to the sectoral and regional levels. *Hypothesis 1d:* The pronounced reduction of GHG emissions observed in underallocated firms at the firm level also holds true when comparing firms from different sectors and regions. *Hypothesis 1e:* Sectors/regions in which firms experienced a substantial decrease in their Allocation Factor between 2012 and 2013 exhibit greater emission reductions.

Hypothesis 2a: There was no significant impact on competitiveness indicators for companies subjected to EU ETS Phase III regulations compared to non-regulated companies. The prevailing consensus in the literature review suggests that the EU ETS has had limited or no adverse economic repercussions on regulated firms in previous Phases of the ETS. In comparison to this established benchmark, the empirical methodology employed in this paper is suitable for examining whether more stringent regulatory measures have either positively or negatively affected the competitiveness of regulated companies. In essence, this hypothesis tests whether the outcome aligns with the neoclassical economic theory, which implies adverse competitive effects, or with the Porter hypothesis, which posits that environmental regulation can stimulate innovation and enhance competitiveness. *Hypothesis 2a* suggests that the status quo of limited adverse competitive consequences remains, pointing to the possibility of successful mitigation of potential negative effects by the government, the existence of innovative mechanisms as detailed by the Porter hypothesis, or a combination of these factors.

Hypothesis 2b: Firms in sectors/regions that did not significantly adjust their emission path had less negative/more positive competitiveness effects. This hypothesis extends the analysis by investigating the connection between the stringency of emission path adjustments at the regional and sectoral levels and the impact on companies' competitiveness. Drawing from the initial examination of GHG emissions in the earlier part of the analysis, the study will provide insights into which sectors and regions have made substantial reductions in their Phase III emissions compared to Phase II levels, along with an understanding of the underlying mechanisms. This hypothesis explores whether a correlation exists between the degree of required emission reductions and the competitiveness of regulated companies. If companies, on average, are compelled to make more substantial emission reductions, their compliance costs are heightened, potentially diminishing their competitive position compared to non-regulated firms and even to regulated companies in other sectors and regions.

4. Data and Methodology

Having laid the foundations for our empirical investigation by establishing a theoretical framework, reviewing relevant empirical literature and formulating a set of hypotheses that encompass the firm-level effects of EU ETS in its Phase III, we now turn towards the empirical phase of our investigation. In the forthcoming section, we delve into the data sources, variables, and the methodological framework employed to assess the dynamics of GHG emissions and competitiveness indicators within the context of the ETS Phase III.

4.1. Dataset construction and descriptive statistics

A comprehensive dataset has been constructed through the connection and analysis of our two primary sources: the European Union Transaction Log (European Commission, 2023c), and the Orbis database (Bureau van Dijk, 2023), with the contributions of Simon (2021) and Abrell (2023). The EUTL is the central reporting tool of the EU ETS which records free permit allocation, monitors emissions trading and compliance within the system. The transaction log operates with a three-year delay. The Orbis database by Bureau van Dijk is sourced from 462 million companies worldwide, with 45 million of them containing comprehensive financial data of the companies as well. It is a powerful resource for comparing data on private and listed companies alike. Simon's (2021) dataset was created by the Joint Research Centre (JRC) of the European Commission (EC) and serves as a bridge between EU ETS account holders and the Orbis database, simplifying data connection and access. Finally, Abrell's (2023) EUETS.info database plays a crucial role in providing convenient and comprehensive access to EUTL data, addressing its initial burdensome access and the missing interrelationships between EUTL elements. This data gathering and connecting process resulted in an initial pool of 8,964 companies and 15,133 installations. Each company has had one or more installations regulated through EU ETS between 2005-2020 and each were connected to the Orbis database i.e. their BvD identification code was known, as facilitated by the work of Simon (2021). This database provides an opportunity to examine the industry-, country-, and region specific differences within the EU ETS.

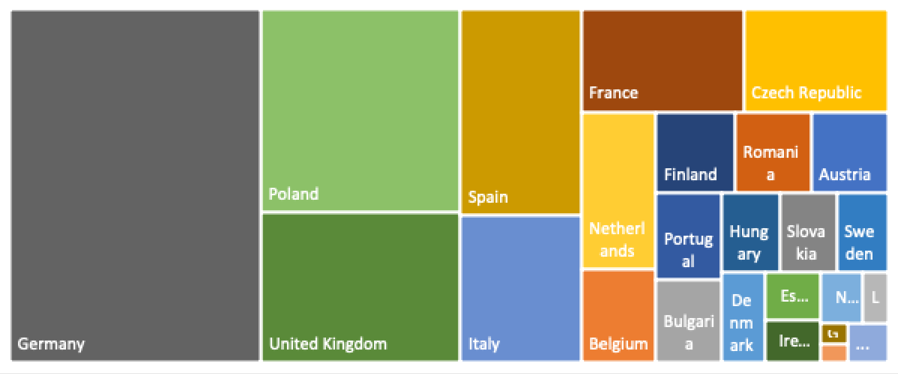

Figure 5, Share of overall emissions across countries over Phase I, II & III of EU ETS (2005-2020).

The distribution of GHG emissions within the EU ETS is depicted in Figure 5, over the span of 2005-2020, encompassing a total of over 47,000 million metric tons of CO2 equivalent (mCO2eq) emissions. During this extensive period, Germany emerges as the dominant contributor to GHG emissions, accounting for a substantial 28.56% of the entire emissions volume. Following closely are Poland, the United Kingdom, and Spain, collectively responsible for 30.84% of the overall emissions. Interestingly, France does not feature among the top 5 highest emitters, despite having the third highest GDP and population in Europe. This phenomenon can likely be attributed to the nation's pronounced emphasis on nuclear energy production, a sector characterized by a significantly lower carbon footprint.

A dynamic visual representation of how the distribution of overall GHG emissions across European regions evolved from the year 2005 to 2020 in sectors covered by the EU ETS is depicted on Figure 6. Across the entire time frame, it is evident that the overall trend in each region exhibits a declining trajectory. This reduction in emissions is particularly pronounced during Phase III of the EU ETS. Notably, the lead held by Western Europe in terms of GHG emissions gradually diminishes over time. This suggests that companies operating in Western European countries have successfully implemented measures to significantly reduce their emissions throughout the various trading periods of the EU ETS. Furthermore, Northern European companies have also made substantial progress in curbing their emission levels. In contrast, the overall emissions from Central and Eastern European countries exhibit a stagnating pattern.

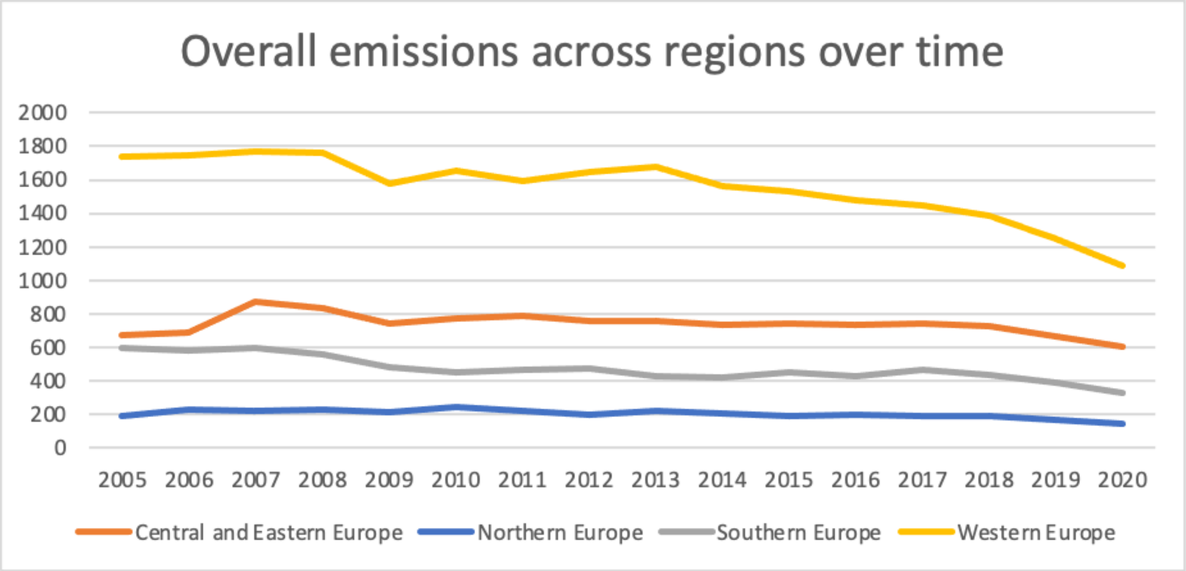

Figure 6, Overall emissions across regions over time.

An overview is provided on Figure 7 of the sectoral distribution of GHG emissions subject to regulation within the EU ETS, classifying sectors according to the NACE Rev. 2 framework (Eurostat, 2008). Notably, a substantial 76% of all emissions fall within just two primary sectors. The foremost contributor to GHG emissions under the regulatory framework is the sector denoted as "D – Electricity, gas, steam, and air conditioning supply." Within this sector, a significant 81% of GHG emissions originate from installations involved in electricity generation (sub-sectoral distribution of overall emissions within sectors C and D are reported in Appendix A). This highlights the vital role of electricity production in the emissions landscape. Additionally, the manufacturing industry (Sector C) emerges as the second largest sector, responsible for a notable 33% of the total emissions regulated by the EU ETS. This sector encompasses a wide array of installations engaged in the production of diverse commodities, including refined petroleum products, iron, steel, cement, paper, and more. The substantial contribution of the manufacturing sector to GHG emissions emphasizes the significance of industrial processes and emissions management within the regulatory framework.

An exploration of the temporal dynamics in total sectoral GHG emissions regulated within the EU ETS is offered by Figure 8. Industrial sectors, except for the electricity production sector due to its substantial share of total emissions, have been aggregated for this investigation. The sector represented as "G – Wholesale and retail trade" emerges as the most substantial among the remaining sectors encompassed by the EU ETS. The emissions from this sector exhibited a trend of stagnation until the commencement of Phase III. At the beginning of Phase III, a marked reduction of approximately 100 mtCO2eq in GHG emissions commenced, a trend that persisted over the seven-year span of this trading phase. An intriguing development in recent years is the shift in emissions between the industrial sectors and the electricity production sector. Since 2018, industrial sectors, when considered collectively, have surpassed the electricity production sector in terms of GHG emissions. This shift could be attributed to the transformation in allocation methods, particularly the fact that from the start of Phase III, electricity production plants no longer receive free allocation, while other industrial sectors experience a more gradual phase-out of free allowances. It is apparent from these trends that the overall emission levels of industrial production plants have remained nearly constant since the initiation of the emissions trading system in 2005. This underscores the sector's limited contribution to the overall reduction of emissions in Europe and raises concerns regarding its role in achieving emission reduction targets and environmental sustainability within the region.

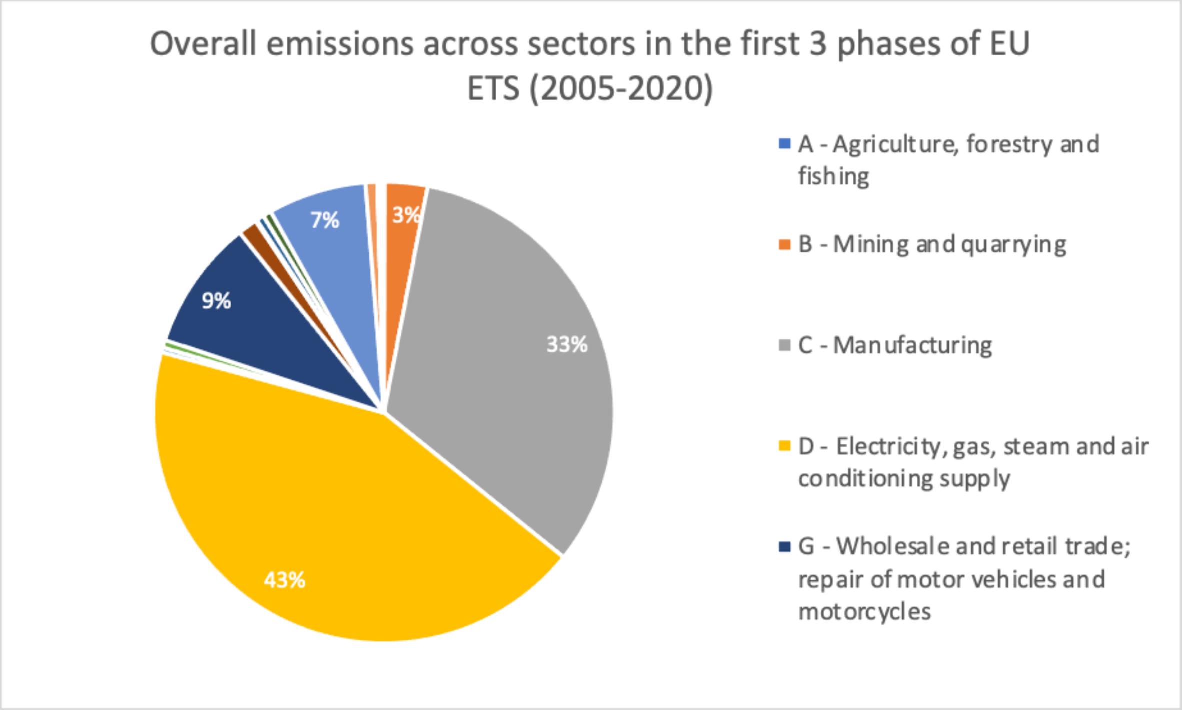

Figure 7, Overall emissions across sectors in the first 3 phases of EU ETS (2005-2020)

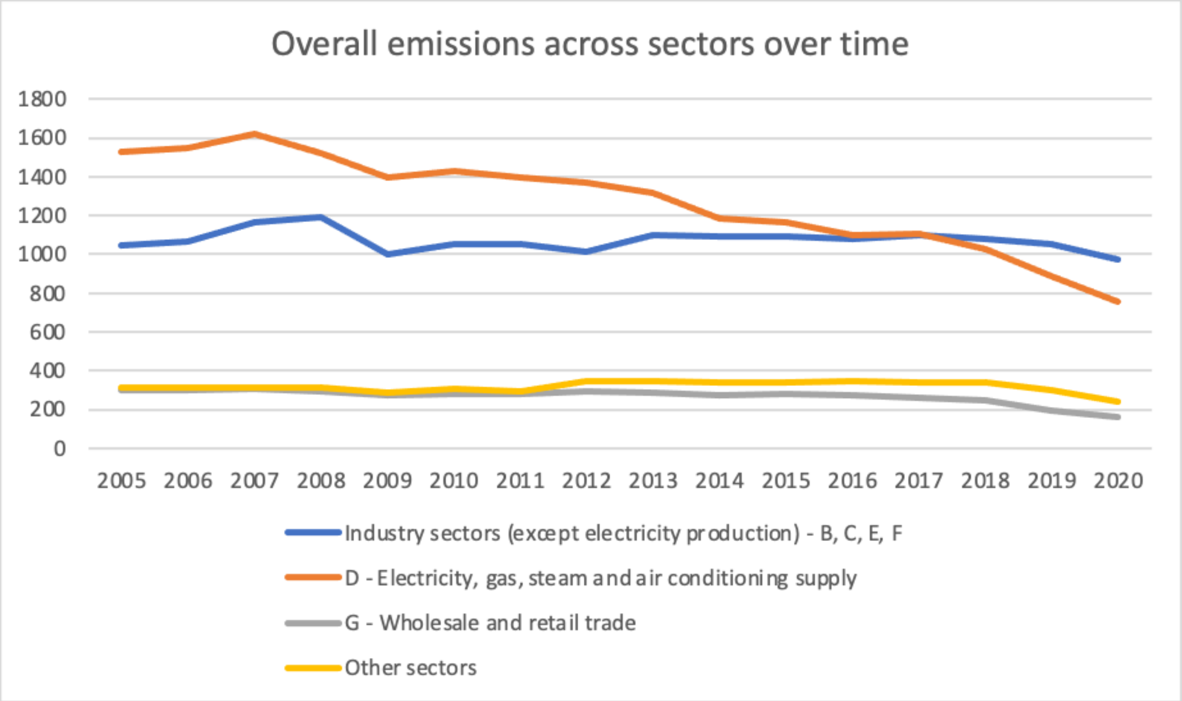

Figure 8, Overall emissions across sectors over time.

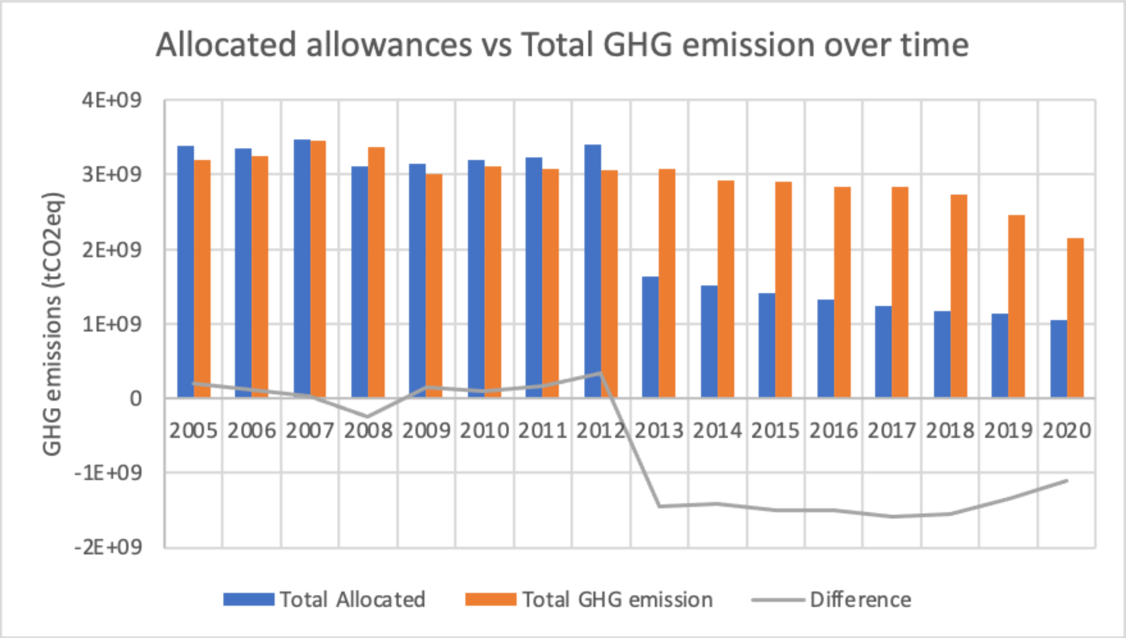

Figure 9, Allocated allowances vs Total GHG emission over time

Figure 9 offers a clear visualization of the pivotal structural shift that took place in the EU ETS between Phase II and Phase III. In the initial two phases of the system's operation, freely allocated allowances consistently outweighed total GHG emissions, effectively creating a non-binding overall emissions cap. However, the transition to auctioning as the primary allocation method starting from Phase III marked a significant transformation. More companies regulated under the EU ETS were confronted with the fundamental dilemma often faced under emission regulations: whether to reduce their emissions or acquire allowances, either through auctions or via trading on the emissions permit market. This shift in allocation mechanisms, coupled with the implementation of a progressively decreasing overall emissions cap, has been instrumental in driving the declining trends in overall GHG emissions observed during these phases. To gain a more comprehensive understanding of this shift, it is essential to explore regional and sectoral trends in the proportion of overallocated companies, with the aim of identifying potential distinctions and variations on these levels.

Figure 10 presents analysis of the proportion of overallocated firms within different regions during the first three trading periods of the EU ETS. This trend closely mirrors the difference between the total allocated emission allowances and the aggregate GHG emissions, indicating that the regulatory burden was approximately fairly distributed across these regions. However, it is worth noting a substantial change in the relative positions of these regions concerning the share of overallocated firms. With the onset of Phase III, a notable transformation occurred, shifting the Central and Eastern European region from the highest proportion of overallocated firms to the region with the lowest overallocation rate. This significant decrease in overallocation might have implications for the companies operating within this region, potentially affecting their competitiveness.

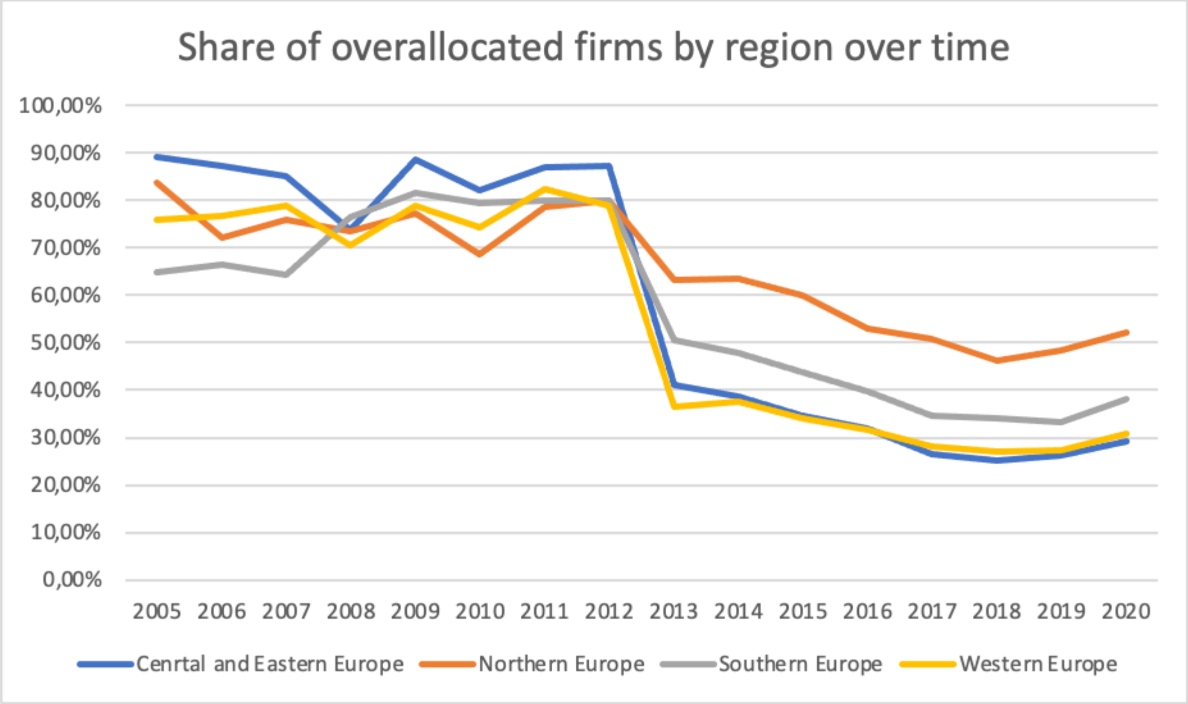

Figure 10, Share of overallocated firms by region over time

The sectoral comparison of the share of overallocated firms in Figure 11 unveils that sectors demonstrated similar movements over the initial trading periods, indicating a relatively equitable distribution of the regulatory burden among companies across sectors. However, the transition to Phase III brought about more noticeable variations. Notably, after 2013, Sector D, "Electricity, gas, steam, and air conditioning supply" experienced the most substantial decline in terms of the proportion of overallocated companies. This shift aligns with the fact that electricity-producing installations, which constitute a significant portion of GHG emissions within this sector, no longer received free emissions allowances from Phase 3 onwards. Our empirical investigation will further explore the consequences of this decline in terms of the competitiveness indicators of companies operating in this sector.

In this comprehensive descriptive and graphical analysis of the first three phases of the EU ETS, our investigation has offered insights into the system's functioning, emissions dynamics, and regional and sectoral implications. A noteworthy pattern emerging from our examination is the consistent decline in emissions over time, with Phase III standing out as a period marked by substantial reductions. At the sectoral level, the dominant contributions of electricity production and manufacturing to GHG emissions underscore the importance of these sectors in emissions management. While industrial sectors have not witnessed significant overall emissions reductions, all other sectors demonstrated noteworthy emission reduction over the first 15 years of the EU ETS operation. Additionally, our analysis of overallocated firms has unveiled compelling regional and sectoral shifts, with Central and Eastern Europe and sector D (Electricity, gas, steam, and air conditioning supply) experiencing a significant decrease in the proportion of overallocated companies from the onset of Phase III. These findings have potential implications for the competitiveness and compliance costs of firms operating within these regions and industries.

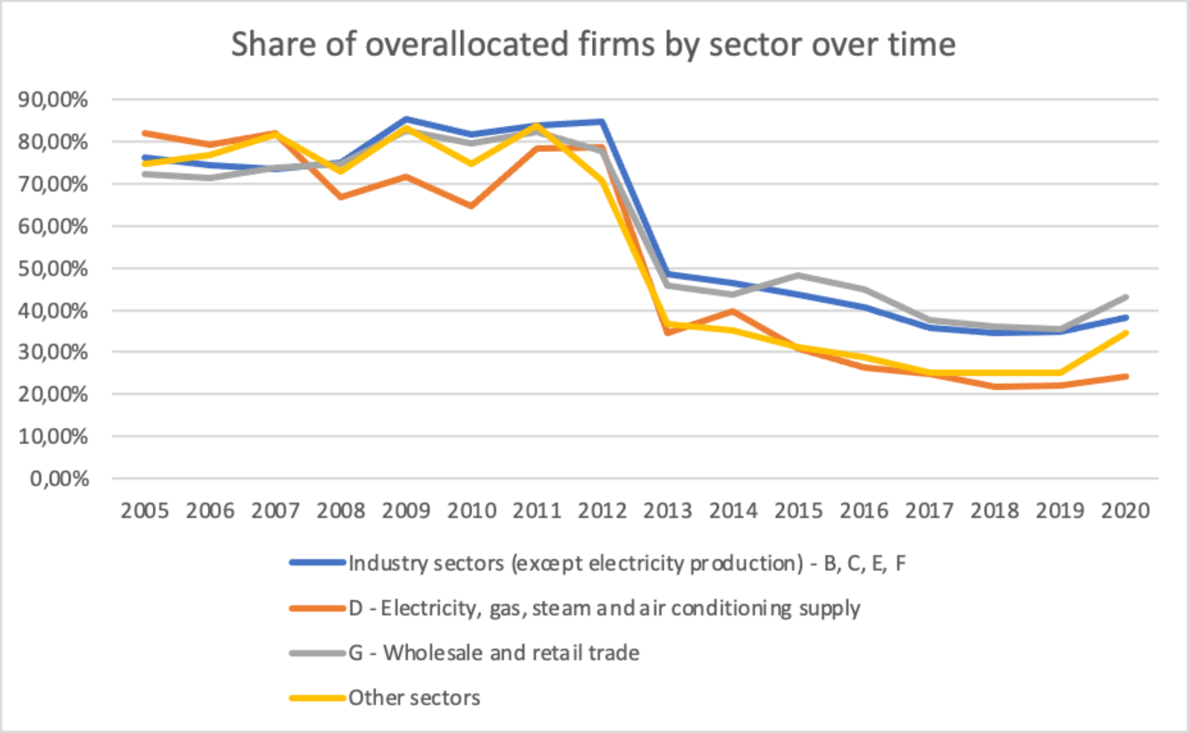

Figure 11, Share of overallocated firms by sector over time

4.2. Final dataset

A specific time frame was chosen for the empirical analysis, focusing on the years 2011-2020, given the limited availability of financial data in the Orbis database in earlier years. As the main aim of the research was to fill the research gap about emission reduction and competitiveness effects of Phase III (2013-2020) of the EU ETS, this timeframe was sufficient for our analysis. The dataset was further refined by narrowing the scope to 4,447 companies based on two criteria: active emission trading in each year the period 2011-2020 and known main NACE Rev. 2 sectors (Eurostat, 2008), enabling sectoral subgroup analysis.

Among these, 907 companies stood out for their completeness, featuring financial data for the crucial year 2012, enabling Propensity Score Matching (PSM). The selection process was further refined through PSM kernel adjustment to 0.1, elaborated in Annex C, resulting in a final dataset of 891 EU ETS companies. The final dataset includes statistics about the number of allocated allowances and the verified emission on a yearly basis for each company from the EUTL. Furthermore it includes, when available, company statistics in each year from Orbis, namely Turnover, Value Added, Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA), Number of employees, Profit margin, Return on Equity (ROE), Total assets, and Working capital. As seen in Figure 12, the mechanisms between allocated allowances and total GHG emissions holds for our final dataset, similarly to the total, unfiltered data. See Appendix B for descriptive statistics of the final dataset.

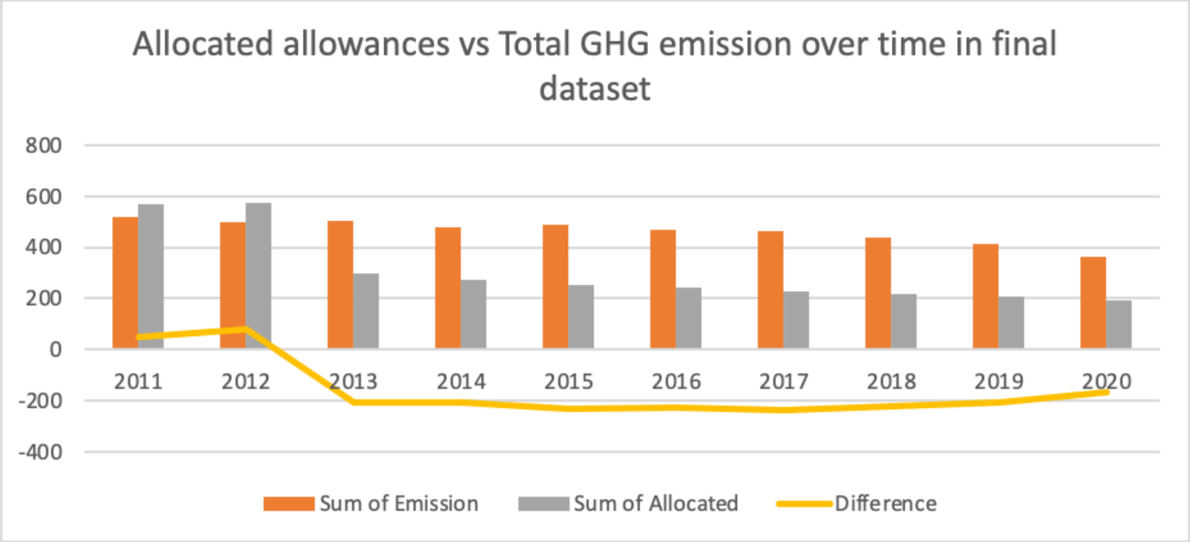

Figure 12, Allocated allowances vs Total GHG emission over time in final dataset

4.3. Identification method

4.3.1. Change in emission path by EU ETS regulated companies

The first research question considers whether firms altered their strategies for reducing emissions between Phase II and Phase III. As discussed previously in section 2.3.3. and 3.2., substantial modifications were made to the allocation and auctioning of emission allowances within the system starting in 2013. During Phase III, about 57% of allowances were distributed via auctioning, while the remaining portion was distributed following specific benchmarking criteria. This was a significant shift in the allocation methods applied within the system compared to Phase II, where 90% of allowances were allocated for free and only

3% were subject to benchmarking, the remaining allocations were distributed via Grandfathering. Therefore, this significant one-time adjustment in the allocation mechanism provides opportunity for empirical research of the effects.

In assessing emission reduction behavior, the study considers a range of factors that could influence emissions apart from being regulated by the EU ETS. Turnover and Total assets are included in the estimation, to control for the economic performance and the size of the firm, respectively. Furthermore country-industry pair level economic performance is included measured with Gross Value Added (GVA) of industries within a given countries' economy from Eurostat (2023a). The empirical analysis aims to test whether there was a change in the GHG emission behavior of regulated companies and what were the underlying determining factors of the sign and size of this potential behavior change during Phase III. The following equation is used to identify this effect:

$$Y_{i,c,s,t} = \beta_0 + \beta_1 \times PhaseIII_t + \beta_2 \times Turnover_{i,t} + \beta_3 \times Total\_assets_{i,t} + \beta_4 \times GVA_{c,s,t} + \eta_{c,s,t} + \varepsilon_{i,c,s,t} \quad (1)$$

where $Y_{i,c,s,t}$ refers to the log of verified GHG emission of company i that operates in country c and in sector s, in year t (t = 2012,…, 2020). $PhaseIII_t$ is a time dummy which take the value 1 for Phase III years (2013-2020) and 0 otherwise. $Turnover_{i,t}$, $Total\_assets_{i,t}$, $GVA_{c,s,t}$ refers to the log of Turnover in million Euros, log of the value of the company's total assets in million Euros, and log of GVA in million dollars of the industry-country pair the company operates in, respectively. To control for cross-year -country and -industry heterogeneity, a set of fixed effects is also included in the regression denoted by $\eta_{c,s,t}$.

To evaluate the effectiveness of the EU ETS in Phase III with respects to accelerating emission abatement effort of regulated companies, a direct comparison is made between emissions in Phase III (2013-2020) and those in the examined years of Phase II (2012). To facilitate a direct comparison between these two distinct periods, the first difference of Equation 1 is compiled. By taking the first difference of every panel variable with respect to the period indicator, $PhaseIII_t$, Equation 1 translates to the following regression estimation:

$$\Delta Y_{i,c,s,t} = \beta_1 + \beta_2 \times \Delta Turnover_{i,t} + \beta_3 \times \Delta Total\_assets_{i,t} + \beta_4 \times \Delta GVA_{c,s,t} + \eta_{c,s,t} + u_{i,c,s,t} \quad (2)$$

where Δ represents the first difference of the variables compared to their Phase II values.

4.3.2. Competitive performance of EU ETS companies in Phase III

When assessing whether the EU ETS Phase III's effects on firms' competitiveness, a fundamental challenge emerges: estimating what their competitive performance would have been if the EU ETS Phase III had not been introduced. This unobservable counterfactual scenario is crucial for evaluating the system's impact. To address this challenge, various techniques have been developed to approximate this counterfactual scenario. For the construction of the control dataset in this study, a Propensity Score Matching (PSM) methodology is used.

PSM offers a solution to selection bias by creating a well-selected control group from a pool of non-participants who closely resemble the treated participants in all relevant pre-treatment characteristics. The key underlying assumption is unconfoundedness or conditional independence which states that treatment assignment is independent of the outcomes given the observed characteristics (Caliendo & Kopeinig, 2008). PSM is able to balance a large number of covariates between treated and untreated groups by focusing on a single variable: the propensity score. The propensity score represents the probability of participating in a program based on observed characteristics, thereby ensuring that subjects with the same propensity score have, on average, the same potential outcomes (Lunt, 2014). By methodically selecting comparable individuals from the control group, PSM provides a powerful tool for estimating the causal effect of a treatment or program, overcoming the challenges posed by selection bias in observational studies.

Following an extensive matching procedure, elaborated on in Appendix C, we successfully established a comparable group of untreated entities by considering their pre-Phase III attributes. The balance test, as demonstrated in Table 1, reflects the minimal disparity between the means of these two cohorts in the variables employed for matching, with differences below 0.1 standard deviation. This process strived to achieve the robustness of our comparative analysis between treated and untreated entities.

Table 1, Balance test of PSM

Variable	**Mean in Treated**	**Mean in Untreated**	**Standardized difference**
Turnover	853328.36	485210.27	0.087
Value Added	199115.08	115761.18	0.072
EBITDA	107217.83	87522.82	0.028
Number of Employees	1461.88	1106.48	0.044

Total Assets	978362.6	535511.43	0.081
Working Capital	104887.4	79394.95	0.037

This study uses a "difference-in-differences" (DiD) identification methodology to evaluate the causal impact of EU ETS regulations on companies' competitiveness, similarly to previous research examining the firm-level effects of environmental regulation (Abrell et al., 2011; Fowlie et al., 2012; Petrick & Wagner, 2014; Marin et al. 2018). DiD is a widely used non-experimental design in policy evaluation and program assessment. The goal is to examine whether the introduction of the policy has led to any significant differences in the outcomes of interest between these groups. The fundamental assumption of DiD is that in the absence of the policy change, both the treatment and comparison groups would have exhibited similar trends over time (parallel trends assumption) (Figure 13).

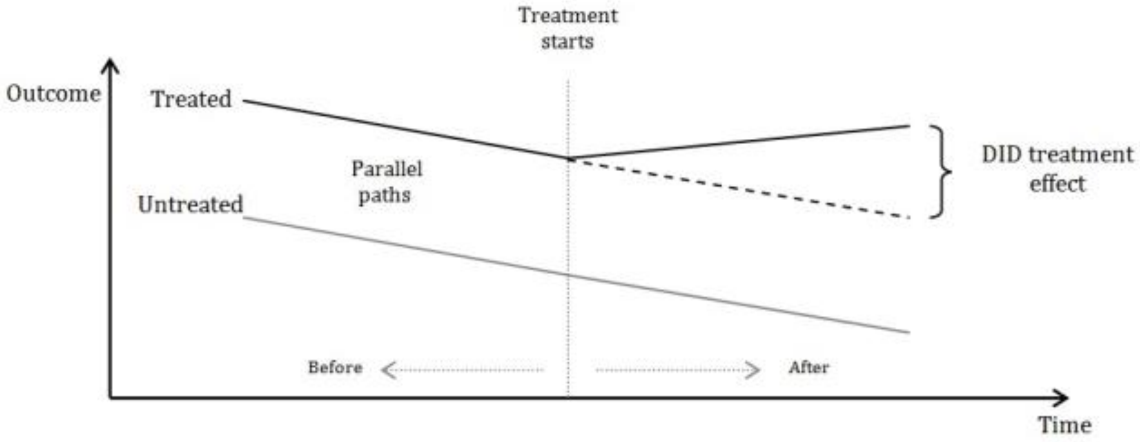

Figure 13, Baseline DID setting and the parallel trend assumption. Source: Villa, 2016

DiD compares the changes observed over time between two distinct groups: one group that is exposed to the policy change or intervention (treated), and another group that remains unaffected by it (control). To translate it to mathematical formulas, the DiD setting is given by the following equation:

$$\begin{aligned} DID = \{ & E(Y_{it=1} | D_{it=1} = 1, P = 1) - E(Y_{it=1} | D_{it=1} = 0, P_i = 0) \\ & - E(Y_{it=0} | D_{it=0} = 0, P_i = 1) - E(Y_{it=0} | D_{it=0} = 0, P_i = 0) \end{aligned} \tag{3}$$

where i is the unit of measurement, $t = 0$ is the pre-treatment period, $t = 1$ is the treated period, Y_i is the outcome variable, D_i is the treatment indicator, and P_i is the period indicator (pre-treatment, treatment). Additional covariates, that are assumed not to be affected by the treatment, can be included for a more robust estimation:

$$DID = \{E(Y_{it=1}|D_{it=1} = 1, P_i = 1, X_i) - E(Y_{it=1}|D_{it=1} = 0, P_i = 0, X_i) - E(Y_{it=0}|D_{it=0} = 0, P_i = 1, X_i) - E(Y_{it=0}|D_{it=0} = 0, P_i = 0, X_i) \tag{4}$$

where X_i represents the set of covariates. To identify the effect of treatment assignment, the above equation translates to the following estimation for treated observation *i* in *t* = 1:

$$Y_i(D,P) = \beta_1(D = 1, P = 1) + \beta_2(D) + \beta_3(P) + \beta_4(X_i) + e_i(D,P) \tag{5}$$

or generally:

$$Y = \beta_0 + \beta_1 DP + \beta_2 D + \beta_3 P + \beta_4 X + e \tag{6}$$

where similarly, *D* is the treatment indicator and *P* is the period indicator, *X* is the set covariates included in the regression, and *e* is the error term. The parameter of interest is β_1 which represents the effect of the treatment (*D* = 1) in the period of the treatment (*P* = 1). By taking the first difference of this equation with respect to *P*, we get

$$\Delta Y = \gamma_0 + \gamma_1 D + \gamma_2 \Delta X + u \tag{7}$$

As discussed in Section 2.1., competitiveness can be assessed using two fundamental measurement approaches: the analysis of factors that drive competitiveness, including resource productivity and internationalization; and the evaluation of competitive success, which is determined by market performance, financial results, and overall economic prosperity (Ellerman et al., 2010). In this study the focus is on the financial results of companies, due to data constraints. The following financial indicators are used as proxies for the companies' competitive performance: Added value, ROE (Return on Equity), EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization), and profit margin. Added value represents the economic value created by a company's primary activities, making it a valuable indicator of a firm's competitive advantage. ROE assesses a company's profitability relative to the equity held by shareholders. It serves as a critical financial measure, reflecting how efficiently a company utilizes shareholders' capital to generate profits. Higher ROE values are often associated with enhanced competitiveness. EBITDA provides an insight into a company's core operational performance by excluding non-operational expenses. This metric is less influenced by financial and accounting decisions, making it a robust indicator of competitiveness. Profit margin evaluates a company's profitability concerning its revenue.

Elevated profit margins are indicative of improved competitiveness, especially when they are consistently sustained over time (Corporate Financial Institute, 2023).

In the estimation of the causal effect of EU ETS Phase III regulation on companies' competitive performance, several covariates were also included to control for effects that potentially drive competitiveness, however are assumed not to be related to falling under the regulation. Turnover controls for the financial well-being of the company, while the value of total assets proxies for the size of the company. Furthermore, similarly to the emission reduction specification, economic performance indicators at both the country and country-industry pair levels are also incorporated to control for external effects that might drive the competitiveness of the firm. Finally, country and industry-level fixed effects are also utilized to control for the specific environment the company operates in. Therefore, equation 6 translates to the following in the case of this study:

$$Y_{i,c,s,t} = \beta_0 + \beta_1 \times Treated_{i,t} \times PhaseIII_t + \beta_2 \times Treated_{i,t} + \beta_3 \times PhaseIII_t + \beta_4 \times Turnover_{i,t} + \beta_5 \times Total\_assets_{i,t} + \beta_6 \times GVA_{c,s,t} + \eta_c + \lambda_s + e_{i,c,s,t} \tag{8}$$

where $Y_{i,c,s,t}$ is the log of the outcome variable (*Added Value, ROE, EBITDA, Profit Margin*) of company *i* in year *t*, $Treated_{i,t}$ is a binary variable indicating if company *i* was under EU ETS Phase III treatment in year *t*, $PhaseIII_t$ is the period indicator which tells us whether *t* is in Phase III of EU ETS (2013-2020*), $Turnover_{i,t}$* is the log is the company *i*'s turnover in million euros in year *t*, $Total\_assets_{i,t}$ is the log of the value of total assets in million Euroes of company *i* in year *t*, $GVA_{c,s,t}$ is the Gross Value Added in the country-industry pair in the industry company *i* operates in, η_c is a country fixed effect and finally, λ_s is a sector fixed effect.

After taking the first-difference with respect to *PhaseIII*, similarly to Equation 7, we will have the following, final form of the regression:

$$\Delta Y_{i,c,s,t} = \gamma_0 + \gamma_1 \times Treated_{i,t} + \gamma_2 \times \Delta Turnover_{i,t} + \gamma_3 \times \Delta Total\_assets_{i,t} + \gamma_4 \times \Delta GVA_{c,s,t} + \eta_c + \lambda_s + u_{i,c,s,t} \tag{9}$$

Our main variable of interest is γ_1 which identifies the effect of being treated on the change in the competitive performance in Phase III compared to Phase II. Via the combination of PSM and DID methodologies, we will be able to estimate the average treatment effect on the treated (ATT) for our final data sample if companies under the EU ETS. Therefore, γ_1, our main variable of interest can be rewritten as

$$\gamma_1 = ATT_{Phase\ III} = E\left(Y_i^{Phase\ III} - Y_i^{Phase\ II} \middle| Treated_i = 1\right) - E\left(Y_i^{Phase\ III} - Y_i^{Phase\ II} \middle| Treated_i = 0\right) \tag{10}$$

5. Results

The results of our empirical investigation based the methodology developed in the previous section to test the hypotheses of the paper will be presented in two parts. The two subsections also correspond to the two research questions of the study, namely RQ1: What was the effect of Phase III of the EU ETS on firm level emissions among regulated companies?; RQ2: How did the increased regulatory stringency in EU ETS Phase III impact regulated companies' competitiveness? In our presentation of the empirical findings, we will consistently incorporate and report on year fixed effects, or in the context of the DID specification, the interaction of treated firms with year fixed effects. This approach enables us to effectively investigate temporal patterns in the outcome variables. Opting for an assessment of overall effects without the exploration of intertemporal trends within Phase III would be unwise, as the regulatory framework underwent dynamic intensification with each passing year, implying a heterogeneous impact on the outcomes of regulated companies over time.

In order to assess the potential heterogeneity of effects over time, across countries, and among industries, we will initially present results from seven distinct specifications for each outcome variable. These specifications involve various combinations of fixed effects. By comparing the size and significance of the outcome variable, we can gain valuable insights into whether the observed impact is more pronounced within specific subsets of companies in comparison to others. Subsequently, we will proceed to present regional and sectoral analyses for each outcome variable. These detailed specifications enable us to explore the dynamics both between and within subgroups. Furthermore, they provide a robust framework for assessing our hypotheses about regional and sectoral variations in the shifts observed in emission levels and competitiveness.

5.1. Emission reduction by EU ETS regulated companies in Phase III

In our empirical assessment of Research Question 1 and its associated hypotheses (1a-1e), we will employ the first differences methodology, as outlined in Section 4.3.1. This methodology enables us to discern the changes in emissions over time by calculating the differences between 2012 and Phase III emissions in each year. The key coefficients of interest are those belonging to the year fixed effects. These year fixed effects are instrumental in capturing the differential effects of each year within Phase III in comparison to the reference year, 2012, the final year of Phase II. In line with *Hypothesis 1a*, we anticipated that the coefficients will be statistically significant, indicating a measurable impact of each year of Phase III on the outcome variables. Second, we expected them to be negative, signifying a reduction in GHG emissions over the years of Phase III. Lastly, these coefficients were expected to demonstrate a decreasing trend, as the regulatory stringency of the EU ETS becomes progressively more stringent with each year.

The results presented in Table 2, which correspond to the findings of Equation 2 with first differences in *Log(Emissions)* serving as the dependent variable, exhibit a substantial alignment with our initial expectations. Across various specifications, a general trend emerges—a notable and statistically significant reduction in overall emissions during the years of Phase III. However, variations in the extent of this reduction are evident among the specifications. The most robust reduction in emissions over the course of Phase III materializes when year and country fixed effects are included. This underscores the significance of country-specific factors in contributing to the variations in emission levels among regulated companies. The introduction of the industry fixed effect alongside the country fixed effect also results in a significant and stable reduction in emissions throughout the years compared to the Phase II baseline emission levels. This indicates a pronounced degree of heterogeneity among industries in terms of how firms adjust their emissions to conform to the regulatory framework. Moreover, it is noteworthy that the first difference of *Log(Turnover)*, a variable incorporated in our regression to control for firms' economic performance, emerges as a significant factor influencing emissions. This outcome is intuitive, as well-performing companies, particularly those within carbon-intensive sectors, are more likely to increase their production volume, thereby elevating their overall emission levels.

Table 2, Results of the estimation of Equation 2 with the first difference of the natural logarithm of firm-level GHG emissions as the dependent variable and with different combinations of fixed effects..

⊿Log(Emissions)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
2014	-0.06*** (0.02)	-0.07*** (0.02)	-0.06*** (0.02)	-0.06*** (0.02)	-0.22*** (0.01)	-0.06*** (0.02)	0.50* (0.28)
2015	-0.06 (0.04)	-0.09*** (0.03)	-0.06* (0.03)	-0.07** (0.03)	0.02 (0.02)	-0.07* (0.04)	-0.07 (0.60)
2016	-0.06 (0.04)	-0.09*** (0.03)	-0.06* (0.03)	-0.08** (0.03)	0.10* (0.05)	-0.07* (0.04)	0.40 (0.35)
2017	-0.03	-0.08**	-0.03	-0.05	0.19***	-0.05	0.54*

	(0.05)	(0.04)	(0.04)	(0.04)	(0.06)	(0.05)	(0.30)
2018	-0.06	-0.12***	-0.06	-0.08**	0.09	-0.08	0.15
	(0.05)	(0.04)	(0.04)	(0.04)	(0.08)	(0.05)	(0.30)
2019	-0.12	-0.18**	-0.11	-0.14**	-0.22**	-0.13*	0.29
	(0.08)	(0.07)	(0.07)	(0.06)	(0.09)	(0.07)	(0.37)
2020	-0.22***	-0.26***	-0.21***	-0.23***	-0.99***	-0.22***	0.23
	(0.08)	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.31)
ΔLog(Total Assets)	0.01	0.03	-0.01	0.00	0.01	0.01	0.00
	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
ΔLog(Turnover)	0.18**	0.18**	0.17**	0.17**	0.17**	0.18**	0.17**
	(0.08)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
ΔLog(Sectoral GVA)	-0.02	0.32**	-0.03	0.15	0.35	0.10	0.10
	(0.20)	(0.13)	(0.16)	(0.14)	(0.46)	(0.22)	(0.15)
Constant	0.04**	0.11***	0.26	0.35	0.37	0.44***	0.01
	(0.02)	(0.02)	(0.25)	(0.24)	(0.25)	(0.09)	(0.06)
Country FE	No	Yes	No	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	Yes	Yes	Yes
Year*Country FE	No	No	No	No	Yes	No	No
Country*Industry FE	No	No	No	No	No	Yes	No
Year*Industry FE	No	No	No	No	No	No	Yes
Observations	6,483	6,483	6,483	6,483	6,483	6,483	6,483
R-squared	0.020	0.054	0.052	0.082	0.100	0.109	0.087

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Hypothesis 1b posits that the reduction in GHG emissions will be more pronounced for underallocated companies i.e. those receiving fewer allocated allowances than their GHG emissions. To investigate the validity of this hypothesis, a subgroup analysis distinguishing between overallocated and underallocated companies was performed, incorporating Country and Industry fixed effects to account for the observed heterogeneity between these subsets. The results are presented in the first two column of Table 3. The results of this analysis indicate a consistent reduction in emissions throughout all years of Phase III for both overallocated and underallocated companies. However, the reduction is statistically significant in nearly all years for underallocated companies, whereas overallocated companies exhibit statistical significance only at the beginning and conclusion of Phase III. This observation suggests an initial shock for companies at the outset of the new trading period, and a promising trend toward the conclusion of Phase III, where even overallocated companies substantially reduced their GHG emissions. In summary, these findings lend support to *Hypothesis 1b*, affirming that underallocated companies experienced a more substantial reduction in GHG emissions compared to their overallocated counterparts.

According to *Hypothesis 1c*, firms that have undergone a significant decrease in their Allocation Factor (AF) during the transition from Phase II to Phase III exhibited more substantial reductions in their emissions. To explore this hypothesis in more depth, we conducted a comparison between two groups of companies. The first group experienced a notable reduction of over 0.5 in their AF between 2012 and 2013, marking a substantial shift in their allowance allocation. The second group encountered a less dramatic change in their allocation during the same period. The results, as depicted in columns 3 and 4 of the analysis, highlight an important distinction. Both groups exhibited reductions in their emissions, indicative of their efforts to comply with regulatory requirements. However, the group subjected to the more significant reduction in their emission allowances experienced a considerably greater reduction in GHG emissions compared to the group with a milder shift in allocation. This outcome aligns with *Hypothesis 1c*, underscoring that firms facing a pronounced and abrupt reduction in their AF during the transition between phases were more likely to make more substantial emissions reductions in response to the regulatory changes.

Table 3, Results of the estimation of Equation 2 with the first difference of the natural logarithm of firm-level GHG emissions as the dependent variable and subgroup analysis based on overallocation in each year and the decrease in the Allocation Factor at the introduction of Phase III.

⊿Log(Emissions)	(1) Overallocated	(2) Underallocated	(3) Large decrease (AF_{2013}-AF_{2012} < -0.5)	(4) No large decrease (AF_{2013}-AF_{2012} > -0.5)
2014	-0.091**	-0.052***	-0.106***	-0.024
	(0.032)	(0.016)	(0.026)	(0.019)
2015	-0.125	-0.064*	-0.111**	-0.034
	(0.092)	(0.032)	(0.043)	(0.041)
2016	-0.146	-0.066**	-0.076*	-0.062
	(0.098)	(0.031)	(0.039)	(0.049)
2017	-0.154	-0.053	-0.075	-0.019
	(0.141)	(0.036)	(0.053)	(0.061)
2018	-0.163	-0.095**	-0.111*	-0.039
	(0.152)	(0.038)	(0.058)	(0.067)
2019	-0.261	-0.135***	-0.155**	-0.106
	(0.251)	(0.047)	(0.072)	(0.117)
2020	-0.336*	-0.218***	-0.248***	-0.198**
	(0.188)	(0.039)	(0.066)	(0.093)
⊿Log(Total Assets)	-0.117	0.038	0.049	-0.045
	(0.076)	(0.049)	(0.046)	(0.072)
⊿Log(Turnover)	0.239**	0.111	0.182**	0.145*

	(0.114)	(0.067)	(0.070)	(0.079)
⊿Log(Sectoral GVA)	0.251	0.132	0.300	-0.106
	(0.652)	(0.142)	(0.188)	(0.331)
Constant	0.330	0.134	0.859***	-0.222
	(0.372)	(0.223)	(0.139)	(0.385)
Country FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Observations	2,042	4,441	3,012	3,471
R-squared	0.140	0.087	0.137	0.085

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

For a more nuanced investigation of the potential variations in GHG emission reductions at less aggregated scales, we turn our attention to regional and sectoral subgroup analyses. Our goal is to gain deeper insights into the heterogeneity of emission reduction patterns between regions and sectors, that we have already seen indication for in the considerably increased significance of the overall emission reduction results when we included country-level and sectoral fixed effects. The analysis focuses on four major European regions, consistent with the classification of the Publication Office of the European Union (2023) that categorizes each European country into one of these regional groupings. Additionally, we delve into the emissions profiles of specific industrial sectors, with a particular focus on the "D – Electricity, gas, steam, and air conditioning supply" and "C – Manufacturing" sectors. These sectors are by far the two largest contributors to overall GHG emissions within the EU ETS. Furthermore, the "B - Mining and quarrying" sector is investigated separately, as it accounts for the third-largest share of emissions within our examined sample dataset. All other sectors are collectively analyzed.

Hypotheses 1d and 1e posit that the observed phenomena of greater emission reductions among underallocated companies and those with a substantial decrease in their Allocation Factor (AF) also hold on regional/sectoral levels. In other words, firms in regions/sectors characterized by a lower proportion of overallocated firms throughout Phase III and/or a significant reduction in their companies' AF between Phases II and III should experience more substantial reductions in their GHG emission levels during Phase III, according to our hypothesis.

Figure 10 highlights the dynamic changes in the proportion of overallocated companies across different regions. Notably, Central and Eastern Europe experienced the most significant decline in the share of overallocated firms from Phase II to Phase III, moving from the top position in the first two phases to a lagging position in the majority of Phase III in this respect. Consequently, it is expected, as suggested by our hypothesis, that the relatively higher increase in regulatory stringency faced by companies in this region would incentivize them to reduce their GHG emissions to a greater extent compared to companies in other regions. Figure 6 illustrates that companies operating in Central and Eastern Europe made a comparatively smaller contribution to the overall reduction in emissions within the EU ETS during the first two phases, particularly when compared to regions such as Western Europe and Northern Europe. Therefore, the anticipated decline in the emission levels of Central and Eastern European companies in Phase III, as proposed by our hypothesis, would contribute to a more equitable distribution of the overall regulatory burden.

To delve into the sectoral distribution of emissions and evaluate the hypotheses 1d and 1e with respect to industries as well, we must consider the trends observed in Figure 11. This figure illustrates that industrial sectors without sector D (Electricity, gas, steam, and air conditioning supply) exhibited a notably less pronounced decrease in the share of overallocated companies compared to firms in sector D. Our empirical analysis will specifically concentrate on the comparison between sector D and C - Manufacturing, given the latter's substantial contribution to industrial emissions. In our regression estimations, we anticipate that companies operating in sector D have enacted more substantial emission reductions compared to those in sector C. This expectation is further underscored by the fact that, as depicted in Figure 8, other industrial sectors overtook sector D in terms of their combined overall GHG emissions during the second part of Phase III.

Table 4, Results of the estimation of Equation 2 with the first difference of the natural logarithm of firm-level GHG emissions as the dependent variable and subgroup analysis based on region and industry

∆Log (Emissions)	(1) Central and Eastern Europe	(2) Northern Europe	(3) Southern Europe	(4) Western Europe	(5) Sector B	(6) Sector C	(7) Sector D	(8) Other
2014	0.076* (0.036)	-0.009 (0.039)	0.033 (0.024)	-0.008 (0.020)	-0.214 (0.218)	0.050 (0.032)	-0.032 (0.078)	-0.006 (0.062)
2015	0.208** (0.062)	0.153* (0.049)	0.098 (0.060)	0.013 (0.026)	-0.243 (0.273)	0.085* (0.046)	-0.010 (0.139)	0.114 (0.099)
2016	0.298*** (0.059)	-0.361 (0.287)	0.179** (0.057)	0.022 (0.027)	-0.216 (0.378)	0.142** (0.067)	-0.006 (0.240)	0.046 (0.100)
2017.	0.415***	-0.203	0.168**	0.017	-0.190	0.130*	0.067	-0.119

	(0.103)	(0.273)	(0.053)	(0.037)	(0.329)	(0.066)	(0.310)	(0.117)
2018	0.268***	-0.038	0.210**	-0.006	-0.439	0.130**	0.053	-0.087
	(0.076)	(0.299)	(0.053)	(0.041)	(0.352)	(0.060)	(0.338)	(0.141)
2019	0.281	-0.123	0.256*	-0.007	-0.561	0.136	0.071	-0.029
	(0.248)	(0.298)	(0.094)	(0.034)	(0.552)	(0.084)	(0.367)	(0.101)
2020	0.430**	-0.311	0.143*	-0.001	-0.441	0.161*	-0.088	0.026
	(0.144)	(0.576)	(0.062)	(0.026)	(0.668)	(0.084)	(0.332)	(0.083)
⊿Log(Total Assets)	-0.114**	-0.079	0.025	-0.041	0.043	-0.008	-0.015	0.026
	(0.047)	(0.084)	(0.038)	(0.036)	(0.153)	(0.030)	(0.046)	(0.042)
⊿Log(Turnover)	0.230	0.780***	0.056	0.458**	0.063	0.284***	0.094	-0.026
	(0.137)	(0.029)	(0.051)	(0.142)	(0.137)	(0.066)	(0.071)	(0.066)
⊿Log(GVA)	-1.590**	-1.168	-0.814*	0.133	-0.103	-0.104	-0.901	-0.024
	(0.572)	(2.173)	(0.331)	(0.198)	(1.024)	(0.248)	(1.586)	(0.355)
Constant	-0.015	0.555	0.628**	-0.025	0.170	-0.081**	0.100	-0.146*
	(0.044)	(0.541)	(0.174)	(0.023)	(0.328)	(0.037)	(0.065)	(0.073)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	No	No	No	No
Observations	1,453	306	5,508	3,674	433	6,616	2,473	1,419
R-squared	0.084	0.272	0.015	0.036	0.120	0.023	0.089	0.012

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results of our estimation with subgroup analysis based on region and industry are reported in Table 4. In light of our formulated hypotheses and the descriptive analysis, our initial expectations were centered on observing noteworthy reductions in GHG emissions among companies situated in Central and Eastern Europe, as well as within sector C - Electricity, gas, steam, and air conditioning supply. Contrary to our initial expectations. the results presented in Table 8 reveal that, all else being equal, companies in Central and Eastern European region did not exhibit substantial emission reductions during Phase III of the EU ETS on average. Instead, the data suggests that, on average, these companies experienced a statistically significant increase in emissions compared to their Phase II levels over most of the years in Phase III.

A potential explanation for this counterintuitive result is the potentially significant heterogeneity between the companies in the region even after the inclusion of country and industry fixed effects which suggests that companies significantly differ within countries across sectors as well as within sectors across the region. Central and Eastern Europe, as a whole, experienced a slight reduction in emissions during Phase III, as depicted in Figure 6. The empirical analysis of the data indicates that this reduction did not uniformly translate to individual companies within the region. Some companies may have increased their emissions during Phase III, offsetting the efforts of others to reduce.

Another plausible factor for the limited effectiveness of heightened regulatory stringency in reducing average emissions within the region, after controlling for various influencing factors, could be attributed to the composition of the regional energy mix. Given that the energy production sectors had historically been the largest contributors to GHG emissions covered by the EU ETS, this aspect warrants significant consideration. A key factor is the reliance on various energy resources, particularly those with high GHG emission intensities. If a substantial portion of energy production is dependent on such carbon-intensive resources and if cleaner, low-emission energy alternatives are not readily accessible or economically viable, this can contribute to elevated emissions.

Empirical data clearly reveals that Central and Eastern European countries exhibit a significantly higher dependence on these carbon-intensive energy sources, including coal, oil, and natural gas (see appendix D, Figure A3). Although there has been a noticeable reduction in this reliance over the course of Phase III, these resources still accounted for over 15% of all energy production in the region in 2020. This figure starkly contrasts with the situation in other European regions, where such resources contributed to less than 5% of energy production. This underscores the unique challenges faced by Central and Eastern European nations in reducing environmentally detrimental energy production. It underscores the necessity for complementary region-specific policies and tailored strategies aimed at addressing these distinct challenges effectively.

Another factor that may have contributed to this unanticipated outcome is differences in energy prices, particularly electricity costs, which can influence a company's motivation to curtail emissions. Companies operating in regions with lower energy prices might have reduced incentives to invest in cleaner technologies or energy-efficient processes. To investigate the relevance of this channel, the average price of electricity for non-household consumers was calculated across regions in Phase III of EU ETS (see Appendix D, Figure A4). In the case of Central and Eastern European countries, despite their high reliance on carbon-intensive energy resources, lower energy costs may have mitigated the cost-related incentives to transition to cleaner and more environmentally friendly energy sources or to implement emission reduction measures. This financial consideration, in the context of varying energy prices, serves as an additional factor that could help explain the relatively high emissions in the Central and Eastern European region during Phase III of the EU ETS.

With respect to the estimation results on the sectoral distribution of the change of GHG emissions in Phase III compared to Phase II, we can indeed observe, that firms operating in sector D (Electricity, gas, steam, and air conditioning supply) exhibited slight but statistically insignificant reductions in their emission levels, after controlling for the size and economic performance of firms as well as including country fixed effects to control for heterogeneous response of firms across countries. In comparison, firms in sector C - Manufacturing have slightly increased their GHG emission after controlling for the same variables. It is also important to point out that we cannot observe a decreasing trend in the emissions level of companies in this sector either, suggesting the potential inadequacy of the gradual shift towards auctioning in industrial sectors as an instrument for achieving this goal.

The composition of the emission levels within sectors also plays a vital part in this investigation. The exact compositions of GHG emissions across subsectors with respect to Sectors C and D is reported in Appendix A. The manufacturing sector is extremely heterogeneous with respect to the emission levels of each sub-sector. This variability can result in divergent emission trends within the sector. Companies between different subsectors may have undertaken emission reduction efforts at different paces, and the success of such initiatives is influenced by factors like available technologies, and market conditions, specific to the subsectors. As Sector D is the most significant contributor to GHG emissions of industrial sectors which have now overtaken energy production as the largest emitter group, this warrants a meticulous subsector analysis as well in future research of the Manufacturing sector. In contrast, the Electricity production subsector is responsible for over 81% of emissions in sector D, making it a more homogeneous and more easily impactable sector by the instruments of the EU ETS.

5.2. Competitiveness effect of EU ETS Phase III on regulated companies

In our empirical investigation concerning Research Question 2 and its associated hypotheses (2a, 2b), we adopt the Difference-in-Differences (DiD) methodology, as detailed in Section 4.3.2. This method allows us to analyze changes in competitiveness over time by assessing the differential response to the implementation of Phase III based on whether a company falls under EU ETS regulation or not. The main variables of interest in our analysis are the interaction terms involving a binary variable denoting whether a firm has been subjected to the regulatory "treatment" and its interaction with year fixed effects spanning the entire Phase III period (2013-2020). The "Treated" variable quantifies the differential change in competitiveness for firms during this period, depending on whether they fall under EU

ETS regulation or not. The analysis of year fixed effect coefficients allows us to identify temporal trends in competitiveness indicators. To make the fundamental parallel trends assumption more credible in our study, which attributes changes in relative competitiveness to the treatment, we incorporate control variables that are expected to be independent of the treatment but may influence the outcome variables.

To conduct our empirical investigation on the effect of the EU ETS Phase III on competitiveness, we examined these effects separately for each of our competitiveness indicators (Added value, Return on Equity (ROE), EBITDA, and Profit margin), that proxy for the fundamentally unmeasurable and somewhat subjective notion of competitiveness. Aligning with *Hypothesis 2a,* and drawing from previous empirical research findings, we anticipated statistically insignificant coefficients, signifying that the treatment had no direct impact on the competitiveness indicators. Concerning the subgroup analyses, *Hypothesis 2b* suggests companies operating in sectors/regions where, on average, firms did not significantly reduce their GHG emissions had less negative/more positive competitiveness effects. In effect, after our preceding empirical analysis, this hypothesis refers to Central and Eastern Europe, Southern Europe, and D – Manufacturing sector.

5.2.1. Added value

Value added (VA) is a suitable indicator for measuring competitiveness. Companies that excel in creating additional value demonstrate their ability to stand out in the market and gain a competitive edge. VA quantifies this notion by measuring the incremental difference between a company's return on investment and its cost of capital. Essentially, VA gauges the value generated by a company from the funds invested in it, providing a valuable metric for assessing a firm's competitiveness. By focusing on creating value beyond the baseline, companies attract and retain customers, thus solidifying their position in a competitive market (Corporate Finance Institute, 2023).

Table 5, Results of the estimation of Equation 9 with the first difference of log(Added Value) as the dependent variable

⊿Log(Added Value)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treated*2014	0.100*** (0.025)	0.151*** (0.044)	0.092*** (0.023)	0.130*** (0.043)	-0.423*** (0.043)	0.107* (0.056)	0.204* (0.106)
Treated*2015	0.174*** (0.046)	0.206*** (0.050)	0.169*** (0.041)	0.189*** (0.048)	-0.345*** (0.058)	0.174** (0.064)	0.284 (0.208)
Treated*2016	0.240***	0.256***	0.235***	0.239***	-0.431***	0.228***	0.078

	(0.068)	(0.061)	(0.065)	(0.060)	(0.050)	(0.078)	(0.267)
Treated*2017	0.270***	0.277***	0.269***	0.264***	0.492***	0.256**	-0.128
	(0.086)	(0.069)	(0.085)	(0.071)	(0.064)	(0.093)	(0.363)
Treated*2018	0.275***	0.275***	0.277***	0.265***	-0.261***	0.259***	-0.024
	(0.083)	(0.063)	(0.085)	(0.066)	(0.087)	(0.088)	(0.434)
Treated*2019	0.296***	0.290***	0.299***	0.281***	-0.252*	0.279***	-0.028
	(0.085)	(0.060)	(0.088)	(0.065)	(0.127)	(0.092)	(0.464)
Treated*2020	0.268***	0.264***	0.266***	0.251***	-0.332***	0.240***	-0.273*
	(0.070)	(0.060)	(0.069)	(0.060)	(0.102)	(0.082)	(0.151)
Total assets	-0.009	-0.009	-0.010	-0.010	-0.012	-0.007	-0.010
	(0.028)	(0.028)	(0.029)	(0.030)	(0.030)	(0.031)	(0.030)
Turnover	0.173***	0.166***	0.160**	0.153**	0.149**	0.146**	0.151**
	(0.059)	(0.056)	(0.065)	(0.063)	(0.062)	(0.057)	(0.065)
Sectoral GVA	-0.515*	-0.249	-0.568	-0.313	-0.135	-0.427	-0.272
	(0.298)	(0.199)	(0.361)	(0.237)	(0.355)	(0.347)	(0.216)
Constant	-0.042*	-0.183***	0.278**	0.246**	0.289**	1.364***	-0.025
	(0.023)	(0.054)	(0.111)	(0.109)	(0.113)	(0.074)	(0.142)
Country FE	No	Yes	No	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	Yes	Yes	Yes
Year*Country FE	No	No	No	No	Yes	No	No
Country*Industry FE	No	No	No	No	No	Yes	No
Year*Industry FE	No	No	No	No	No	No	Yes
Observations	10,941	10,941	10,941	10,941	10,941	10,941	10,941
R-squared	0.012	0.020	0.015	0.023	0.030	0.055	0.026

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 presents the estimation results concerning the impact of EU ETS regulation on the added value of regulated companies when compared to pre-Phase III levels. These findings deviate from our initial assumptions, as they reveal notable and statistically significant effects on added value across most model specifications. Remarkably, the results indicate a significant positive effect that tends to increase over time in the majority of specifications. *Hypothesis 2a* suggests that anticipated negative competitiveness effect of environmental regulation was counterbalanced successfully by the mitigation negative effects by the government, the existence of innovative mechanisms as detailed by the Porter hypothesis, or a combination of these factors. In our case, as we have observed positive overall competitiveness effects with respect to this indicator, an even more successful mitigation is suggested. This outcome implies the existence of a mechanism in which companies required to allocate additional resources toward emission abatement experience positive impacts on their competitiveness. This suggests that environmental regulations can be associated with a net gain in competitiveness for companies adhering to such regulations.

The introduction of Industry and Country fixed effects, amplifies the observed effect on the outcome. This underscores the considerable heterogeneity among sectors and countries, stemming from distinct characteristics inherent to companies within these subgroups. However, intriguingly, Specification (5) introduces a negative effect which deviates from all other specifications. This negative outcome suggests that the inclusion of the interaction between Country and Year fixed effects unveils a nuanced dynamic that has a negative impact on the outcome variable. Some specific combinations of country and year within this interaction is linked to a reduction in the competitiveness indicator when contrasted with the main effects considered in isolation. To address this discrepancy in the results, we will incorporate both specifications (4) & (5) into our subsequent subgroup analysis.

Table 6 and 7 present the outcomes of our subgroup analyses, which focus on the impact of EU ETS compliance on the change in Added Value. We anticipated that companies within the C – Manufacturing sector, as identified in our sectoral analysis, and those operating in Central and Eastern Europe and Southern Europe, as identified in our regional comparison, would experience more favorable competitiveness effects. This expectation stemmed from the observation that these firms, on average, did not play as significant a role in the collective GHG reduction efforts throughout EU ETS Phase III. Consequently, these companies were not as burdened by additional adaptation costs related to transitioning to less carbon-intensive production methods.

Table 6, Results of the estimation of Equation 9 with the first difference of log(Added Value) as the dependent variable with sectoral subgroup analysis, applying specifications (4) & (5) from Table 9

⊿Log(Added Value)	(1) Sector B	(2) Sector B	(3) Sector C	(4) Sector C	(5) Sector D	(6) Sector D	(7) Other	(8) Other
Treated*2014	-0.23	-1.05**	0.19**	-1.69***	-0.03	-0.14	0.10	0.06
	(0.35)	(0.41)	(0.07)	(0.06)	(0.18)	(0.13)	(0.09)	(0.08)
Treated*2015	-0.38	-0.68***	0.23***	-2.15***	0.09	-0.31**	0.24**	0.43***
	(0.290)	(0.20)	(0.07)	(0.09)	(0.19)	(0.12)	(0.09)	(0.04)
Treated*2016	-0.45	-0.86*	0.31***	-1.79***	0.14	0.31**	0.25*	0.47***
	(0.30)	(0.44)	(0.09)	(0.07)	(0.24)	(0.14)	(0.12)	(0.09)
Treated*2017	-0.20	-0.32	0.33***	-1.88***	0.11	-0.89***	0.27***	0.50***
	(0.26)	(0.88)	(0.11)	(0.11)	(0.29)	(0.15)	(0.08)	(0.09)
Treated*2018	-0.30	-0.37	0.32***	-2.77***	0.13	-2.03***	0.30***	0.51***
	(0.28)	(0.75)	(0.10)	(0.14)	(0.31)	(0.14)	(0.09)	(0.13)
Treated*2019	-0.29	-0.55	0.32***	-4.27***	0.19	-2.25***	0.36***	0.64***
	(0.31)	(0.77)	(0.11)	(0.21)	(0.35)	(0.15)	(0.08)	(0.21)
Treated*2020	-0.47	-1.01	0.32***	-3.44***	0.08	-2.25***	0.31**	0.64***

	(0.41)	(0.69)	(0.10)	(0.17)	(0.31)	(0.15)	(0.11)	(0.19)
Total assets	0.04	0.02	-0.01	-0.01	-0.02	-0.02	0.03	0.03
	(0.16)	(0.19)	(0.03)	(0.03)	(0.05)	(0.05)	(0.04)	(0.04)
Turnover	0.06	0.05	0.29***	0.29***	0.09	0.07	-0.03	-0.03
	(0.15)	(0.16)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)
Sectoral GVA	0.57	2.23	-0.14	12.93***	-1.10	5.17***	0.00	0.06
	(0.84)	(3.27)	(0.28)	(0.69)	(1.57)	(0.33)	(0.31)	(0.33)
Constant	0.11	-0.27**	-0.24***	-0.33***	0.04	-0.06	-0.15*	0.11***
	(0.27)	(0.11)	(0.07)	(0.05)	(0.14)	(0.11)	(0.08)	(0.02)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year* Country FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	433	433	6,616	6,616	2,473	2,473	1,419	1,419
R-squared	0.128	0.165	0.028	0.036	0.091	0.139	0.023	0.050

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results, depicted in Table 6, revealed that our initial expectations for the sectoral subgroup assessment were only partially validated. Specifically, when we incorporate both Country and Industry fixed effects, we observe that firms in the Manufacturing sector exhibit a positive, increasing and statistically significant impact on added value relative to unregulated firms, on average. Sector D companies, in contrast, shows no significant alteration in the change in their added value. However, when we further introduce the interaction of the Year and Country fixed effects into the model, a surprising dynamic emerges. Companies in sector C, or Manufacturing, are now projected to experience a significant decline in their competitiveness on average, and this decline is even more pronounced than that observed in sector D. In essence, the Year and Country interaction terms reveal a significant relationship within the Manufacturing sector that has a substantial negative impact on added value compared to the more simplified model without these interaction effects. These interaction effects imply that the temporal changes and country-specific dynamics have a combined impact that is unfavorable for companies operating in the Manufacturing sector. This might be due to various factors such as shifting consumer preferences or economic fluctuations within specific countries. Consequently, the substantial negative influence on added value highlights the need for a more nuanced understanding of how these factors interact to shape the competitiveness of businesses in this sector. This further emphasizes the need for subsector analysis in future research to understand the underlying factors influencing this outcome.

Table 7, Results of the estimation of Equation 9 with the first difference of Added Value as the dependent variable with sectoral subgroup analysis, applying specifications (4) & (5) from Table 9

Δlog(Added Value)	(1) Central and Eastern Europe	(2) Central and Eastern Europe	(3) Northern Europe	(4) Northern Europe	(5) Southern Europe	(6) Southern Europe	(7) Western Europe	(8) Western Europe
Treated*2014	-0.04 (0.19)	-0.36** (0.13)	0.44** (0.13)	0.07 (0.19)	0.09* (0.04)	0.15** (0.04)	0.10 (0.08)	0.18 (0.13)
Treated*2015	0.13 (0.22)	-0.24 (0.16)	0.63** (0.15)	0.66*** (0.11)	0.20* (0.08)	0.00 (0.05)	0.10 (0.09)	-0.20 (0.14)
Treated*2016	0.29 (0.23)	-0.36** (0.14)	0.43*** (0.06)	0.11 (0.20)	0.33** (0.11)	0.20* (0.08)	0.13 (0.1)	0.28* (0.14)
Treated*2017	0.35 (0.27)	0.50 (0.34)	0.63* (0.21)	0.56 (0.29)	0.42** (0.11)	0.00 (0.11)	0.11 (0.12)	0.24 (0.18)
Treated*2018	0.31 (0.25)	-0.08 (0.19)	0.65** (0.18)	0.41 (0.21)	0.45*** (0.09)	-0.02 (0.13)	0.11 (0.12)	0.84*** (0.06)
Treated*2019	0.46 (0.26)	0.04 (0.27)	0.73** (0.22)	0.18 (0.89)	0.45*** (0.10)	0.15 (0.11)	0.11 (0.11)	0.44*** (0.09)
Treated*2020	0.41 (0.27)	-0.11 (0.22)	0.712** (0.20)	-0.15 (0.58)	0.32** (0.10)	0.41*** (0.09)	0.15 (0.12)	1.02*** (0.09)
Total Assets	-0.11* (0.05)	-0.11* (0.05)	-0.10 (0.12)	-0.15 (0.12)	0.03 (0.04)	0.02 (0.04)	-0.05 (0.04)	-0.05 (0.05)
Turnover	0.24 (0.13)	0.23 (0.12)	0.74*** (0.03)	0.77*** (0.03)	0.05 (0.05)	0.05 (0.05)	0.47** (0.15)	0.47** (0.15)
Sectoral GVA	-1.31** (0.51)	-1.13 (0.73)	-2.04 (1.98)	-9.95*** (1.56)	-0.85 (0.40)	-0.17 (0.48)	0.11 (0.21)	0.27 (0.16)
Constant	0.13* (0.07)	0.13* (0.07)	-0.10 (0.75)	0.05 (0.89)	0.53* (0.19)	-0.25 (0.16)	-0.17 (0.12)	-0.20 (0.11)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year*Country	No	Yes	No	Yes	No	Yes	No	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,453	1,453	306	306	5,508	5,508	3,674	3,674
R-squared	0.098	0.115	0.342	0.398	0.019	0.021	0.041	0.044

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The outcomes of the regional subgroup analysis, as presented in Table 7, reveal noteworthy findings. In the first specification, companies based in Northern and Southern Europe exhibit a notable, positive, and progressively increasing influence on Added Value. This suggests that they have been able to effectively adapt to the more stringent regulatory constraints of EU ETS Phase III. In contrast, firms in Central and Eastern Europe and Western Europe do not exhibit a statistically significant impact on their added value compared to their unregulated counterparts. However, in the second specification, the incorporation of the Year and Country interaction fixed effects unveils a different scenario. Here, only Western European companies demonstrate a positive and ascending competitive effect on added value. All in all, Central and Eastern European enterprises do not display a favorable impact on their added value in either specification. This outcome challenges the expectations formulated under *Hypothesis 2b*, however, it provides further support for the Porter hypothesis. Given that companies in this region, on average, managed to maintain their emission profiles with minimal adjustments, they exhibited a comparatively lower degree of adaptation to the evolving market dynamics within their respective sectors. These dynamics might have inherently demanded a more substantial investment in carbon intensity reduction as a means to sustain competitiveness, in line with the Porter hypothesis.

5.2.2. ROE

Return on Equity (ROE) serves as a fundamental financial metric in evaluating a company's competitive performance. It quantifies the company's capacity to transform equity investments into profits. This ratio, expressed as a percentage, is calculated by dividing the firm's net income by its shareholders' equity. ROE offers a valuable tool for assessing investment returns and sheds light on a company's competitive standing. Moreover, a sustained and increasing ROE is indicative of the company's capability to generate shareholder value, signifying prudent reinvestment of earnings to foster productivity and profitability (Corporate Financial Institute, 2023).

Table 8, Results of the estimation of Equation 9 with the first difference of log(ROE) as the dependent variable

Δlog(ROE)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treated*2014	0.24** (0.10)	0.29*** (0.09)	0.22* (0.11)	0.26** (0.10)	0.29*** (0.10)	0.23** (0.11)	0.24 (0.25)
Treated*2015	0.35*** (0.11)	0.41*** (0.10)	0.35*** (0.12)	0.40*** (0.12)	0.62*** (0.10)	0.39*** (0.12)	0.41 (0.34)
Treated*2016	0.46*** (0.10)	0.52*** (0.09)	0.45*** (0.11)	0.51*** (0.11)	0.90*** (0.11)	0.49*** (0.11)	0.81** (0.36)
Treated*2017	0.46*** (0.13)	0.53*** (0.11)	0.46*** (0.14)	0.52*** (0.13)	0.96*** (0.14)	0.50*** (0.13)	0.47 (0.63)
Treated*2018	0.41*** (0.10)	0.49*** (0.08)	0.42*** (0.11)	0.49*** (0.10)	0.94*** (0.17)	0.46*** (0.10)	0.75 (0.48)
Treated*2019	0.38*** (0.12)	0.46*** (0.10)	0.38** (0.14)	0.46*** (0.12)	1.06*** (0.20)	0.43*** (0.12)	0.70 (0.63)

Treated*2020	0.23** (0.11)	0.27** (0.11)	0.23* (0.13)	0.26** (0.12)	0.84*** (0.19)	0.24* (0.12)	0.50 (0.7)
Total assets	0.00 (0.02)	-0.01 (0.02)	0.00 (0.02)	0.00 (0.02)	-0.01 (0.02)	0.00 (0.02)	0.00 (0.02)
Turnover	0.04 (0.04)	0.04 (0.04)	0.03 (0.04)	0.04 (0.04)	0.03 (0.04)	0.04 (0.05)	0.03 (0.04)
Sectoral GVA	0.09 (0.47)	-0.15 (0.35)	0.00 (0.49)	-0.29 (0.38)	-1.11** (0.52)	-0.03 (0.35)	-0.27 (0.41)
Constant	-0.31*** (0.07)	-1.05*** (0.08)	0.08 (0.14)	-0.67*** (0.17)	-0.62*** (0.15)	-0.83*** (0.04)	-0.73*** (0.17)
Country FE	No	Yes	No	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	Yes	Yes	Yes
Year*Country FE	No	No	No	No	Yes	No	No
Country*Industry FE	No	No	No	No	No	Yes	No
Year*Industry FE	No	No	No	No	No	No	Yes
Observations	8,143	8,143	8,143	8,143	8,143	8,143	8,143
R-squared	0.052	0.071	0.058	0.075	0.085	0.098	0.079

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8 presents the regression results, revealing a consistently positive and increasing average treatment effect across the various specifications. This outcome, once again, deviates from our initial hypothesis, implying a notably positive impact of being under regulatory oversight on firms' competitive performance, measured in this case by ROE. The magnitude of this effect increases with the incorporation of different combinations of fixed effects, with the most substantial impact observed in specification (5). This particular specification encompasses Country and Industry fixed effects, along with an interaction fixed effect involving country and year. The positive influence on the outcome variable, ROE, when incorporating these indicators, underscores significant heterogeneity among firms operating in distinct sectors and countries, even within the same country over time. These factors contribute to explaining a significant portion of the variance observed in our outcome variable, ROE, and, therefore, warrant further exploration via regional and sectoral subgroup analyses utilizing specification (5).

Table 9, Results of the estimation of Equation 9 with the first difference of log(ROE) as the dependent variable with sectoral subgroup analysis

∆log(ROE)	(1) Sector B	(2) Sector C	(3) Sector D	(4) Other	(5) Central and Eastern Europe	(6) Northern Europe	(7) Southern Europe	(8) Western Europe
Treated*2014	-1.28**	0.41***	-0.15	0.57***	0.49***	0.33	0.45*	-0.10

	(0.52)	(0.11)	(0.15)	(0.17)	(0.08)	(0.18)	(0.15)	(0.05)
Treated*2015	-1.59*	0.55***	-0.05	0.79**	0.85***	0.75***	0.52***	0.04
	(0.86)	(0.14)	(0.12)	(0.27)	(0.10)	(0.11)	(0.09)	(0.09)
Treated*2016	-1.95***	0.69***	0.00	0.60**	1.01***	0.81***	0.62***	0.19
	(0.58)	(0.13)	(0.16)	(0.21)	(0.07)	(0.12)	(0.08)	(0.14)
Treated*2017	-3.42***	0.67***	-0.02	0.75*	1.13***	0.80**	0.65***	0.18
	(0.77)	(0.15)	(0.17)	(0.37)	(0.15)	(0.19)	(0.10)	(0.14)
Treated*2018	-4.41***	0.62***	-0.02	0.60**	1.20***	0.64**	0.48**	0.26
	(0.90)	(0.12)	(0.15)	(0.25)	(0.13)	(0.12)	(0.11)	(0.15)
Treated*2019	-5.85***	0.58***	-0.08	0.65**	1.35***	0.62**	0.43*	0.18
	(1.09)	(0.13)	(0.18)	(0.30)	(0.17)	(0.17)	(0.16)	(0.10)
Treated*2020	-5.95***	0.35**	-0.18	0.61	1.13***	0.28*	0.36**	-0.07
	(1.03)	(0.16)	(0.15)	(0.380)	(0.15)	(0.12)	(0.07)	(0.11)
Total assets	-0.08	0.00	0.00	0.02	-0.10	-0.12	0.03	-0.01
	(0.16)	(0.03)	(0.02)	(0.07)	(0.06)	(0.06)	(0.01)	(0.03)
Turnover	-0.41**	0.18**	-0.02	-0.13	0.10	0.19	0.00	0.09
	(0.14)	(0.07)	(0.07)	(0.12)	(0.12)	(0.13)	(0.07)	(0.07)
Sectoral GVA	20.10***	-0.42	1.36**	0.18	-1.31*	0.24	0.57	-1.05**
	(2.59)	(0.42)	(0.57)	(0.57)	(0.63)	(2.62)	(0.63)	(0.39)
Constant	0.58	-1.60***	-0.26**	-0.20	-0.21**	-0.34	0.06	-1.02***
	(0.40)	(0.09)	(0.10)	(0.12)	(0.08)	(1.26)	(0.14)	(0.11)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year*Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	No	No	Yes	Yes	Yes	Yes
Observations	259	4,673	2,079	1,132	991	388	4,024	2,740
R-squared	0.377	0.082	0.103	0.085	0.100	0.177	0.086	0.073

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9 presents the outcomes of the sectoral and regional subgroup analysis, aligning with our initial expectations. We anticipated that companies within the Manufacturing (C) sector, as well as those in Central and Eastern Europe and Southern Europe, would demonstrate more favorable competitiveness effects. The data confirms these expectations when examining the average change in Return on Equity (ROE) in comparison to the pre-Phase III period, relative to the control group. Central and Eastern European firms exhibited a notable upward trend in their relative ROE change. Moreover, Northern Europe also displayed a positive ROE effect which aligns with the legitimacy of the Porter hypothesis, as these companies not only significantly reduced their emissions but also gained a competitive edge.

The additional regression analyses, where EBITDA and Profit margin are considered as dependent variables, further substantiate our findings. Notably, across most specifications, there is a consistently positive and increasing effect observed. Furthermore, the subgroup analyses align with our hypotheses, highlighting that sectors, particularly Manufacturing (C), and regions, specifically Central and Eastern Europe and Southern Europe, which exhibit a smaller reduction in their average emission levels, tend to experience more positive competitive outcomes. These results, presented in Appendix E, provide a valuable sensitivity test that complements our primary analysis using Value Added and ROE as the outcome variables.

6. Discussion and Limitations

In our analysis, we sought to shed light on the consequences of EU ETS Phase III regulations at the firm-level. Our initial empirical investigation revolved around whether this regulatory framework was effective at the firm level and, if so, how emission reduction was distributed across different firm subgroups, namely regions and sectors. We have found significant and progressively increasing reduction in GHG emissions among regulated firms. This reduction in firm-level GHG emissions was even more pronounced for firms receiving less free allocation than their yearly emission level and for those who experienced a significant drop in their Allocation Factor at the beginning of Phase III.

Our findings point towards the effectiveness of EU ETS Phase III in motivating regulated companies to curtail their GHG emissions. The analysis of underallocated companies indicates the Coase theorem does not hold and in this context, and allocation mechanisms indeed matter. We have attributed this to several market failures including transaction costs, asymmetric information and behavioral anomalies of managers. A detailed exploration of the underlying causes for the Coase theorem's failure to reflect real-world market dynamics is provided in Section 2.2.1 of the Theoretical Framework.

The effectiveness of the increasing regulatory stringency embedded within the system is also underscored by these the majority of our results. The predetermined reduction of overall emission caps exerts pressure on carbon-intensive producers by amplifying direct and indirect costs associated with emissions. Such companies are confronted with the choice of either endure the direct costs linked to carbon-intensive production technologies as the prices of auctioned and traded EU Allowances (EUAs) are expected to rise in response to the reduced cap or making substantial long-term investments in less carbon-intensive technologies. Another contributing mechanism is the gradual phase-out of free allocation. As established previously, allocation does matter in the context of emission trading and the decrease in free allocation leads to increase of compliance costs in case of unchanged emission behavior which incentives carbon reduction investments. Therefore, our results suggest that these mechanisms successfully motivated companies to allocate increased efforts and resources towards carbon reduction initiatives.

Our regional comparison led to an unexpected result: Central and Eastern European companies, despite experiencing the most significant reduction in the proportion of overallocated firms from Phase II to Phase III, did not exhibit, on average, reduced emissions. We delved deeper into this counterintuitive outcome, unveiling three potential underlying factors that may elucidate this counterintuitive result. First, the higher heterogeneity of companies within this region could have contributed to varied responses to the regulatory changes. Second, the region's countries displayed a relatively high reliance on "dirty" energy resources, fossil fuels. This reliance might have hindered emissions reductions efforts. Third, the energy prices within this region were relatively low during the specific period under analysis. These lower energy prices may have offered fewer economic incentives for firms to invest in emissions reduction initiatives.

In the context of sectoral subgroup analysis, our hypotheses regarding a positive relationship between the increased significance of the change in allocation methods and emissions reduction in specific sectors were partially validated. Firms in sectors that experienced a more substantial rise in regulatory stringency were indeed associated with relatively lower emissions compared to sectors with less pronounced changes in regulatory stringency. Their emission reductions were not statistically significant however. An overview of our hypotheses related to our first research question, and their evaluation is presented in Table 10.

Table 10 – Summary of hypothesis evaluation related to RQ1

Research Question 1: What was the effect of Phase III of the EU ETS on firm level emissions among regulated companies?	
Hypothesis 1a: There was a significant and increasing reduction in greenhouse gas (GHG) emissions at the firm level over the years of Phase III for regulated companies.	**Supported**
Hypothesis 1b: The reduction of GHG emissions is more pronounced for firms that have been underallocated, meaning they have been distributed free allowances below their verified emissions.	**Supported**
Hypothesis 1c: GHG emissions are more substantially reduced in firms that experienced a considerable decrease in their Allocation Factor (AF = Allocated allowances / Verified Emissions) between 2012 and 2013, marking the transition from Phase II to Phase III.	**Supported**

Hypothesis 1d: The pronounced reduction of GHG emissions observed in underallocated firms at the firm level also holds true when comparing different sectors and regions.	Regional analysis: **Rejected**
	Sectoral analysis: **Partially supported**
Hypothesis 1e: Sectors/regions in which firms experienced a substantial decrease in their Allocation Factor between 2012 and 2013 exhibit greater emission reductions.	Regional analysis: **Rejected**
	Sectoral analysis: **Partially supported**

Regarding the results of our analysis about the firm-level competitiveness effects of the EU ETS Phase III regulation, we have made some intriguing findings. Particularly, we have estimated, on average, a significant positive effect on the competitiveness of regulated companies across estimations with all four competitiveness indicators. This finding supports the Porter hypothesis as opposed to the Pollution Haven hypothesis based on neoclassical economic theory. The Porter hypothesis is further reinforced by the increasing trend in their competitiveness when compared to unregulated companies. The hypothesis indicates that over time the necessary investments to reduce GHG emissions provide an increasing competitive edge for these companies compared to their counterparts and this mechanism is reinforced by our data. In essence, our results suggest that over time, the mandatory investments made by companies to reduce their GHG emissions not only comply with regulatory requirements but also achieve a growing competitive advantage in comparison to their non-regulated counterparts.

This result is particularly interesting in the context of the concerns expressed by various stakeholders, including those within carbon-intensive industries and countries, as the new phase of the EU ETS commenced. Many had expressed concerns about the potential negative impacts on competitiveness that could arise from the increased regulatory stringency. The fact that our findings indicate a positive and growing effect on the competitiveness of regulated firms not only challenges these initial worries but also suggests that the EU ETS Phase III has provided an avenue for firms to thrive in a more sustainable and environmentally responsible manner while bolstering their competitive positions.

In our regional and sector level analysis, our hypotheses received partial support. The results suggest that firms operating in sectors and regions where, on average, reductions were not as pronounced as anticipated, for various plausible reasons, enjoyed less positive effects on their competitiveness. This analysis further highlights the significance of sectoral and regional disparities among firms. It underscores the consequences of a one-size-fits-all approach typically employed by the EU ETS, which might magnify regional disparities within the European Union.

Table 11 - Summary of hypothesis evaluation related to RQ2

Research Question 2: How did the increased regulatory stringency in EU ETS Phase III impact regulated companies' competitiveness?	
Hypothesis 2a: There was no significant impact on competitiveness indicators for companies subjected to EU ETS Phase III regulations compared to non-regulated companies.	**Rejected**
Hypothesis 2b: Firms in sectors/regions that did not significantly adjust their emission path had less negative/more positive competitiveness effects.	**Partially supported**

In conclusion, our findings offer compelling evidence supporting the efficacy of emission trading systems in tackling greenhouse gas emissions. According to our findings, these systems effectively incentivize the transition towards less carbon-intensive production technologies while, notably, do not exert any negative impact on the competitive performance of regulated companies, thereby mitigating concerns related to carbon leakage. However, our analysis underscores the presence of substantial regional disparities, highlighting the necessity for targeted support and distinct treatment for enterprises operating in vulnerable sectors and regions. Specifically, it is imperative that regional governments and the European Union intensify their efforts to facilitate the shift toward less carbon-intensive energy production technologies in Central and Eastern Europe.

Our study provides valuable insights into the firm-level impacts of the EU ETS Phase III regulation. However, it is important to acknowledge the limitations of our analysis and outline potential avenues for future research. We opted to include only companies with emissions data available for all examined years (2011-2020). This may introduce selection bias, as exit and entry of firms could be correlated with their characteristics. For instance, some installations might have shut down due to the added marginal cost of production under Phase III, potentially biasing our estimates upwards. Future research should explore ways to address this selection bias more effectively. Furthermore, to construct a more robust Propensity Score Matching (PSM), a larger and more comprehensive dataset encompassing all companies within the examined countries and sectors would have been ideal. Unfortunately, data limitations constrained the feasibility of this approach. Utilizing growth of variables instead of static values in PSM could align the dataset more closely with the parallel trend assumption, but limited availability of financial data before 2012 hindered this estimation.

The competitiveness indicators we utilized are financial proxies and do not encompass non-financial aspects of a company's competitiveness, such as market share, innovation, company age, or average wages. Future research should consider a broader set of indicators to comprehensively evaluate competitiveness effects. Additionally, our study lacks a true pre-treatment period as Phase II of the EU ETS was already in operation. While we controlled for this limitation as best as possible, examining baseline covariate trends for the entire Phase II would have offered a more robust test of the parallel trend assumption. The ideal scenario would involve accessing data from before the introduction of the EU ETS (pre-2005) to construct pre-treatment variables. Lastly, the assumption that covariates such as turnover and employment are not correlated with the treatment status may not hold in reality. In practice, these variables could also be affected by regulatory treatment.

7. Conclusion

Our study of the EU ETS Phase III regulation's impact at the firm-level yielded critical insights. Regulated companies achieved a significant and increasing reduction in greenhouse gas emissions, demonstrating the effectiveness of emission trading systems in promoting emissions reduction. Concerns about negative competitiveness effects were dispelled, as regulated firms exhibited a significant and increasing positive effect on competitiveness indicators. This finding aligns with the Porter hypothesis, suggesting that environmental regulations can enhance a firm's competitiveness. These results carry substantial implications for global climate mitigation efforts. Emission trading systems, when well-designed, can serve as powerful tools to reduce greenhouse gas emissions without compromising a firm's competitive edge. As the world seeks to combat climate change, these findings underscore the potential of market-based mechanisms in achieving environmental and economic sustainability simultaneously.

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Appendices

Appendix A – Sub-sectoral composition of EU ETS GHG emissions in sectors D and E

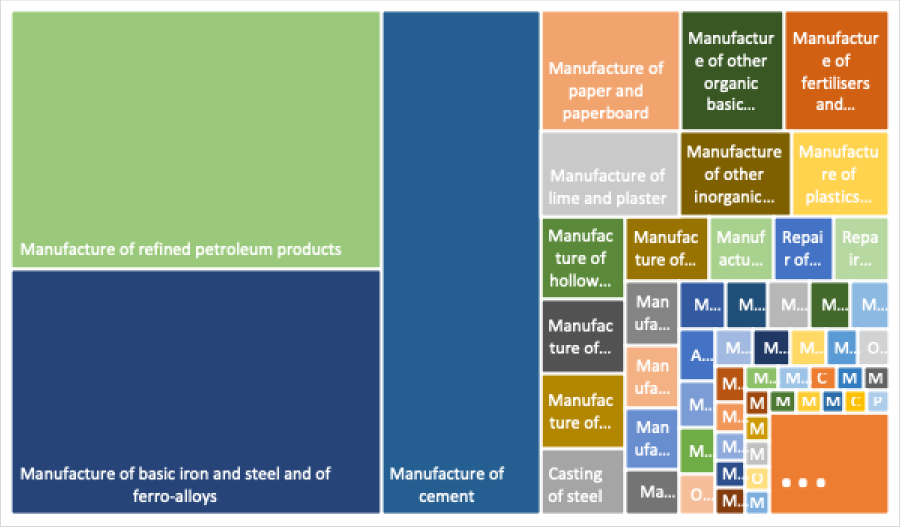

Figure A1, The composition of GHG emissions within sector D - Manufacturing

Figure A2, The composition of GHG emissions within sector C - Electricity, gas, steam and air conditioning supply

Appendix B – Descriptive statistics of final dataset and comparison to overall dataset

Table A1, Distribution of countries in final dataset

Country	Number of companies	Share of final dataset	Share in overall dataset	Difference
Austria	2	0,22%	1,94%	-1,72%
Belgium	7	0,79%	2,59%	-1,80%
Bulgaria	53	5,95%	1,47%	4,48%
Cyprus	1	0,11%	0,26%	-0,15%
Czechia	2	0,22%	3,66%	-3,44%
Germany	250	28,06%	15,32%	***12,74%***
Denmark	3	0,34%	3,10%	-2,76%
Spain	170	19,08%	10,95%	***8,13%***
Finland	9	1,01%	2,52%	-1,51%
France	55	6,17%	9,26%	-3,09%
United Kingdom	98	11,00%	8,05%	2,95%
Greece	13	1,46%	0,78%	0,68%
Hungary	17	1,91%	2,09%	-0,18%
Ireland	7	0,79%	1,16%	-0,37%
Italy	94	10,55%	8,76%	1,79%
Lithuania	1	0,11%	0,99%	-0,88%
Luxembourg	1	0,11%	0,32%	-0,21%
Poland	21	2,36%	7,91%	***-5,55%***
Portugal	15	1,68%	3,03%	-1,35%
Romania	8	0,90%	2,01%	-1,11%
Sweden	46	5,16%	3,27%	1,89%
Slovenia	17	1,91%	3,27%	-1,36%
Slovakia	1	0,11%	8,05%	***-7,94%***
Total	891	100%	92,51%	8,49%

Table A2, Distribution of sectors in final dataset

Sector	Number of companies	Share in final dataset	Share in overall dataset	Difference
A – Agriculture, forestry and fishing	4	0,45%	1,28%	-0,83%
B – Mining and quarrying	32	3,59%	2,09%	1,50%
C – Manufacturing	609	68,35%	52,45%	***15,90%***
D – Electricity, gas, steam and air conditioning supply	193	21,66%	22,20%	-0,54%

E – Water supply; sewerage, waste management and remediation activities	11	1,23%	1,43%	-0,20%
F – Construction	7	0,79%	1,25%	-0,46%
G – Wholesale and retail trade; repair of motor vehicles and motorcycles	20	2,24%	3,55%	-1,31%
H – Transportation and storage	15	1,68%	4,40%	-2,72%
Total	891	100%	88,64%	11,36%

Appendix C – The process of the creation of the control group via the application of Propensity Score Matching (PSA)

For the creation of the Propensity Score Matched control group, the following steps were undertaken. First, a random sample was drawn from the EU ETS countries (EU+EEA members). The selection aimed to maintain similar proportions of sectors as observed in the treated group, ensuring that the pool mirrored the sector distribution of the companies subjected to the ETS. Additionally, the pool was designed to be at least ten times larger than the number of companies present in the treated group for each sector. Furthermore, a manual exclusion was implemented to remove EU ETS companies that received free allocated allowances, ensuring that the pool consisted of companies not benefiting from such allowances. After these data cleaning and selection processes, the total size of the PSM pool amounted to 12,439 companies.

For the estimation of the propensity score procedure outlined in Lunt (2014) was followed. The aim was to determine the propensity score, $p(X) = Pr(D=1|X)$, where X represents the set of pre-treatment characteristics (Turnover, Value Added, EBITDA Number of employees, Total Assets, Working Capital, Profit Margin, ROE), and D is an indicator of the treatment received by firms. The inclusion of X is essential to meet the conditional independence assumption (CIA). This assumption states that firms with the same values of X_i will differ in their outcome Y_i only due to their participation in the ETS. First, a logistic regression model was employed using data from the year 2012, representing the "pre-treatment" period. This model aimed to identify which firm characteristics were most informative in determining the likelihood of being treated. Subsequently, a lasso regression analysis method, known for its variable selection capabilities, was applied to refine the set of covariates that would be included in the final propensity score estimation. To assess the quality of the propensity score model, a Hosmer–Lemeshow test was conducted to test its goodness of fit. The results of this test indicated a significant improvement in model fit compared to the initial logistic regression model.

Next, the process of a one-to-one propensity score matching was carried out. The PSM successfully achieved a standard difference below 0.2 standard deviations for all matched covariates. Subsequently, an examination of the graphical representations led to the decision to set a narrow caliper of 0.1 to ensure that the Common Support or Overlap Condition holds. This is a critical prerequisite that guarantees a positive likelihood for individuals with identical covariate values to be part of both the treatment and control groups. It ensures that there is some level of ambiguity in the relationship between covariates and treatment assignment, preserving the validity of the analysis. The caliper serves as a crucial tool in achieving this condition, limiting the acceptable differences between matched pairs and thereby ensuring that only suitable and high-quality matches are retained, reducing the likelihood of accepting unsuitable matches (Lunt, 2014). At the expense of omitting 16 companies from the treated dataset, the outcome of this adjustment was a notable reduction in standardized differences, with all values falling below 0.1 standard deviation (Table 5)., indicative of a highly successful match.

Appendix D – Central and Eastern Europe energy supply case study

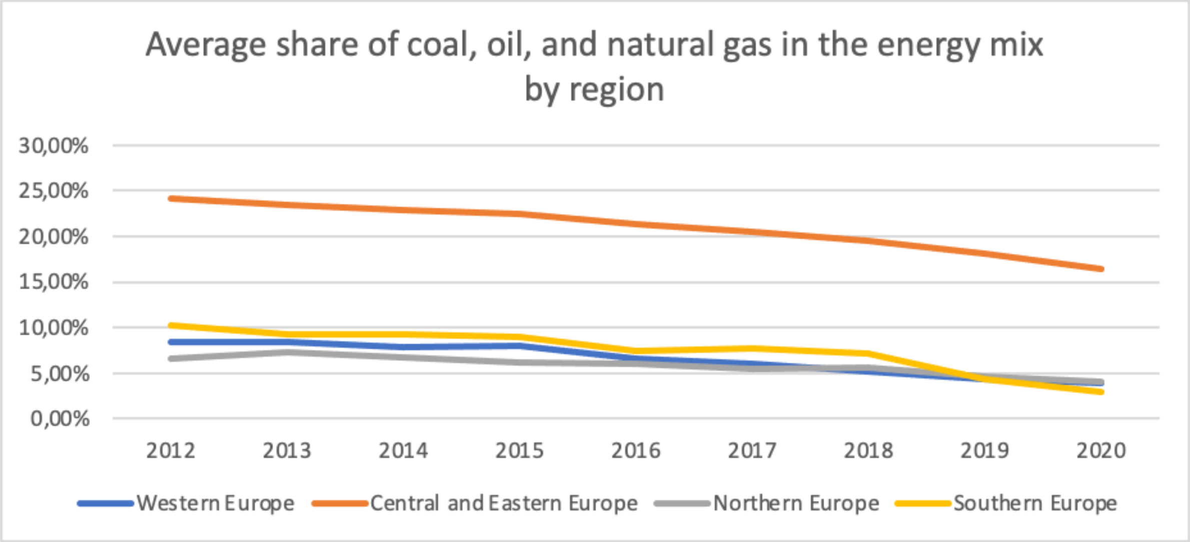

Figure A3, Average share of coal, oil, and natural gas in the energy mix by region. Author's calculation, based on Eurostat (2023b)

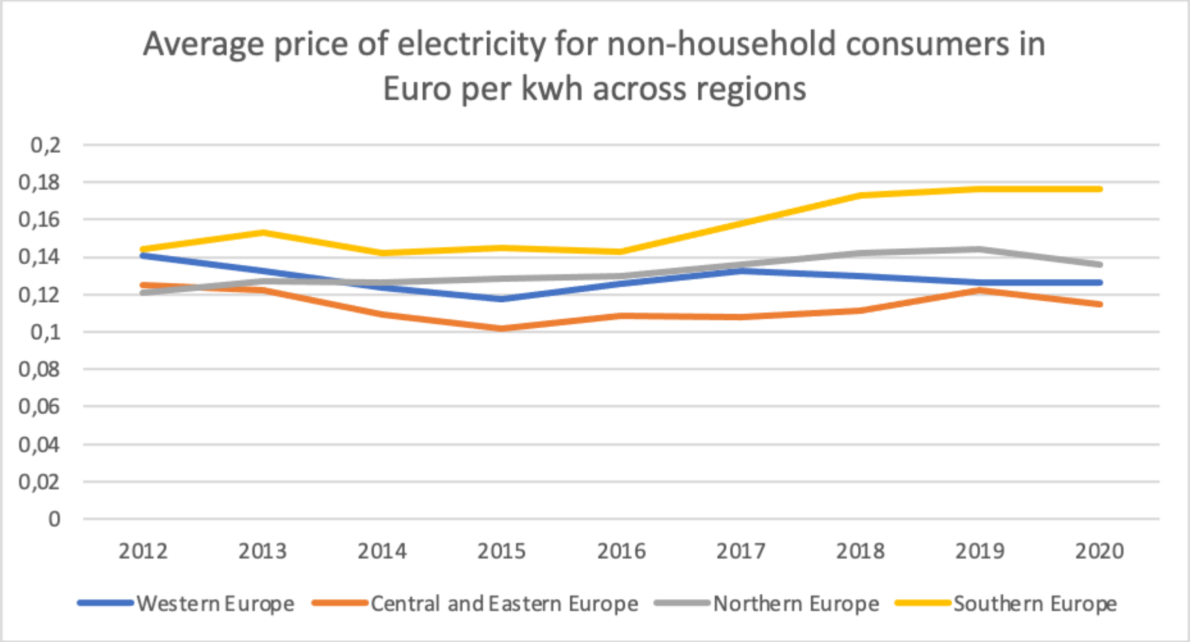

Figure A4, Average price of electricity for non-household consumers in Euro per kwh across regions. Author's calculation based on Eurostat (2023c)

Appendix E – Competitiveness results with EBITDA and Profit margin as the outcome variables

Table A3, Results of the estimation of Equation 9 with the first difference of log(EBITDA) as the dependent variable

Δlog(EBITDA)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
2014	0.103*	0.132*	0.094*	0.101	0.953***	0.096	0.474***
	(0.053)	(0.073)	(0.052)	(0.071)	(0.076)	(0.075)	(0.137)
2015	0.160**	0.171*	0.155**	0.153*	0.960***	0.144*	0.660**
	(0.073)	(0.090)	(0.069)	(0.078)	(0.113)	(0.083)	(0.259)
2016	0.250**	0.255**	0.245***	0.240**	0.933***	0.233**	0.519*
	(0.095)	(0.113)	(0.087)	(0.093)	(0.080)	(0.098)	(0.287)
2017	0.255**	0.253*	0.259**	0.251**	-0.161	0.239**	0.532**
	(0.112)	(0.130)	(0.104)	(0.107)	(0.163)	(0.112)	(0.225)
2018	0.240**	0.233*	0.247**	0.236**	1.166***	0.221*	0.512*
	(0.111)	(0.125)	(0.110)	(0.106)	(0.159)	(0.110)	(0.299)
2019	0.218*	0.208	0.228*	0.217*	1.039***	0.203	0.022
	(0.121)	(0.142)	(0.119)	(0.116)	(0.267)	(0.119)	(0.349)
2020	0.191	0.181	0.188	0.176	0.947***	0.158	-0.801**
	(0.120)	(0.131)	(0.112)	(0.110)	(0.202)	(0.117)	(0.337)
Total assets	0.021	0.019	0.019	0.018	0.016	0.013	0.018
	(0.046)	(0.048)	(0.046)	(0.048)	(0.048)	(0.051)	(0.048)
Turnover	0.135	0.134	0.113	0.115	0.111	0.129	0.114
	(0.126)	(0.125)	(0.121)	(0.121)	(0.122)	(0.119)	(0.120)
Sectoral GVA	0.166	0.436	0.068	0.186	0.441	0.239	0.058
	(0.394)	(0.597)	(0.357)	(0.415)	(0.945)	(0.311)	(0.327)
Constant	-0.059	-0.231**	0.134	-0.049	-0.029	0.646***	-0.017
	(0.034)	(0.097)	(0.184)	(0.133)	(0.175)	(0.062)	(0.170)
Country FE	No	Yes	No	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	Yes	Yes	Yes
Year*Country FE	No	No	No	No	Yes	No	No
Country*Industry	No	No	No	No	No	Yes	No
Year*Industry FE	No	No	No	No	No	No	Yes
Observations	9,858	9,858	9,858	9,858	9,858	9,858	9,858
R-squared	0.007	0.014	0.013	0.019	0.024	0.048	0.024

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A4, Results of the estimation of Equation 9 with the first difference of log(EBITDA) as the dependent variable and with sectoral and regional subgroup analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δlog(EBITDA)	B	C	D	Other	Central and Eastern Europe	Northern Europe	Southern Europe	Western Europe
2014	-0.190	0.161**	-0.262	0.243	0.900***	-0.373	0.196**	-0.004
	(1.029)	(0.075)	(0.214)	(0.266)	(0.036)	(0.312)	(0.045)	(0.072)
2015	0.962	0.172*	-0.093	0.344	0.934***	-0.225	0.191**	0.023
	(1.221)	(0.088)	(0.161)	(0.312)	(0.054)	(0.390)	(0.067)	(0.061)
2016	1.301	0.321***	-0.075	0.307	0.888***	-0.166	0.227	0.124
	(1.466)	(0.108)	(0.189)	(0.357)	(0.025)	(0.390)	(0.159)	(0.076)
2017	3.961*	0.290**	-0.009	0.330	-0.334***	-0.096	0.250	0.095
	(2.083)	(0.135)	(0.225)	(0.362)	(0.084)	(0.389)	(0.175)	(0.072)
2018	3.605	0.292**	-0.096	0.259	1.187***	-0.137	0.222	0.044
	(2.977)	(0.134)	(0.226)	(0.344)	(0.068)	(0.399)	(0.167)	(0.073)
2019	4.769	0.257	-0.039	0.245	1.134***	-0.279	0.167	0.046
	(3.423)	(0.154)	(0.255)	(0.363)	(0.146)	(0.430)	(0.196)	(0.060)
2020	2.558	0.214	-0.107	0.338	0.996***	-0.430	0.246	0.047
	(2.758)	(0.149)	(0.249)	(0.397)	(0.098)	(0.501)	(0.122)	(0.068)
Total assets	-0.104	-0.003	0.035	0.086**	-0.024	-0.241	0.068	-0.095*
	(0.269)	(0.046)	(0.105)	(0.033)	(0.055)	(0.278)	(0.068)	(0.041)
Turnover	0.335	0.430***	-0.121	0.129*	0.136	0.609**	0.012	0.646***
	(0.194)	(0.071)	(0.191)	(0.068)	(0.207)	(0.136)	(0.137)	(0.114)
Sectoral GVA	-15.878	0.154	-0.459	1.277	-0.201	-1.265	2.150	-0.211
	(11.250)	(0.366)	(1.041)	(1.267)	(0.704)	(0.622)	(1.017)	(0.140)
Constant	0.777	-0.289***	0.149	-0.302*	-0.046	-0.416*	0.587	-1.328***
	(0.452)	(0.098)	(0.198)	(0.142)	(0.133)	(0.176)	(0.349)	(0.073)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year*Country	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	No	No	Yes	Yes	Yes	Yes
Observations	375	5,841	2,430	1,212	1,212	471	4,844	3,331
R-squared	0.271	0.041	0.057	0.027	0.108	0.092	0.028	0.034

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A5, Results of the estimation of Equation 9 with the first difference of log(Profit margin) as the dependent variable

Δlog(Profit margin)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
2014	0.301**	0.358**	0.294**	0.338**	0.423***	0.324*	0.159
	(0.114)	(0.132)	(0.118)	(0.146)	(0.102)	(0.156)	(0.256)
2015	0.461***	0.523***	0.465***	0.527***	0.753***	0.490**	0.527**
	(0.140)	(0.159)	(0.149)	(0.179)	(0.126)	(0.187)	(0.224)
2016	0.606***	0.674***	0.611***	0.683***	0.491***	0.643***	0.789***
	(0.152)	(0.164)	(0.164)	(0.186)	(0.134)	(0.200)	(0.277)
2017	0.593***	0.666***	0.610***	0.695***	0.924***	0.637***	0.590**
	(0.160)	(0.171)	(0.177)	(0.196)	(0.168)	(0.204)	(0.266)
2018	0.537***	0.611***	0.556***	0.647***	0.803***	0.589***	0.952***
	(0.106)	(0.118)	(0.126)	(0.145)	(0.194)	(0.149)	(0.316)
2019	0.542***	0.622***	0.567***	0.669***	0.873***	0.597***	0.892**
	(0.129)	(0.144)	(0.149)	(0.170)	(0.250)	(0.172)	(0.339)
2020	0.488***	0.528***	0.505***	0.555***	0.694***	0.503**	0.921***
	(0.148)	(0.158)	(0.159)	(0.180)	(0.238)	(0.190)	(0.321)
Total assets	0.019	0.016	0.021	0.019	0.017	0.017	0.019
	(0.014)	(0.014)	(0.015)	(0.015)	(0.015)	(0.016)	(0.016)
Turnover	0.063**	0.066**	0.060**	0.063**	0.058*	0.068**	0.061*
	(0.027)	(0.025)	(0.029)	(0.029)	(0.029)	(0.027)	(0.030)
Sectoral GVA	-0.025	-0.177	-0.220	-0.612	-1.507**	-0.191	-0.672
	(0.286)	(0.476)	(0.346)	(0.439)	(0.721)	(0.305)	(0.415)
Constant	-0.264***	-0.861***	-0.346	-0.931*	-0.868**	-2.542***	-0.732***
	(0.052)	(0.134)	(0.422)	(0.448)	(0.400)	(0.049)	(0.138)
Country FE	No	Yes	No	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	Yes	Yes	Yes
Year*Country FE	No	No	No	No	Yes	No	No
Country*Industry	No	No	No	No	No	Yes	No
Year*Industry FE	No	No	No	No	No	No	Yes
Observations	8,017	8,017	8,017	8,017	8,017	8,017	8,017
R-squared	0.056	0.065	0.061	0.070	0.080	0.094	0.074

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A6, Results of the estimation of Equation 9 with the first difference of log(Profit margin) as the dependent variable and with sectoral and regional subgroup analysis

∆log(Profit margin)	(1) B	(2) C	(3) D	(4) Other	(5) Central and Eastern Europe	(6) Northern Europe	(7) Southern Europe	(8) Western Europe
2014	-0.153 (0.466)	0.533*** (0.137)	0.003 (0.111)	0.350 (0.263)	0.589*** (0.143)	0.875 (0.517)	0.612*** (0.033)	-0.184 (0.131)
2015	-0.792 (0.442)	0.704*** (0.169)	0.155 (0.150)	0.618** (0.274)	0.953*** (0.133)	1.139** (0.306)	0.718** (0.150)	-0.047 (0.108)
2016	-0.561 (0.638)	0.876*** (0.168)	0.279 (0.168)	0.445 (0.274)	0.681* (0.322)	1.233** (0.346)	0.931** (0.195)	0.096 (0.078)
2017	1.496 (1.738)	0.867*** (0.184)	0.270* (0.152)	0.540 (0.342)	1.204*** (0.238)	1.130* (0.371)	0.907** (0.220)	0.073 (0.088)
2018	1.056 (1.834)	0.806*** (0.134)	0.270* (0.149)	0.456 (0.292)	1.187*** (0.276)	1.068* (0.354)	0.707** (0.151)	0.130 (0.075)
2019	0.053 (1.935)	0.800*** (0.132)	0.209 (0.158)	0.678* (0.347)	1.377*** (0.365)	1.078* (0.393)	0.733*** (0.106)	0.077 (0.090)
2020	0.419 (1.745)	0.682*** (0.182)	0.197 (0.115)	0.565 (0.319)	1.178** (0.345)	0.843 (0.369)	0.772*** (0.127)	-0.050 (0.075)
Total assets	0.083 (0.085)	0.039 (0.024)	-0.011 (0.025)	-0.013 (0.049)	0.017 (0.041)	-0.010 (0.070)	0.029 (0.025)	0.017 (0.013)
Turnover	0.530 (0.301)	0.062* (0.035)	0.057 (0.054)	0.022 (0.145)	0.054 (0.060)	-0.385** (0.114)	0.100*** (0.011)	-0.073 (0.092)
Sectoral GVA	-8.146 (8.905)	-0.206 (0.238)	0.186 (0.833)	-0.298 (1.031)	-2.588*** (0.700)	3.988* (1.402)	0.240 (0.513)	-0.258 (0.260)
Constant	1.000*** (0.274)	-1.577*** (0.129)	0.066 (0.125)	0.009 (0.150)	0.212* (0.111)	-1.190 (1.077)	-0.930* (0.355)	-1.805*** (0.084)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year*Country	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	No	No	Yes	Yes	Yes	Yes
Observations	271	4,579	2,050	1,117	983	375	3,940	2,719
R-squared	0.356	0.091	0.068	0.064	0.118	0.208	0.091	0.053

Clustered standard errors on the country level in parentheses
*** p<0.01, ** p<0.05, * p<0.1