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The EU Emission Trading System: reducing carbon emissions and implications on firm performance

Abstract

Is the European Union Emission Trading System (EU ETS) successful in reducing carbon emissions and what is the effect at firm-level? This paper researches whether the implementation of new regulation as of January 2013 accelerated emission reduction efforts by companies under EU ETS regulation, while also examining the effect on the financial performance of participating companies. Using emissions data from the European Union Transaction Log (EUTL) and financial data from Orbis, the analysis suggests that the EU ETS did not induce an acceleration in emission reductions in Phase III relative to Phase II. The EU ETS could potentially lead to additional costs for participating companies as they must buy allowances to cover their yearly emissions. This would create a competitive disadvantage for regulated companies relative to competitors outside the EU that are not regulated. However, this research finds that EU ETS regulated companies do not experience any negative effects on financial performance. Altogether, these results add to the limited empirical literature on the effectiveness of the EU ETS in reducing carbon emissions and the effect on the financial performance of participating companies after the policy change in January 2013.

Keywords: EU ETS, financial performance, competitiveness, emission reduction, allowances

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Introduction

For a long time, there have been discussions about the imminent threat of climate change. However, there have always been many conferences discussing the consequences and solutions, but no serious action had been taken up until the Paris Agreement in 2015. The Paris Agreement introduced a global framework to fight climate change by restricting global warming to below 2°C by 2050, while targeting 1.5°C (UNFCCC, 2015). The Paris Agreement is the first-ever universal, legally binding global climate change agreement. Companies need to cut their carbon emissions in order to comply to the goals set out in the Paris Agreement. These companies should reduce their greenhouse gas emissions as much as possible and offset their remaining emissions by buying carbon offsets. Carbon offsets are schemes that allow individuals and companies to invest in environmental projects around the world in order to offset their carbon emissions (The Guardian, 2011). The European Union Emission Trading System (EU ETS) is the largest and most ambitious emissions trading scheme in the world. The EU ETS is considered to be the foundation of the EU's policy to tackle climate change (European Commission, 2020). The EU ETS is a 'cap-and-trade' system, which caps the total GHG emissions of all participants to the EU ETS. The EU ETS legislation creates allowances which are essentially rights to emit greenhouse gas (GHG) emissions (European Commission, 2020). At the end of each year, participants must surrender an allowance for every tonne of CO2 equivalent (tCO2e) that has been emitted during that year. If a participant's verified emissions exceed its allowances, then it must either consider reducing its emissions or to buy additional allowances on the carbon market. Allowances are sold through auctions, or can be traded between participants (European Commission, 2016). This paper aims to assess the effectiveness of the EU ETS in reducing carbon emissions and researches the effect at firm-level. For this purpose, the following research question is formulated:

"Is the EU Emissions Trading System successful in reducing carbon emissions and what is the impact at a firm-level?"

Investigating this question is important for several reasons. First, the EU ETS will only be considered successful if it significantly reduced carbon emissions in Europe. The EU ETS was introduced in 2005 with a pilot phase, named Phase I (2005-2007). After Phase I, new regulation was adopted for Phase II (2008-2012) to strengthen and increase the effectiveness of the system. Flaws to the system were addressed quickly and new regulation was also imposed during the course of Phase III (2013-2020). It is therefore important to investigate whether the new regulation increased the effectiveness of the EU ETS in reducing carbon emissions. Second, the EU ETS may affect the financial performance and thus competitiveness of the companies under regulation. A company's direct costs to comply under the EU ETS is the difference between its verified emissions and the freely allocated allowances multiplied by the EUA price. Indirect costs to comply under the EU ETS are costs coming from investments to reduce carbon emissions – investments in renewable energy, phasing out coal plants, less employee travelling etc. Preferably, participants will comply to the EU ETS not by buying additional allowances, but by actively making investments to reduce their carbon footprint, as this leads to a direct reduction in total carbon emissions. As many of the participating companies compete internationally, this could potentially affect their competitiveness relative to companies operating in unregulated parts of the world. The EU ETS will ultimately be judged based on its effectiveness in reducing carbon emissions, however, this should not negatively affect the competitiveness of its participants.

As global warming and climate change are at the top of the global agenda, this paper researches a highly relevant modern-day topic. This paper builds upon the scarce existing empirical literature that has studied the effectiveness of the EU ETS in reducing carbon emissions and the effect at firm-level. Prior research in this field has been conducted by Abrell *et al.* (2011), Demailly and Quirion (2008), Anger and Oberndorfer (2008), Arlinghaus (2015) and Wagner and Patrick (2014). The shared conclusion of these studies is that EU ETS participating firms have reduced emissions, while not experiencing any negative effects on competitiveness. However, all these studies have only researched Phase I and Phase II of the EU ETS. There were many issues with the EU ETS during both phases. Along the way, the European Commission – who is responsible for the implementation of the EU ETS – has introduced new regulation to increase the effectiveness of the EU ETS. For example, a new approach of allocating allowances to participants was introduced in Phase III, which should induce additional emission abatements. However, there is still a lack of empirical evidence on the effectiveness of Phase III (Verde *et al.*, 2018). This paper attempts to find the empirical evidence to assess the effectiveness of the adopted regulation in Phase III, and examines whether this has led to an acceleration in emission reductions relative to Phase II, while also studying the effects on the financial performance of participants. Thus, this paper does not merely investigate whether the EU ETS induced emission reductions but examines whether there has been an acceleration in emission reductions in Phase III as a result of new regulation. By investigating the acceleration of emission reductions in every individual year during Phase III, this paper investigates trends and can therefore also examine whether the regulation introduced at the start of Phase III induced short-term or long-term effects.

The data for this research is obtained from the Orbis database and the European Union Transaction Log (EUTL). Orbis contains detailed data of 375 million private and public companies worldwide. As the companies under EU ETS regulation are both private and public companies, it was important to use a database that contains financial data on both. Furthermore, the EUTL is run by the European Commission and records and checks all transactions within the EU ETS (European Commission, 2020). EUTL provides data on verified emissions, allocated allowances and surrendered units of 14,128 stationary installations reporting under the EU emission trading system. The data from EUTL and Orbis are used to create one dataset, which combines emissions data with financial data. The EUTL data on emissions and the Orbis data on financials were matched based on company registration codes, which resulted in a final dataset of 994 companies. When a company receives less allocated allowances than its verified emissions it is called underallocation. The opposite is overallocation, which means a company receives more allowances than its verified emissions. The incentive to reduce verified emissions is expected be higher for underallocated companies since they must buy extra allowances on the carbon market.

Using a robust analysis suggests that, on average, the EU ETS did not lead to an acceleration in emission reductions in Phase III relative to Phase II. However, when examining sub-samples of under- and overallocated companies, the analysis suggests that the EU ETS did induce an acceleration in emission reductions for underallocated companies, while overallocated companies did not increase their emission reduction efforts. Using a robust analysis on the effect of the EU ETS on financial performance by applying a difference-in-difference framework, the results show that participating companies did not experience any negative effects on ROE, number of employees and profit margin. Actually, participating companies realized a higher growth in profit margin, which was mostly a result of significantly higher profit margins for overallocated companies. This suggests that overallocated companies benefited from their participation in the EU ETS. The overall conclusion is that the EU ETS induced an acceleration in emission reductions for underallocated companies in Phase III without having a negative effect on the financial performance of these companies. However, overallocated companies seemed to benefit financially from their participation in the EU ETS, without increasing emission reduction efforts.

This paper is structured as follows. Chapter 2 reviews the literature, where it explains the history of carbon offsets and gives an extensive introduction and assessment to the complicated EU ETS. Chapter 3 describes the data and the methodological procedure for this study and Chapter 4 analyses the results. Chapter 5 concludes and reviews the findings and next steps for future research.

2. Theoretical Framework

The Guardian (2011) describes carbon offsets as ‘schemes that allow individuals and companies to invest in environmental projects around the world in order to balance out their own carbon footprints.; The European Union Emission Trading System (EU ETS) is the largest emissions trading scheme in the world and is considered to be the cornerstone of the EU’s policy to combat climate change (European Commission, 2020). However, the trading in carbon offsets received a lot of criticism after Phase I (2005-2007): the EU ETS failed to reduce overall emissions and initiated an overallocation of permits to pollute onwards (Gilbertson, Reyes and Lohmann, 2009). However, new regulation has been introduced over the course of Phase II (2008-2012) and Phase III (2013-2020) to increase the effectiveness of the EU ETS.

2.1. Carbon offsetting

Over the past 50 years, our planet has warmed significantly and there is a 95 percent probability this was the result of human activities (IPCC, 2014). Scientists attribute the observed trend in global warming over the last decades to the human expansions of GHGs (NASA, 2020). The Paris Agreement (2015) for the first time unifies the world into a shared cause to undertake ambitious efforts to tackle climate change (UNFCCC, 2015). The Paris Agreement introduced a global framework to fight climate change by restricting global warming to below 2°C by 2050, while targeting 1.5°C (UNFCCC, 2015). Limiting global warming to 1.5-degrees Celsius is crucial to maintaining a habitable planet that can support the world’s population, as well as its flora and fauna in vulnerable ecosystems.

The responsibility in reducing the emission of greenhouse gasses lay with governments, companies and also individuals. Governments should impose clear regulation and limits to national carbon emissions. Companies should adhere to the regulation and reduce their carbon footprint. However, as not all governments impose regulation on carbon emissions, companies should show intrinsic motivation and commitment to reduce their carbon footprint. Many companies worldwide have already committed to becoming “carbon neutral” or even “carbon negative” in the coming years: Jeff Bezos, CEO of Amazon, pledged to have the company carbon neutral by 2040; Microsoft has committed to become carbon negative by 2030; Heathrow Airport pledged to become carbon neutral in its operations by 2030; and, Siemens announced to become carbon neutral by 2030. Also, new climate laws in Finland, Sweden and Denmark have the ultimate goal for the countries to become carbon neutral by 2035, 2045 and 2050, respectively. Other large companies, like Coca-Cola and Starbucks, have committed to cut carbon emissions by 25%. These large companies are taking the lead and are setting examples for more companies to follow. To stimulate more companies following the example set by Amazon, Microsoft, Siemens and Heathrow Airport, the United Nations Framework Convention on Climate Change (UNFCCC) introduced the “Carbon Neutral Now Pledge”. Companies taking the pledge commit to (i) measure and report GHG emissions, (ii) reduce absolute GHG emissions, and (iii) offset remaining emissions with UN Certified Emission Reductions (CERs) (UNFCCC, 2020). The third commitment is crucial in becoming carbon neutral. Most companies will always have a carbon footprint, even if the company drastically reduces its GHG emissions. To become carbon neutral companies should offset their remaining emissions using carbon offsets. As climate change is now on top of the global agenda, more and more companies are becoming aware of their responsibility in tackling global warming (World Economic Forum, 2020). Due to the recently increased attention for global warming, carbon offsets have increased in popularity. Corporations and governments are starting to realize the potential of carbon offsetting.

The basic theory of emissions trading has been established and developed over the last century. The conceptual foundations for carbon trading began in 1920 with Arthur Pigou (Hepburn, 2007). Pigou is famous for introducing the concept of externalities and the idea that 'externality problems could be corrected by the imposition of a "Pigouvian Tax"'. Pigou pointed out the social benefits of forcing companies to pay for the costs of their pollution (Pigou, 1920). Ronald Coase further developed Pigou's theories, by showing that efficient results could be realized by allocating property rights and allowing trade (Coase, 1960). In 1960, Coase introduced the Coase Theorem, that describes the 'economic efficiency of an economic allocation or outcome in the presence of externalities.' In 1968, John Dales proposed the first application of these ideas to pollution (Hepburn, 2007). Dales came up with a proposition of a market where companies traded permits issued by the government, granting the company the right to emit a certain amount of pollutant; nowadays referred to as the "cap-and-trade" scheme. In a typical "cap-and-trade" scheme, a total number of allowances are issued by the government, which give firms the right to emit pollution (Hepburn, 2007). These allowances have positive value, because fewer allowances are issued than firms actually need. Since allowances have a price, firms have an incentive to actively reduce emissions when this is cheaper than buying additional allowances. The best way to reduce global carbon emissions is for companies to cut these emissions from their supply chain, however if this is not possible, companies should think about carbon offsetting. By giving a price to allowances, as in a cap-and-trade system, companies should first be forced to actively cut their carbon emissions before resorting to carbon offsetting.

In the late 1980s, the first voluntary carbon trades occurred by parties not subject to regulatory requirements and a while later the world saw its first forward carbon trades (Hepburn, 2007). The UNFCCC introduced its first international measures to address climate change in 1992. Building on the 1992 UNFCCC framework, the 1997 Kyoto Protocol sets legally binding restrictions on GHG emissions in industrialized countries and aims to develop innovative mechanisms to keep the costs of reducing emissions low (European Commission, 2004). Countries that committed to limit or reduce GHG emissions under the Kyoto Protocol must meet their targets primarily through national measures. To support countries in meeting these targets, the Kyoto Protocol introduced three market-based mechanisms (see Section 2.1.1.), thereby creating what is now known as the carbon market (UNFCCC, 2020). The Kyoto Protocol has initiated the emergence of international carbon markets. The largest international carbon market is the EU ETS, which was introduced on February 16, 2005 (Hepburn, 2007).

2.1.1. Kyoto's additional market-based mechanisms

As stated above, countries with commitments under the Kyoto Protocol must limit or reduce GHG emissions. To support these countries to meet their targets, three market-based mechanisms were introduced, also referred to as Kyoto's "flexible mechanisms". These mechanisms serve as an additional possibility to reduce net carbon emissions, besides reducing its own carbon footprint through actively cutting emission.

The most well-known of the three instruments is emissions trading, which enables the trade in emission units between developed countries. Each country compliant to the Kyoto Protocol is assigned a certain number of units, based on its emission reduction target. If a country achieves a greater reduction than determined by the Kyoto Protocol, it can sell its surplus of emission units to other countries. A country that does not succeed to comply with the emission reduction target can purchase additional emission units (UNFCCC, 2020).

The second instrument is the Clean Development Mechanism (CDM), which 'allows countries with emission reduction commitment under the Kyoto Protocol to introduce and develop an emissions-reduction project in developing countries' (UNFCCC, 2020). Such projects are rewarded with Certified Emission Reduction (CER) credits. These CER credits can be used to meet Kyoto targets. The CDM stimulates companies to invest in sustainable development and reduce emissions, while also giving industrialized countries some flexibility in how to meet their emission reduction targets (UNFCCC, 2020).

The third instrument is known as Joint Implementation (JI), which 'allows a country with an emission reduction commitment to earn Emission Reduction Units (ERU) from an emission-reduction project in a developed country' (UNFCCC, 2020). Joint Implementation offers countries that have committed to the Kyoto Protocol a flexible and cost-efficient means to realize emission reductions, while the host country benefits from the foreign investments (UNFCCC, 2020).

Some of the key arguments in favor of carbon offsetting are that it would (i) be an economically efficient measure to reduce global carbon emissions, (ii) transfer money from developed to developing nations, and (iii) help with development and technology transfer in developing countries (Hyams and Fawcett, 2013). The most important difference between the CDM and JI schemes is that CDM schemes operate in developing countries, while JI schemes operate in developed countries, primarily in Eastern Europe (Hyams and Fawcett, 2013).

2.1.2. Participation: Voluntary vs. Mandatory

There are two main types of global carbon offset markets currently in operation: a compliance market and a voluntary market. The compliance markets, established by the Kyoto Protocol, are regulated by mandatory international, regional and national carbon reductions schemes, such as the EU ETS, CDM and the California Carbon market. To meet their targets, mandatory carbon markets allow participants to trade in carbon offsets under strict regulation and control. The voluntary market is an informal market governed by a mix of non-governmental and private-sector organizations (Lovell, 2010). This market offers 'businesses, NGOs and individuals the opportunity to offset their personal emissions on a voluntary basis as a matter of corporate social responsibility (CSR) or as response to market pressure and public opinion' (FairClimateFund, 2020). Voluntary carbon offsets are often sold to individuals to offset their participation in activities that directly or indirectly emit carbon, such as flight. This paper will only discuss the mandatory carbon market and, more specifically, the EU ETS.

2.1.3. Ethical and moral principles of carbon offsetting

The ethical basis for using carbon offsetting as an approach to tackle climate change is often disputed (Sandel, 1997; Caney and Hepburn, 2011; Anderson, 2012; Hyams and Fawcett, 2013). The UN states that carbon offsetting stimulates companies to invest in sustainable development and reduce emissions, while also giving industrialized countries some flexibility in how to meet their emission reduction targets. Arguments against carbon offsetting have often questioned its ethics and effectiveness and led to dividing the environmental movement. Environmental organizations, like WWF, actively support the process of carbon offsetting, whereas others, like Friends of the Earth and environmental campaigner George Monbiot, firmly reject its use. This paragraph discusses the underlying ethical and moral principles of carbon offsetting, whereas the scientific legitimacy is discussed in Section 2.4.

In the voluntary market, the motivation of individuals and organizations buying carbon offsets is questioned. It is suggested that corporate users often buy offsets for their reputation, often referred to as "greenwashing", and that corporate users buy carbon offsets to clear their conscience, while continuing to participate in high carbon activities (Hyams and Fawcett, 2013). On the contrary, in the mandatory carbon market, regulated by legal mechanism, the primary motivation is to adhere to the imposed regulation (Spash, 2010). Hyams and Fawcett (2013) state that ethical issues are more salient in the case of voluntary offsets than for mandatory schemes.

Many arguments have been made about the underlying ethical and moral principles of emission trading. First, Robert Goodin (1994) argues that emissions trading involves owning a kind of good that should not be owned. Emissions trading assumes that 'humans have property rights in the natural world, and this would be undesirable as the natural world should not be treated as people's private property' (Goodin, 1994). However, Caney and Hepburn (2011) argue that 'emissions trading does not rely upon the private ownership of Earth's atmosphere and is compatible with a commitment to global stewardship'. Second, Michael Sandel (1997) argues that emissions trading is objectionable because it ‘allows people to alienate responsibilities that is inappropriate for them to alienate’. At country level, this argument suggests that each state should shoulder its own burden and that high-emitting countries should not pay other countries to discharge their duty (Sandel, 1997). Sandel (1997) argues that emission trading creates opportunities for wealthy countries to evade their emission obligations. However, Caney and Hepburn (2011) claim this argument to be unpersuasive because ‘trading between firms and/or states can protect the environment without creating civic duties; environmental goals and stewardship can be achieved by allocating the responsibility to states, rather than to individual citizens.’ A third concern, expressed by Sandel (1997), is that turning emissions into a commodity that can be traded removes the moral stigma associated with it. He argues that if a company is fined for emitting excessive pollutants, the community conveys its judgement that the polluter disobeyed the law. However, a fee for buying additional carbon credits makes pollution just another cost of doing business. According to Sandel (1997), organizations should adhere to a fixed quota and if these organizations exceed their individual quota, this would be considered a crime that should be penalized, and not an option which they can pay for with an additional fee. Caney and Hepburn (2011) claim this argument to be unpersuasive, because ‘each individual tonne of carbon dioxide emitted does not constitute a moral wrong – it is the aggregate damage that is problematic. An emission trading system is able to prevent this damage, without the need to criminalize the activity of emitting and impose a system of fines.’

2.2. European Union Emission Trading System

The European Union Emission Trading System (EU ETS) is the world’s largest and most ambitious carbon trading scheme. The EU ETS has been identified as the primary mechanism to achieve compliance with the EU’s commitments under the Paris Agreement and Kyoto Protocol. The 1997 Kyoto Protocol to the United Nations Framework Convention for Climate Change (UNFCCC) set legally binding GHG reduction targets for 37 industrialized countries from 2008 to 2012 (European Commission, 2015). In order to meet the Kyoto commitments there was a need for strict policy instruments and regulation. This led to the introduction of the EU ETS Phase I in 2005. The EU ETS is currently in Phase III, while Phase IV starts in 2021. In total, around 45-50% of total EU GHG emissions are covered by the EU ETS.

The European Commission explains the EU ETS in their EU ETS Handbook (European Commission, 2016):

‘The EU ETS is a ‘cap-and-trade’ system, which caps the total GHG emissions of all participants in the system. The EU ETS legislation creates allowances which are essentially rights to emit GHG emissions (European Commission, 2020). An allowance to emit GHG emissions is referred to as European Union Allowance (EUA). Each year, a proportion of the allowances are given to certain participants for free, while the rest are auctioned or traded between participants. At the end of the year, participants must surrender an allowance for every tonne of CO2 equivalent (tCO2e) that has been

emitted during that year. These allowances are then cancelled to ensure they are not used again. If a participant's verified emissions exceed its allowances, then it must either consider reducing its emissions or to buy more allowances on the market.'

A company's direct costs to comply under the EU ETS is the difference between its verified emissions and the freely allocated allowances multiplied by the EUA price. Due to the limited or capped supply of allowances and the demand for them from participants that do not meet their reduction target, allowances have value. Participants to the EU ETS can also use 'international credits' from CDM (CER) and JI (ERU) towards fulfilling part of their obligations under the EU ETS. CERs and ERUs must be exchanged for EU ETS emission allowances, EUAs (1 EUA = 1 CER = 1 ERU). International credits from nuclear, afforestation and reforestation are not accepted. By allowing companies to use international credits, the EU ETS stimulates investments in clean technologies and low-carbon development in developing countries (European Commission, 2016). It is important to understand that the primary objective of the EU ETS is to motivate participants to reduce absolute carbon emissions and not motivating participants to simply offset verified emissions by buying allowances. For this to be successful, the costs of reducing the company's carbon emissions should be lower than the costs of buying additional allowances. Otherwise, participants may prefer buying allowances, as this comes cheaper. The price of allowances (EUA) is therefore an important factor for the success of the EU ETS

Participation in the EU ETS is mandatory for companies in sectors that emit (i) carbon dioxide (CO2), (ii) nitrous oxide (N2O) and (iii) perfluorocarbons (PFC). A target set by the EU ETS aimed to reduce emissions in 2020 from sectors covered by the EU ETS by 21% compared to 2005. The EU is on track to surpass this target. As part of the EU's 2030 climate and energy framework, emissions in 2030 from sectors covered by the EU ETS will be cut by 43% from 2005 levels (European Commission, 2020). The EU ETS is an important frontrunner for developing an international carbon market. Many countries, such as China, South Korea, Canada, Japan, Switzerland and the United States, already have their own national or regional system operating. According to the European Commission (2016), the international carbon market is expected to develop through linking compatible ETSs around the world. As a result, this would help to 'reduce the costs of cutting emissions, increase market liquidity, level the international playing field, stabilize carbon prices and support global cooperation on climate change' (European Commission, 2020).

2.2.1. Legislation

As of 2020, the EU ETS includes all 27 Member States, as well as Norway, UK, Iceland and Liechtenstein. The EU ETS is an environmental law, which means that decisions concerning the EU ETS are made by the European Commission (European Commission, 2015). The key institutions involved are the European Parliament, European Commission and the European Council. Once legislation is adopted it must be implemented and the Member States carry the primary responsibility for the implementation of EU law. The European Commission is responsible for ensuring that EU legislation is correctly implemented. Each year, Member States must report to the European Commission on how the EU ETS Directive is being applied in their country. When a Member State fails to comply with EU law, the European Commission may start infringement proceedings (European Commission, 2015). Compliance to the EU ETS is ensured through a strict penalty and enforcement structure and significant fines are imposed if companies fail to surrender sufficient allowances in time. The cap is maintained effectively as firms face an obligation to surrender their allowances at the end of the year. (European Commission, 2015).

2.2.2. Allocation of allowances: Auctioning vs. Free allocation

Allowances are allocated either by free allocation, where installations receive allowances for free, or via auctioning. During Phases I (2005-2007) and Phase II (2008-2012), most allowances were allocated for free, while during Phase III the majority of allowances will be provided via auctioning (European Commission, 2015). As of Phase III, approximately 50 percent of total allowances will be auctioned.

Through auctioning allowances, market participants are given the chance to acquire allowances at the market price, while giving some transparency in the allocation method (European Commission, 2015). Depending on the bidding platform, bidders can submit any number of closed bids with a size of 500 to 1000 allowances. Each bid must specify the number of allowances at a given price. Auctioning is offered by two platforms: the European Energy Exchange (EEX) and the ICE Futures Europe (ICE). The EU ETS Directive specifies that at least 50% of the proceeds from the auctioning of allowances should be invested in specific climate and energy activities. These activities include the 'reduction of GHG emissions, the development of renewable energies, carbon capture and storage, energy efficiency and measures to avoid deforestation' (European Commission, 2020). According to the European Commissions, around 80% of auction proceeds in the period 2013 to 2018 were used for climate- and energy-related purposes.

The use of free allocation cuts the costs of compliance for industries. This is particularly important if other developed countries do not take equivalent action to reduce GHG-emissions. This would lead to an economic disadvantage for companies subject to EU ETS regulation when competing internationally with companies that do not have any restrictions on GHG emissions. Free allocation can reduce this potential disadvantage. During Phases I and II, a majority of allowances were allocated based on a procedure called "grandfathering", which is based on historical GHG emissions. This approach has been widely contested as it would reward high emitters while taking into account early actions to reduce emissions (European Commission, 2015). Therefore, from Phase III onwards, a new approach is used for the free allocation of allowances called benchmarking. Unlike grandfathering, benchmarking allocates allowances based on companies' production performance instead of their historical emissions. Under the benchmarking approach, highly efficient installations receive more free allowances relative to GHG-intensive installations. Thus, increasing the incentive for inefficient installations to take action to reduce emissions (European Commission, 2020).

2.2.3. Phase I (2005-2007)

The EU ETS became operational on 1 January 2005 and included all Member States of the EU. Phase I was a 3-year pilot to prepare for Phase II, which would cover the first Kyoto Commitment Period from 2008 to 2012. Its primary goal was to develop the infrastructure and provide the experience for the following Phases (Perdan and Azapagic, 2011). Phase I only covered CO2 emissions from power generators and energy-intensive industries and 95 percent of all allowances were allocated to businesses for free. Phase I succeeded in '(i) establishing a price for carbon, (ii) free trade in emission allowances across the EU and (iii) the infrastructure needed to monitor, report and verify emissions from the businesses covered.' However, Phase I emission caps were based on estimates due to the absence of reliable emissions data. As a result, the total amount of issued allowances exceeded emissions – supply significantly exceeded demand. In 2007, this led to the price of allowances falling to zero (European Commission, 2020). According to the World's Bank annual Carbon Market Reports, trading volumes rose from 321 million allowances in 2005 to 2.1 billion allowances in 2007.

2.2.4. Phase II (2008-2012)

Phase II began on 1 January 2008 and would run for five years, till 31 December 2012. Key features of Phase II were (i) a 6.5% lower cap on allowances compared to 2005, (ii) extension of geographical coverage by including Iceland, Liechtenstein and Norway, (iii) the proportion of free allocation fell to approximately 90%, (iv) the penalty for non-compliance was increased to €100/tCO2, from €40/tCO2 during Phase I, and (v) businesses were allowed to use international credits originating from CDM or JI (European Commission, 2020). As the data on verified annual emission data from Phase I was now available, the cap on allowances was reduced in Phase II. However, the 2008 economic crisis led to higher than expected emissions reductions, which lead to a large surplus of allowances and credits. This had a large impact on the carbon price throughout Phase II (European Commission, 2020). According to the World's Bank annual Carbon Market Reports, trading volumes rose from 3.1 billion allowances in 2008 to 7.9 billion allowances in 2012, worth €56 billion. In 2005, the trading volume was only 321 million allowances.

2.2.5. Phase III (2013-2020)

Phase III will run from 1 January 2013 to 31 December 2020. Phase III will experience significant differences from Phase I and II, as it will (i) incorporate more industrial sectors and greenhouse gasses, (ii) auctioning will progressively replace free allocation and (iii) the introduction of a single, EU-wide cap on emissions instead of the previous system of national caps (European Commission, 2009). International offset credits (CDM/JI) will continue to be valid for compliance under the EU ETS and the EU emissions cap will linearly decrease with 1.74% every year (IETA, 2010). By 2020, these new measures should deliver an overall reduction of 21% of verified emissions compared to 2005.

Due the lower demand for allowances in the aftermath of the 2008 economic crisis, there was a significant surplus of allowances at the start of Phase III. The EU ETS was not able to effectively respond to unexpected economic conditions. Besides, the surplus of allowances continued to grow due to the imports of international credits and overlapping. In the short term, the surplus risked 'undermining the orderly function of the carbon market and in the long-term, the surplus threatened to affect the ability of the EU ETS to meet emissions reduction targets cost effectively' (The Oxford Institute for Energy Studies, 2018).

From the start of Phase III, EUA prices consistently remained below €10/tCO2e due to the lack of mechanisms to address the surplus of allowances resulting from the aftermath of the economic crisis and high import of international credits (World Bank, 2019). EU lawmakers have introduced measures to address to surplus since 2014, however carbon prices only started to significantly increase after the post-2020 (Phase IV) reforms had been adopted. As more certainty developed on the future of the EU ETS after Phase III, the EUA price increased from €13/tCO2e to €21/tCO2e. According to the World's Bank annual Carbon Market Reports, trading volumes rose to 10.8 billion allowances in 2018, worth €160 billion.

It is very clear that the shortcomings – related to the surplus of allowances – experienced in the early years of Phase III undermined the effectiveness of the system in the years to follow (The Oxford Institute for Energy Studies, 2018). The Phase IV reform should aim to address these shortcomings to prevent them from happening again.

2.2.6. Phase IV (2021-2030)

Sectors covered by the EU ETS must reduce their emissions by 43% compared to 2005 levels to achieve the EU's GHG reduction target for 2030. Phase IV will start on 1 January 2021 and will run for 10 years, till 31 December 2030. To achieve the target of 43% emission reduction, new, clear and more effective measures have been put into place (European Commission, 2018). First, the total number of allowances will decline at an annual rate of 2.2% from the start of Phase IV, compared to 1.74% in Phase III. Second, the Market Stability Reserve (MSR) – the mechanism established by the EU to reduce the surplus of emissions allowances – will be substantially reinforced. Between 2019 and 2023, the amount of allowances held by the MSR will double to 24% of the allowances in circulation, whereafter the regular rate of 12% will be restored in 2024. The new regulation aims to more effectively address the historical surplus of EUAs, making the EU ETS more responsive to changes in demand and to be able to deal with any future imbalance. Third, the revised EU ETS regulation provides fair rules to address the risk of carbon leakage. Carbon leakage refers to the risk that companies may transfer their production to other jurisdictions with laxer measures to cut GHG emissions as a result of the increased costs of adhering to the regulation of the climate policy in their own jurisdiction. This could lead to an increase in total global GHG emissions (European Commission, 2015). The system of free allocation will be extended until 2030 and has been amended to focus on the sectors with the highest risk of relocating their production outside of the EU. These sectors will receive 100% of their allocation for free. For less exposed sectors, free allocation will be phased out after 2026 to 0 at the end of Phase IV. Lastly, the new regulation helps the industry and power sectors to meet the innovation and investment challenges of the low-carbon transition via various low-carbon funding machines (European Commission, 2018).

The EU does not plan to continue the use of international credits for EU ETS compliance in Phase IV, meaning that the exchange of CERs and ERUs for EUAs will not be allowed (European Commission, 2020). Article 6 of the Paris Agreement, which is considered to support market based cooperation, provides for '(i) a mitigation mechanism to replace existing mechanisms (such as CDM and JI) and provide for certification of emission reductions for use towards nationally determined contributions, and (ii) accounting rules, which will enable linking of international emission reduction schemes while ensuring the integrity of commitments.' Many stakeholders believe these provisions may suggest the linkage of emission trading schemes and facilitation of crediting mechanisms (UNFCCC, 2017). Over the comping years, these provisions should be applied through implementing decisions.

It is expected that the adopted Phase IV reform will significantly improve the functioning of the EU ETS (The Oxford Institute for Energy Studies, 2018). Many of the new features aim to improve the flexibility of the system to react to unexpected changes. The lack of flexibility in previous phases was one of the main shortcomings, which led to a structural allowance surplus. The ability to adjust the auctioning level for production shifts means that the system will be able to react rapidly to future economic changes, with the objective to avoid large allowance surpluses. As a result of strengthening the MSR by doubling its allowance intake rate to 24% for the first five years of Phase IV, the market will be tightened. This will speed up the restoration of the supply-demand balance by reducing the existing surplus twice as fast. Another measure that will tighten the market is the increase of the linear emissions cap reduction factor from 1.74% to 2.2%. (The Oxford Institute for Energy Studies, 2018)

2.3. Assessment of the EU ETS

In existing literature, the environmental impact of the EU ETS is primarily assessed against two specific primary objectives: (i) has the EU ETS contributed towards emission reductions and (ii) has the EU ETS induced incentives for investment in low carbon technology (Laing *et al.*, 2013)?

In the period 2008-2013, there is a split in literature focusing on the EU ETS prior and after the economic crisis. During this period, most studies on the effectiveness of the EU ETS focus on the first four years of the EU ETS (pre-economic crisis), covering Phase I and the first year of Phase II. This is perhaps due to the difficulties with establishing credible econometric "counterfactuals" after an economic downturn (Liang *et al.*, 2013). By performing a counterfactual analysis Ellerman and Buchner (2008) estimate abatement in Phase I in the range of 120-300 MtCO2; Phase I CO2 emissions were between 2.4% and 4.7% lower than they would have been without the EU ETS. A study by Delarue *et al.* (2008) finds that emissions reduction in the power sector account for 90 MtCO2 in 2005 and 60 MtCO2 in 2006. Anderson and Di Maria (2011) estimate a total abatement in Phase I of 247 MtCO2. One of the most detailed study's to date was conducted by Abrell, Ndoye-Faye and Zachmann (2011), in which they control for economic activity. Abrell *et al.* (2011) find that emission reductions in 2007-2008 were 3.6% larger than for the period 2005-2006, which indicates that EU ETS had a stronger effect in Phase II relative to Phase I. Liang *et al.* conclude that literature points to attributable emissions savings in the range of 40-80 MtCO2 per year, which is about 2-4% of the total capped emissions.

The 2008 economic crisis had a significant impact on European emissions, and thus on the effectiveness of Phase II (Laing *et al.*, 2013). As a result, estimations of abatements were heavily impacted. Due to the impact of the economic crisis there is little literature assessing the emission reduction impacts of the EU ETS after 2008, as untangling the effects of the economic crisis and the EU ETS is very complex. What part of EU emissions reductions were initiated by the EU ETS and what part was a result of the economic downturn following the 2008 crisis? Declercq *et al*. (2011) estimated that the impact of the economic crisis on the European power sector was approximately 150 MtCO2. Also, a report commissioned by the UK's Climate Change Committee suggested that the reductions in overall EU emissions during Phase II can be attributed more to the economic crisis than to the EU ETS. Grubb *et al*. (2012) show that evidence that the economic crisis has caused a 'structural break in the evolution of emissions and energy intensity in the EU.' A study by New Carbon Finance in 2009 estimated that 40% of the 3% fall in 2008 emissions compared to 2007 were due to the EU ETS. After analyzing few studies on the impact of the EU ETS post-financial crisis, Liang *et al.* (2013) conclude that the EU ETS has led to some small levels of abatement. However, the success of the EU ETS in realizing emission reductions during Phase II may be questioned on the basis of the role played by the economic crisis (Borghesi and Montini, 2016).

If Phase III of the EU ETS is considered to be successful and effective, the environmental delivery is key. The new measures introduced at the start of Phase III targeted to deliver an overall reduction of 21% of verified emissions compared to 2005 to comply with the Kyoto Protocol. This EU ETS target for end of 2020 has already been reached, far ahead of time. During Phase III, total emissions have been declining, on average, by 45 Mt per year, considerably faster than the cap, which declines by 36 Mt per year (European Roundtable on Climate Change and Sustainable Transition (ERCST), 2019). Figures of the European Environment Agency (EEA) show that, compared to 2005, emissions from EU ETS covered installations had already decreased by 26.4% by the end 2017. Thus, the EU ETS has reached its target for 2020 ahead of time. However, existing literature argues what part of this emission reduction can be contributed to the EU ETS. Borghesi and Montini (2016) state the observed emissions reduction has been largely influenced by the aftermath of the economic crisis on the European industrial production. They suggest that the economic recession and the expansion of the EU ETS to Central and Eastern Europe countries have played a crucial role to help the EU achieve the Kyoto Protocol target.

Limited research has been conducted to further assess the effectiveness of Phase III. Therefore, assessing the impact of the EU ETS on emission reductions, relative to external factors, such as the 2008 economic crisis, is challenging. EEA data shows that emissions of installations covered by the EU ETS have decreased from 2.38 billion tCO2 in 2005 to 1.68 billion tCO2 in 2018. This equals an annual average reduction 50 million tCO2 or 2.46% per year. Based on the same data, GHG emissions covered by the EU ETS fell by 8.7% in 2019. According to Reuters, this fall was primarily due to a decrease in emissions from power stations as coal-fired output was replaced by gas-fired generation and renewable energy sources. Sam van der Plas, Policy Director at Carbon Market Watch, claims that this shows how successful the EU ETS has been in phasing out coal and lignite in the power sector.

Muûls *et al.* (2016) very well discuss correlation versus causation. As Muûls *et al.* state: 'Any evaluation of the EU ETS could draw a correlation between being part of the EU ETS and changes in emission, employment or innovation. However, correlation is not causation.' As a result of structural economic change, emissions in Europe have been declining since well before the introduction of the ETS in 2005. The 2008 economic crisis negatively impacted economic activity, which in turn led to a reduction in GHG emissions in the EU. It is challenging to disentangle the emission reductions that are attributable to the EU ETS from other correlated downward trends such as the economic crisis (Muûls *et al.*, 2016).

In existing literature there is an overall consensus that the EU ETS has a positive impact on emission reductions. However, there is an ongoing debate about the fraction of these emission reductions attributable to the EU ETS, and the limited coverage of Phase III in existing literature makes it even more difficult to reach a consensus. Nevertheless, the EU ETS shows some remarkable achievements over the course of its three phases. The EU ETS has become the largest carbon market in the world and the first cross-border cap-and-trade system (Borghesi and Montini, 2016). The creation of the EU ETS involved challenging collaborations between European bodies, Member States, and a variety of private entities – each pursuing own interests (Hepburn, 2007). Besides, the fundamentals laid out by the EU ETS are implemented by many other emissions trading schemes around the world. The EU ETS demonstrates the will of the EU to stand as a leader in the international battle against climate change (Borghesi and Montini, 2016). However, the success of the EU ETS has not only been characterized by great achievements but also by significant shortcomings, which potentially undermined the effectiveness of the system (Borghesi and Montini, 2016).

2.3.1. Problems

Borghesi and Montini (2016) identify three main problems that have undermined the functioning of the system in Phase I and II: (i) price volatility, (ii) governance problems and (iii) monitoring problems related to fraud and non-transparency. These problems led to the structural surplus of EUAs and were mainly caused by freely allocated allowances, the overallocation of these allowances and a lack of central governance. This led to heavy criticism on the EU ETS. Critics claimed that the majority of the offsets did not deliver the emission reductions they promised, while the EU ETS failed to reduce the overall emission of GHG. Besides, there was a lot of criticism on international credits that could be exchanged for EUAs, as many questioned the validity of CDM and JI projects. These problems primarily refer to Phase I and II of the EU ETS, while some are also valid for Phase III. The European Commission has constantly adopted new regulation and enforced strict governance to eliminate the problems associated with the EU ETS. All problems and criticism during Phases I-III have been considered and analyzed to increase the effectiveness of Phase IV (European Commission, 2020).

The first problem mentioned by Borghesi and Montini (2016) refers to the high price volatility. The observed price volatility increased uncertainty among participants to the EU ETS. In the absence of strong market price signals, this may have induced some of these firms to postpone costly investments in low-carbon technologies (Gronwald and Ketterer, 2012; Gronwald and Hintermann, 2015). In Phase I, the price volatility was mainly caused by an overallocation of emission allowances, which led to spot prices of €0.06 per tCO2 at the end of 2007. In Phase II, the high price volatility was a direct result of the 2008 economic crisis as the demand for emissions allowances fell sharply. Moreover, the decentralized system and the lack of strict and clear rules for the national caps contributed to the problem of structural oversupply of allowances (Borghesi and Montini, 2016). In 2019, the ERCST concluded that the carbon market was performing well in terms of price volatility, with more consistent levels than during Phase I and II. The second problem is referred to as the "governance" problem. Borghesi and Montini (2016) and Hepburn (2007) claim that Member States had too much freedom in defining the national allocation plans (NAPs) for allowances. Through the NAP, each EU country could decide on the allocation of their emissions allowances. Mainly because of the political pressure on governments from parties who wanted to receive more allowances, NAPs ended up allocating too many emission allowances (Sijm, 2005; Gilbert *et al.*, 2004). This overallocation also characterized Phase II, however in many cases the European Commission asked the Member States to modify their initial NAPs. Among Member States there were significant differences concerning cap-setting. The absence of strict and clear governance undermined the stringency of the system. A third issue present in Phases I and II was the existence of some monitoring problems and failures in the functioning of the national registries in some Member States. Several frauds and severe security incidents occurred in the EU ETS market during Phase I and II, which highly destabilized the effectiveness of the overall EU ETS (Borghesi and Montini, 2016). To properly address these fraud problems, in 2013, the EU introduced new anti-fraud measures and national registries were replaced with a Union registry administered by the European Commission. In the report "Evaluation of the EU ETS Directive" commissioned by the European Commission in 2015, no big issues have been found in the practical implementation of the EU ETS; i.e. monitoring, reporting, verification and accreditation. Similarly, the centralized Registry system has proven reliable and secure. This suggests that the anti-fraud measures and new regulation on registry that were introduced in 2013 had the desired effect.

However, the report advises vigilance, since allowance prices rising in the future may also increase the incentive for fraudulent behavior.

The structural surplus of EUAs was already addressed by the European Commission in 2009. However, the newly introduced amendments did not solve all the problems related to the surplus of EUAs. In an attempt to eliminate the surplus of EUAs in Phase III, the European Commission introduced the back-loading initiative in 2013, which aimed to delay auctions for 900 million allowances planned for the period 2014 to 2016. This initiative aimed to rebalance the supply and demand in the EU ETS market and reduce price volatility. However, the European Commission considered this to be a temporary solution, as a more structural reform was needed to eliminate the surplus of EUAs. Therefore, the European Commission proposed the establishment of the Market Stability Reserve (MSR) in 2014. The MSR aimed to (i) address and manage the overallocation and surplus of EUAs, while also (ii) aiming to increase the resilience of the regime, by adjusting the number of EUAs to be auctioned, depending on various market circumstances. The MSR started operating from 1 January 2019. The structural surplus of EUAs remained a large problem during Phase III. To further address and tackle the surplus of allowances in Phase IV the European Commission imposed new, stringent measures. First, the total number of allowances will decline at an annual rate of 2.2% in Phase IV, compared to 1.74% in Phase III. Second, the Market Stability Reserve (MSR) will be considerably reinforced. Between 2019 and 2023, the amount of allowances held by the reserve will double to 24% of the allowances in circulation, whereafter the regular rate of 12% will be restored as of 2024. The new regulation aims to more effectively address the historical surplus of EUAs, making the EU ETS more responsive to changes in demand and to be able to deal with any future imbalance.

Other problems concerned the validity of international credits. According to a 2017 study by the European Commission, 85% of the offset projects used by the EU under the UN's Clean Development Mechanism (CDM) failed to reduce emissions. As CDM/JI projects, and thus the international credits (CERs/ERUs) earned through these projects, are often characterized by systematic failures, fraud and corruption, non-transparency, and lack of governance, the EU does not envisage continuing the use of international credits for EU ETS compliance in Phase IV (European Commission, 2020). This should again increase the effectiveness of the EU ETS in emission reductions after 2020.

Another issue of the EU ETS is referred to as carbon leakage. Carbon leakage refers to the risk that companies may transfer their production to other jurisdictions with laxer measures to cut GHG emissions as a result of the increased costs of adhering to the regulation of the climate policy in their own jurisdiction. This could lead to an increase in total global GHG emissions (European Commission, 2015). Producers that face competition from jurisdictions not imposing a price on GHG emissions are at a competitive disadvantage and risk losing market share. This can cause production to move to countries without or with lower CO2 costs. As a result, this may increase overall global emissions, which is the exact opposite of what the EU ETS is trying to accomplish; emission reductions. To tackle carbon leakage in Phase IV, the system of free allocation will be extended until 2030 and has been modified to focus on sectors at the highest risk of relocating their production outside of the EU.

The EU ETS is the largest emission trading system in the world and also the first on such a scale. Ellerman (2010) referred to the EU ETS as a prototype to be followed in the ETS field. Many problems presented itself during the course of Phases I-III, especially during Phase I and II. However, the European Commission has constantly adopted new regulation to stimulate the effectiveness of the system. As the EU ETS will enter its fourth phase in 2021, the European Commission amended existing regulation and adopted new measures to ensure its success. All problems previously expressed in literature and assessments reports have been addressed. Governments, companies and individuals are becoming more aware of the potential of carbon offsets in tackling climate change. Therefore, it is crucial for emission trading systems, like the EU ETS, to operate without failures and shortcomings. This will balance demand and supply of allowances and will lead to a fair carbon price. As a result, confidence in emission trading systems will increase, which should in turn induce global emission reductions.

2.4. Realizing the potential of carbon credits

Christine Lagarde, President of the European Central Bank, regards climate change as the great existential challenge of our times. Without mitigation actions, global temperatures are projected to rise by 4-degrees Celsius above pre-industrial levels by 2100. This would expose the earth to severe and irreversible risks. All countries in the world are exposed to this urgent threat, which induced a multilateral response: 190 parties submitted climate strategies for the 2015 Paris Agreement. In the Paris Agreement, parties to the UNFCCC reached an agreement to tackle climate change and to accelerate and intensify action and investments needed for a sustainable net-zero carbon future (UNFCCC, 2020). The Paris Agreement primarily aims to reinforce the global response to the threat of climate change by restricting a global temperature rise to 1.5-degrees Celsius above pre-industrial levels. In order to reach this target, the world needs to drastically cut back on GHG emissions. Companies should prioritize emission reductions in their supply chain and factories. However, not all emissions can be eliminated in this process. As climate change has climbed to the top of the agenda over the past years, companies and governments are now, more than ever, looking into various ways to reduce their carbon footprint. Purchasing carbon credits through carbon trading systems may prove to be a very effective way to offset GHG emissions. Carbon offsets are vitally important in neutralizing the emission that cannot be avoided. For carbon credits to be effective, carbon must have a price. Pricing carbon allows for the trading in carbon credits under schemes such as the EU ETS.

According to Lagarde (2019) there is a ‘growing consensus that carbon pricing is the single most effective mitigation instrument.’ As of 2020, 57 carbon tax and emissions trading systems are in operation at the regional, national, and sub-national level (World Bank, 2019). Together these initiatives cover 11 GtCO2e worldwide, which is 20% of global GHG emissions. According to data from the

World Bank, after years of languishing in relative obscurity, global carbon markets rebounded in 2017 and into 2018. In 2018, countries raised approximately $44 billion in revenues from carbon pricing. In 2017, this number was $33 billion, while in 2016 revenues from carbon pricing totaled $22 billion. It seems that after the Paris Agreement of 2015, the potential of carbon pricing is finally being realized. Baranzini *et al* (2017) provide seven reasons to argue that carbon pricing is one of the most effective ways, at a reasonable cost, in reducing emissions. Also, according to Dominioni and Heine (2019), there is a broad agreement among scholars and policymakers that an effective and efficient carbon emissions mitigation strategy includes carbon pricing. However, carbon pricing is held back by a lack of public support. This lack of public support can possibly be explained by the critique carbon pricing, and carbon trading in general, have received over the last two decades. The EU ETS was characterized by many problems and shortcomings, which had a huge impact on its effectiveness and success. Ethical issues evolving around carbon pricing and the severe problems concerning the EU ETS during Phases I-III potentially still affect the public opinion on carbon offsets. However, according to Lagarde (2019), Baranzini *et al.* (2018) and Dominioni and Heine (2019), carbon pricing is a very effective carbon emissions mitigation strategy. For carbon trading systems to gain public support, Phase IV of the EU ETS must prove to be successful in reducing GHG emissions, as it is the frontrunner of all carbon trading systems in the world. This will certainly impose challenges and demands clear future directions.

2.4.1. Challenges for the EU ETS

In its annual State of the EU ETS report, the European Roundtable for Climate Change and Sustainable Transition (ERCST) (2019), outlined various challenges for that need to be monitored to ensure the effectiveness and success of the EU ETS Phase IV.

During the course of 2020, the European Commission is expected to implement secondary legislation to the EU ETS. The implementation of secondary legislation could have a significant impact on the effectiveness of the EU ETS during Phase IV (ERCST, 2019). The European Commission must ensure that new legislations will have a positive effect rather than a negative effect. Also, EU elections could have serious implications on climate policy within the EU. With Ursula von der Leyen, the European Commission has a new president as of 2019. The EU ETS Phase IV Directive was adopted in March 2018, when Jean-Claude Juncker was still President of the European Commission (European Commission, 2018). Von der Leyen will remain President of the European Commission until 2024, after which new elections will take place. The result of EU elections may have significant impact on future directions on tackling climate change. Changes in the composition of the EU Parliament towards parties that are less inclined to give priority to climate change ambition will have a significant impact on the success of Phase IV (ERCST, 2019).

Several EU countries foresee a coal-phase out plan by 2030 (ERCST, 2019). An analysis by Sandbag and Agora in 2018 reported that a substantial reduction of coal-fired generation could seriously impact the EU ETS supply-demand balance, as coal still accounted for 37% of total EU ETS covered emissions in 2018. In the event of a coal-phase out, it is crucial to understand how many carbon allowances should be cancelled in order to compensate for the decrease in carbon emissions as a result of the coal phase-out. This will be essential to maintain a proper balance between supply and demand and to evaluate the impact of the coal phase-out on EUA prices (ERCST, 2019). EUA prices are expected to rise over the course of Phase IV, which poses another challenge since this may also increase the incentive for fraudulent behavior and carbon leakage.

The Market Stability Reserve (MSR) started operating in January 2019. The MSR should address the current surplus of EUAs, as well as improving the EU ETS's resilience to major shocks by adjusting the supply of allowances to be auctioned. The 2008 economic crisis led to higher than expected emissions reductions, which lead to a large surplus of allowances and credits. This had a large impact on the carbon price throughout Phase II (European Commission, 2020). The MSR should protect the EU ETS from unexpected events such as the economic crisis. However, the effectiveness of the MSR will be seriously challenged by market events such as the Brexit, phase-out of coal and the COVID-crisis of 2020. The combination of 24% intake rate during the first years of Phase IV and the yearly cancellation of allowances is expected to enable the MSR to cope effectively with the current surplus in its first years of operation (ERCST, 2019; ICIS, 2019). Coal-phase outs are expected to happen gradually over the course of Phase IV, so the MSR should be able to balance supply and demand at least till 2024, whereafter the allowance intake rate will drop to the regular 12%. However, projections by ICIS, ERCST and Wegener Center show that after 2024, the surplus of allowances is expected to follow an upward trajectory. The European Commission may have to adapt MSR design parameters to prevent this from happening. The Brexit will impose other challenges for the MSR, as it is still unclear whether the UK will formally continue to participate in the EU ETS. When the UK formally announces to leave the EU ETS, this may lead to the need to adjust EU ETS parameters (ERCST, 2019).

Potentially the largest challenge to the MSR is the COVID-crisis. One of the reasons of the establishing the MSR was to increase resilience and to increase responsiveness to significant changes in demand due to unexpected market shocks. The crisis has proven to be an unexpected market shock. The COVID-crisis had led to a major decline in of economic activity and a drastic reduction in the use of fossil fuels. The Center for Research on Energy and Clean Air estimates that measures to contain the virus in China, in February alone, caused a reduction in carbon emissions of 200 million tCO2, which equals a drop of 25%. Professor Rob Jackson, Chairman of the Global Carbon Project, estimates that carbon output could fall by more than 5% in 2020. After the 2008 economic crisis, emissions only fell by 1.4%. End of March 2020, the Independent Commodity Intelligence Services (ICIS) estimated a considerable drop in EU emissions of 388.8 million tons for 2020 compared to a pre-COVID environment (-24.4%). Lower emissions in Europe result in a higher number of total allowances in circulation (ICIS, 2020). After learning from the 2008 economic crisis, the MSR should be resilient, to some extent, and be able to properly address the consequences of the COVID-crisis. As COVID is still a global issue as of December 2020, it is impossible to say what impact it will have on the EU ETS over the course of Phase IV. However, as total emissions in Europe have already dropped significantly in 2020, it is fair to conclude that the effectiveness of the MSR to respond to unexpected market shocks will be seriously tested. As of December 2020, the EUA price has recovered to pre-COVID levels, which may indicate that the MSR strengthened the resilience of the system against unexpected market shocks (See Figure 1, Section 4.1).

2.4.2. Future directions

Challenges to the EU ETS call for clear future directions that address these challenges. Two of the most relevant discussions concerning future directions for the EU ETS cover (i) the implementation of a price floor and (ii) the linkage of the EU ETS to emissions trading systems in other countries.

For many years, the EUA price has been far below initial expectations (Flachsland *et al.,* 2018). Flachsland *et al.* (2018) suggest that there is a consensus on the key reasons for prices being lower than initial expectations: (i) an oversupply of allowances due to the economic crisis, (ii) the usage of international credits (CDM/JI) and (iii) allocation based on grandfathering. These issues have been addressed by the 2018 EU ETS reform, which primarily aimed at reducing aggregate allowance supply. The 2018 reform for Phase IV lead to a EUA price increase which can be explained by a growing confidence that the EU ETS will be sustained and the commitment to reduce the supply of allowances. However, there remains a persistent risk that market confidence may be weakened again by the challenges discussed in Section 2.4.1. As a response to the high price volatility in the carbon market, Flachsland *et al.* (2018) argue that a price floor would be an essential feature to the design of the EU ETS. A price floor would help to protect the system against low or declining prices in the future and thus enhance confidence. A price floor is the lowest legal price a commodity can be sold at. Several ETSs, including the Regional Greenhouse Gas Initiative (RGGI), and those in California and Quebec as part of the Western Climate Initiative, introduced price floors for allowances in the form of an auction reserve price. The reserve auction floor was initially proposed by Grubb and Neuhoff in 2006. This auction reserve floor price ensures that allowances demanded at a carbon price lower than the price floor will not enter the market, which should limit the supply of allowances within the EU ETS (Grubb and Neuhoff, 2006). The EU ETS has been a frontrunner on emission trading systems, which gave other countries the advantage to observe its achievements and problems. Based on observations of fluctuating and structural low allowance prices in the EU ETS, other ETSs introduced a price floor to allow for resilience against unexpected market shocks, thereby maintain market confidence (Flachsland *et al.*, 2019). Borghesi and Montini (2016), Helm (2008), Hepburn (2006), Clo (2011) and Hepburn, Grubb and Neuhoff (2006), have all argued in favor of a price floor as a mechanism to enhance confidence in the carbon markets. However, in 2012, the European Commission argued against the introduction of a price floor, claiming that this ‘would alter the nature of the current EU ETS being a quantity-based market instrument.’ The new Climate Commissioner to the European Commission, Frans Timmermans, who got appointed in 2019, claimed not to see the merits of introducing a carbon price floor. Timmermans believes that 'the price is going in the right direction and is confident that it will continue to do so.' However, some Member States (France, Netherlands, Sweden, Denmark, Finland, Ireland, Italy and Portugal), argue that a carbon price floor (CPF) would be beneficial for the effectiveness of the EU ETS. One can conclude that the introduction of a price floor could have significant advantages for the EU ETS and receives a lot of support from Member States, but there is still resistance from the European Commission, which first wants to assess the effectiveness of the MSR.

The EU ETS currently allows for the use of international credits earned through CDM and JI projects for compliance purposes. This is a form a "unilateral" linking, with an ETS recognizing credits produced from various offset projects. However, this will be forbidden in Phase IV due to non-transparency, fraud and other reasons discussed in Section 2.2.6. "Bilateral" linking refers to an ETS linking to another ETS. Both ETSs involved then agree to recognize the allowances from both programs as eligible for compliance under either ETS (Borghesi and Montini, 2016). Currently, the only example of bilateral linking is called the Western Climate Initiative, which is an initiative between California and Quebec. The EU ETS had reached a preliminary agreement with Australia for a bilateral linking to be started in 2018, however this agreement was abandoned by Australia after its decision to repeal its ETS legislation after 2013. Among countries operating ETSs there is a 'willingness to link different ETSs which could ease the transition towards a global carbon market' (Perdan and Azapagic, 2011). Linking established and developing ETSs would have distinctive advantages: '(i) the establishment of a level playing field and (ii) a consistent regulatory framework across national borders' (International Carbon Action Partnership (ICAP), 2010). Linking schemes could also aid international cooperation on reducing emissions, help to address competitiveness concerns, reduce price volatility and reduce costs by increasing access to low cost abatement opportunities (Lazarowicz, 2010). To sum up, geographical expansion of carbon trading by linking international trading systems appears to have real potential (Perdan and Azapagic, 2011). However, there are some obstacles that may affect the time needed for systems to be linked. These obstacles include: 'differences of ambition embodied in the caps, timeline of commitment period and comparable units' (Baron and Bygrave, 2002), treatment of international carbon offsets (Perdan and Azapagic, 2011), price management policies (Frankhauser and Hepburn, 2009), and 'different allocation methodologies' (Grubb and Neuhoff, 2006). These design differences among ETSs contribute to political concerns about financial flows from one system to the other (Perdan and Azapagic, 2011). Nevertheless, there is a growing consensus that a global carbon market would significantly improve the effectiveness of many ETSs around the world to reduce carbon emissions in their respective countries or regions. Article 6 of the Paris Agreement on climate change could be the basis of a framework to set up a global carbon market. Article 6 is one of the most complex concepts of the Paris Agreement and was left unresolved at the UN COP24 Climate Conference in December 2018. Article 6 includes potential regulation on how countries can reduce emissions using international carbon markets, which is critical for tackling climate change. The UN's Climate Conference in

December 2019, COP25, again closed without setting rules for carbon markets under Article 6 of the Paris Agreement. Article 6 includes two paragraphs which relate to carbon markets. Article 6.2 specifies an accounting framework for international cooperation, such as linking of various ETSs. Article 6.4 establishes a central UN mechanism to trade offsets from emissions reductions generated through specific projects (UNFCCC, 2020). Studies show that if designed well, Article 6 has to potential to lead to various advantages, such as reducing costs of complying to the goals of the Paris Agreement and inducing great incentive for private sector to invest in various countries. However, this potential is only realized if the market is credible, reliable and has integrity (World Research Institute, 2019). Therefore, it is of vital importance that Article 6 to the Paris Agreement lays out the foundation to specify a well-defined and robust framework for linking carbon markets in the future (European Commission, 2020). It is clear that the EU ETS will have to link to ETSs in other countries, however it will have to wait until an agreement has been reached on Article 6.

2.5. Effect at firm-level

To comply with the EU ETS, companies must invest in changes to reduce their emission profile or buy carbon offsets. Both of these increase costs of production, which the company may choose to pass-through to the consumer of shoulder by themselves (Muuls *et al.,* 2016). The regulation imposed as a result of the EU ETS can have a serious impact on the competitiveness of the companies operating in the European Union, which is particularly evident if other developed countries do not take equivalent action to reduce carbon emissions. This would lead to an economic disadvantage for the companies subject to EU ETS regulation when competing with companies that do not have any restrictions on carbon emissions. There is a strong believe that 'companies participating in carbon trading put themselves in risk of losing market share to unregulated companies and global competitors, and that these pressures would eventually force them to shift their production chains outside of the European Union' (Muuls *et al.*, 2016). This would dramatically impact unemployment and undermine the effectiveness of the EU ETS, as carbon emissions would be transferred from Europe to unregulated parts of the world (See Section 2.3.1). Also, according to Aldy *et al.* (2012), uneven policy efforts across nations could potentially lead to competitive distortions and as a result to undesired effects such as relocation of economic activity, rising unemployment and carbon leakage. As a result of the abovementioned potential consequences, the introduction of the EU ETS in 2005 faced opposition from a large number of sectors, citing the risk of carbon leakage and loss of competitiveness on global markets as reasons against their inclusion in the system, or calling for preferential treatment (Mehling, 2013).

According to Muuls *et al.* (2016), a company's ability to pass-through emissions costs to the consumer is widely regarded as an indicator of how the EU ETS affects competitiveness – high pass-through rates may ease the impact on competitiveness. The pass-through rate varies between industries, ranging from no cost pass-through to 100% of the carbon price (Arlinghaus, 2015). The ability of a producer to pass through cost increases primarily depends on the competitive nature of the underlying market but is also affected by the amount of the cost increase, the substitutability of the product, as well as changing variables (Reinaud, 2008). Jurisdictions with a price on carbon, like the EU ETS, can adopt various measures to ease the burden of covered entities, such as the free allocation of allowances (see Section 2.2.2). Several policy options have been proposed that may serve to offset competitive distortions arising from differences in stringency of emissions reduction strategies. The discussion on policy response measures has centered on four categories:

1) Financial assistance for affected sectors – a high share of free allocation can help alleviate concerns about competitiveness (Reinaud, 2008)
2) Cost containment and flexibility in ETSs – the economic impact on covered entities can be minimized with cost containment and flexibility provisions which either limit compliance costs across the entire system or afford preferential treatment to certain vulnerable entities (Mehling, 2013)
3) Border adjustment measures – measures that penalize imports from other countries which do not take comparable action (Hufbauer *et al.,* 2009)
4) Extension of domestic climate policies to further offset competitive distortions

However, Mehling (2013) claims that these measures to offset competitive disadvantages face a number of challenges. Particularly, the allocation of free allowances is argued not to be the perfect solution. This argument is now strengthened by the fact that the European Commission will revise the system of free allocation for Phase IV (2021-2030). The system of free allocation will be extended until 2030 but has been amended to 'focus on sectors at the highest risk of transferring their production outside of the European Union.' For other sectors, free allocation will be phased out after 2026 to 0 at the end of Phase IV. Given its nature of putting potential restrictions on international trade, border adjustment measures may risk sparking a trade dispute in front of the World Trade Organization – it is unclear whether border adjustment measures would be fully compatible with international rules on free trade (Mehling, 2013).

In literature researching the effects of the EU ETS on competitiveness, a firm's competitiveness is defined by Dechezleprêtre and Sato (2014) as its long-run profit performance as measured by employment, turnover or value added. An *ex-ante* report by Carbon Trust (2004) concludes that 'participants to the EU ETS will be subject to greater burdens although the ETS does offer competitive advantages compared to alternative regulatory scenarios.' However, *ex-post* literature does hardly find any significant effects of the EU ETS on the competitiveness of the participating firms. Demailly and Quirion (2008) study the impact of the ETS on production and profitability for the steel and iron sector and only find modest competitiveness losses. Abrell *et al.* (2011) study the effect of the ETS on the added value, the profit margin and employment of participating firms and find no evidence that the EU ETS affects these measures of competitiveness. A comparable study by Anger and Oberndorfer (2008), compares overallocated firms, which were practically exempt from payments under the EU ETS, to underallocated firms which had to purchase additional permits at a cost. They find evidence that the EU

ETS allocation mechanism did not have a significant impact on revenues and employment of the participating firms. This suggests that, for Phase I, initial over-allocation or under-allocation of EUAs does not affect a firm's competitiveness based on employment and firm revenue. By examining firm-level micro data, Wagner and Petrick (2014) find that German manufacturing firms have reduced emissions as a result of being subject to EU ETS regulation, while the same firms have not experienced any negative competitiveness effects. According to Arlinghaus (2015), most *ex-post* literature on the competitiveness effects of the EU ETS finds no causal effects of the EU ETS on employment, profits or output. While these studies do not find any evidence for competitiveness effects, they do find substantial emissions abatements. This suggests that the EU ETS was binding and strict enough to induce substantial emission reductions, while not leading to competitive disadvantages for participating firms (Arlinghaus, 2015).

2.6. Hypotheses

The EU ETS is a 'cap-and-trade' system, which works by capping overall GHG emissions of all participants in the system. A target set by the EU ETS aimed to reduce emissions in 2020 from sectors covered by the EU ETS by 21% compared to 2005. The EU is on track to surpass this target. As part of the EU's 2030 climate and energy framework, emissions in 2030 from sectors covered by the EU ETS will be cut by 43% from 2005 levels (European Commission, 2020). The main goal of the EU ETS is to accomplish significant emission reductions. However, the EU ETS, especially during the introduction of Phase I, faced opposition from a large number of sectors, citing the risk of carbon leakage and loss of competitiveness on global markets (Mehling, 2013). The research question is therefore as follows: *Is the EU Emissions Trading System successful in reducing carbon emissions and what is the impact at a firm-level?*

As the main goal of the EU ETS is to reduce carbon emissions in the European Union, it should be expected that the EU ETS had a positive effect on the reduction of the carbon emissions in the EU. Thus, the following hypothesis is evaluated:

Hypothesis 1: *"The EU ETS has accelerated carbon emission reductions in Phase III relative to Phase II"*

Furthermore, it may be expected that underallocated companies increased their emission reduction efforts in Phase III relative to overallocated companies, as the incentive for underallocated companies is much higher. Therefore, the second hypothesis is investigated:

Hypothesis 2: *"Underallocated companies accelerated emission reductions by more than overallocated companies"*

The EU ETS will be considered effective if carbon emissions have been cut significantly over the past three phases. However, it is commonly supposed that companies participating in carbon trading put themselves in risk of losing competitiveness relative to unregulated competitors. The pressure on competitiveness could eventually force these companies to shift their production facilities outside of the European Union (Muuls *et al.*, 2016). This would dramatically impact unemployment and undermine the effectiveness of the EU ETS, as carbon emissions would transfer from Europe to unregulated parts of the world. Therefore, the EU ETS is not only assessed based on its effectiveness in reducing carbon emissions, but also on its impact on employment, ROE and profit margin. However, to comply with the EU ETS, companies must invest in R&D and renewable energy to reduce their emission profile and otherwise buy additional carbon offsets. Both of these increase costs of production, which may negatively affect the competitiveness of the participating companies. Therefore, the following hypothesis is tested:

Hypothesis 3: *"The EU ETS negatively affects financial performance of the companies under regulation"*

A fourth hypothesis is tested to examine whether the EU ETS has a different effect on underallocated companies than overallocated companies. As underallocated companies are net buyers of allowances and overallocated companies are net sellers of allowances, it is expected that underallocated experience a larger negative effect on their financial performance.

Hypothesis 4: *"Underallocated companies experience a larger negative effect on their financial performance relative to overallocated companies"*

Chapter 3 (Data & Methodology) will describe the methodological methods used to test the hypotheses and will also discuss research methods used in previous literature. Wagner and Petrick (2014), Abrell *et al.* (2011) and Anger and Oberndorfer (2007) argue that for all hypothesis the difference-in-difference (DiD) model is highly suitable as it allows to estimate treatment effects comparing the pre- and post-treatment differences in the outcome of a treatment and a control group. Hypotheses 1 and 2 are tested by equation 1 (Section 3.2) and hypotheses 3 and 4 are tested by equation 2 (Section 3.2). The pre-treatment period is Phase II, 2011-2012, and the post-treatment period is Phase III, 2013-2018. The model is performed on multiple subsamples (full sample, underallocated companies and overallocated companies), as relative allocation of emissions may have an impact on the firm's behaviour.

3. Data & Methodology

The data for this research is obtained from the Orbis database and the European Union Transaction Log (EUTL). Orbis contains detailed data of 375 million private and public companies worldwide. Furthermore, the EUTL is a central transaction log, run by the European Commission, which checks and records all transactions taking place within the EU ETS (European Commission, 2020). The data from EUTL is used to comprise the EU ETS data viewer, which provides aggregated data by country, by main activity type and by year on the verified emissions, allocated allowances and surrendered units of 14,128 stationary installations reporting under the EU emission trading system. All of the 14,128 plants are located in the 27 EU member states as well as in Norway, Iceland, Liechtenstein and the UK (due to Brexit the UK will leave the EU after 2020, and thus stops participating in the EU ETS). Many companies in the EUTL database operate as private companies. Therefore, Orbis was selected as a database to retrieve financial information, as it includes both data on private and public companies.

The data from EUTL and Orbis are used to create one dataset, which combines emissions data with financial data. The EUTL data on emissions and the Orbis data on financials were matched through a difficult process, which finally led to a final dataset of 994 companies. The matching process consisted of multiple steps. First, the 14,128 stationary installations had to be matched to their respective companies. This led to a set of 9,458 companies that owned the 14,128 installations. This meant that one company could own multiple installations under EU ETS regulation. Then, the emissions data on 9,458 companies had to be matched to financial data from Orbis. The matching was conducted through the company registration number of the 9,458 companies. The type of company registration number varies per country; however, it allows for matching between Orbis and EUTL on a per country basis. This resulted in a dataset of 1,287 companies, which included both financial and emissions data. After cleaning the dataset for inconsistent values, the final dataset contained data on 994 companies. The final dataset will not only be used to examine the effectiveness of the EU ETS in curbing carbon emissions, but also the effect on the competitiveness of the companies under EU ETS regulation.

3.1 Emissions data

The data on emissions covers the period from 2008 to 2018. This period covers Phase II (2008-2012) and Phase III (2013-2020) of the EU ETS. Therefore, it also covers the transition from Phase II to Phase III on the 1st of January 2013. Phase III introduced new, more strict regulation that should strengthen and improve the effectiveness of the EU ETS in reducing EU carbon emissions. It is important to examine the effectiveness of the EU ETS after the transition to Phase III, as it should have improved as a result of new regulation. The data on emissions will therefore be used to assess the effectiveness of the EU ETS in reducing carbon emissions in Europe over the course of Phase II to Phase III.

The EUTL database on emissions provides data on allocated allowances and verified emissions for the period 2008-2018. Verified emissions is a measure of all direct and indirect carbon emissions caused by the activities of a firm. Direct emissions (Scope 1) include all emissions as a result of the activities of a firm – fuel used on production sites, heating for offices and vehicles owned by the company. Indirect emissions (Scope 2) are emissions coming from electricity purchased and used by the firm. This study does not include Scope 3 emissions, which measures all other indirect emissions from the activities of the organization that are not in the firm's control. Since a company has no control over Scope 3 emissions, these are left out of the dataset. As this study researches a firm's acceleration in emission reductions, it studies a percentage change between yearly verified emissions. Therefore, it is not necessary to scale verified emissions by the size of a company. As compliance to the EU ETS is mandatory for all installations in Europe under European law, all firms owning installations must report verified emissions of the owned installations (See Section 2.2.1). This allows for a strong interpretation of the results, as no companies can circumvent the mandatory yearly carbon disclosure. Allowances are allocated either by free allocation, where installations receive allowances for free, or via auctioning. During Phase I (January 2005 – December 2007) and Phase II (January 2008 – December 2012), most allowances were allocated for free, while during Phase III (January 2013 – December 2020) the majority of allowances will be provided via auctioning (European Commission, 2015). As of Phase III, approximately 50 percent of total allowances will be auctioned. The system of free allocation will be prolonged to Phase IV (January 2021 – December 2030) and has been revised to 'focus on sectors at the highest risk of relocating their production outside of the EU: these sectors will receive 100% of their allocation for free.' For less exposed sectors, free allocation will be phased out after 2026 to 0 at the end of Phase IV. The use of free allocation cuts the costs of compliance for industries. This is particularly important if other developed countries do not take equivalent action to reduce GHG-emissions. This would lead to an economic disadvantage for companies subject to EU ETS regulation when competing internationally with companies that do not have any restrictions on GHG emissions. Free allocation can reduce this potential disadvantage. At the end of every year, a company has to surrender the same amount of allowances as its verified emissions. Therefore, a company has to buy extra allowances if its verified emissions exceed its allocated allowances. A company's direct costs to comply under the EU ETS is the difference between its verified emissions and the freely allocated allowances multiplied by the price of a carbon emission allowance (EUA). Due to the limited or capped supply of allowances and the demand for them from participants that do not meet their reduction target, allowances have value.

When a company receives less allocated allowances than its verified emissions it is called underallocation. The opposite is overallocation, which means a company receives more allowances than its verified emissions. The incentive to reduce verified emissions is expected to be higher for underallocated companies since they must buy extra allowances on the carbon market. To express the level of under- or overallocation for a company, an allocation factor (AF) is calculated (Anger and Oberndorfer, 2008): $Allocation\ Factor = \frac{Allocated\ Allowances}{Verified\ Emissions}$. An AF>1, suggests overallocation and an AF<1 suggests underallocation. During Phase I and II too many allowances were allocated for free.

As a result, there was a significant surplus of allowances, which in turn led to the carbon price falling below €5 by the end of Phase II.

3.2 Financial data

The second part of the dataset contains the financial data. This dataset is used to assess the effect of the EU ETS on a firm's financial performance and competitiveness. The financial data covers the period from 2011 to 2019, as 2011 was the earliest year available in Orbis. To assess a company's competitiveness, the profit margin, number of employees and return on equity (ROE) are used as financial metrics. Tsoutsoura (2004) and McWilliams & Siegel (2000) use the ROE as a metric for financial performance. Abrell *et al.* (2011) use the profit margin and number of employees as indicators for competitiveness in their study on the EU ETS. Other widely used measures in corporate finance for financial performance are a company's stock return or Tobin's Q. However, the EU ETS covers both public and private companies, and since private companies amount for 95% of the dataset, unfortunately it was not possible to use these market metrics.

Table 1: Country distribution of the sample companies

Table 1 provides the descriptive statistics per country. It shows in which countries the companies in the sample are based. The first column gives the number of companies per country for the treatment group. The second column gives the number of companies per country for the control group. The last column combines the control group and the treatment group. The companies are matched one-on-one through Propensity Score Matching and that explains the same number in companies in both groups.

	Control group	Treatment group	Total
Austria (AT)	2	0	2
Belgium (BE)	31	4	35
Bulgaria (BG)	33	42	75
Czech Republic (CZ)	81	74	155
Denmark (DK)	5	3	8
Estonia (EE)	5	14	19
Spain (ES)	146	215	361
Finland (FI)	19	55	74
United Kingdom (UK)	0	62	62
Greece (GR)	26	0	26
Croatia (HR)	15	0	15
Hungary (HU)	56	60	116
Ireland (IE)	8	2	10
Italy (IT)	331	190	521
Lithuania (LT)	12	0	12
Latvia (LV)	14	24	38
Netherlands (NL)	17	25	42
Poland (PL)	6	0	6
Portugal (PT)	32	0	32
Romania (RO)	56	30	86
Sweden (SE)	55	156	211
Slovenia (SI)	8	19	27
Slovakia (SK)	36	19	55
Total	994	994	1988

3.3 Final dataset and control group

The final dataset combines the emissions data from EUTL with financial data from Orbis. As the financial data covers the period 2011-2019 and the emissions data covers the period 2008-2018, the longest possible period that includes both financial and emissions data ranges from 2011-2018. However, this still allows this study to assess the effectiveness over Phase II and Phase III, and thus also the transition from Phase II to Phase III on the 1st of January 2013. The final dataset covers 994 companies from 17 countries (Table 1): Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, Hungary, Ireland, Italy, Latvia, Netherlands, Romania, Slovenia, Slovakia, Spain, Sweden and the United Kingdom. As a result of the matching process through company registration numbers, a large part of the initial companies was eliminated. The 994 companies are classified into six sectors based on the two-digit NACE Rev.2 code: (A) Agriculture, forestry and fishing, (B) Mining and Quarrying, (C) Manufacturing, (D) Electricity, gas and steam, (E) Water supply and (F) Construction. 99 percent of the companies covered by the EU ETS operate in these six sectors. A large majority of the companies in the sample operate in the manufacturing industry (Table 2).

Table 2: Sectoral distribution of the sample companies

Table 2 provides the descriptive statistics per sector. The 994 companies are classified into six sectors based on the two-digit NACE Rev.2 code: (A) Agriculture, forestry and fishing, (B) Mining and Quarrying, (C) Manufacturing, (D) Electricity, gas and steam, (E) Water supply and (F) Construction. It gives the share of companies per sector for both the treatment and the control group. The frequency (*Freq.*) gives the percentage share of the companies in a given sector.

	Treatment	*Freq.*	Control	*Freq.*	Total	*Freq.*
(A) Agriculture, forestry and fishing	130	*13.1%*	115	*11.6%*	245	*12.3%*
(B) Mining and quarrying	39	*3.9%*	46	*4.6%*	85	*4.3%*
(C) Manufacturing	700	*70.4%*	682	*68.6%*	1382	*69.5%*
(D) Electricity, gas and steam	26	*2.6%*	53	*5.3%*	79	*4.0%*
(E) Water supply	85	*8.6%*	83	*8.4%*	168	*8.5%*
(F) Construction	14	*1.4%*	15	*1.5%*	29	*1.5%*
Total	994	*100%*	994	*100%*	1988	*100%*

To effectively assess the financial performance of the 994 companies under EU ETS regulation, it must be compared to a control group. To compile a control group a Propensity Score Matching test was performed in STATA. This matched the treatment group one-on-one with a control group, based on industry, revenue, number of employees, ROE and profit margin. The control group consists of companies that are not under EU ETS regulation and therefore do not incur additional costs from buying allowances. As the control group was not matched based on country, companies in the control group are sometimes based in other countries than the treatment group. This does not cause any problems since companies compete internationally. Table 3 shows the baseline descriptives of the treatment group and the control group. Column 4 gives the difference between the control group (column 2) and the treatment group (column 3). This difference should not be significant as this would violate the parallel trend assumption for a difference-in-difference test, which assumes a parallel trend between the control group and the treatment group in the pre-treatment period. Since all differences are not significant, the parallel trend assumption holds and thus allowing a causal effect to be inferred. Once the matching partners are found, it is then possible to estimate the average effect of participation by assessing the impact of the EU ETS on the dependent variable:

$$y_i = \Delta\bar{Y}_T - \Delta\bar{Y}_C$$

Where $\bar{Y}_T$ is the average for the treatment group and $\bar{Y}_C$ is the average for the control group. It shows the mean of the relevant metrics and a t-test is performed to test the difference between the groups. As the coefficients are not significant, there is no significant difference found between the treatment and the control groups

Table 3: Baseline descriptives for the Parallel Trend Assumption
Table 3 provides the baseline descriptives for the treatment group and the control group, which were matched following a propensity matching score. It gives the mean for the control sample, the treatment sample and the combined, full sample for Phase II, which is the pre-treatment period. The difference shows to what extent both groups match and cannot be significant. If the difference would be significant then the control group and the treatment group would not follow the parallel trend assumption for the difference-in-difference framework.

	All	Control	Treatment	Difference
% Change in Profit Margin	-0.009	-0.006	-0.011	-0.004
	(0.102)	(0.081)	(0.120)	
% Change in ROE	-0.002	0.005	-0.009	-0.014
	(0.427)	(0.461)	(0.390)	
% Change in Employees	-0.010	-0.008	-0.012	-0.004
	(0.179)	(0.190)	(0.168)	
% Change in Revenue	0.033	0.042	0.025	-0.017
	(0.232)	(0.216)	(0.246)	
% Change in GVA	-0.043	-0.043	-0.043	-0.000
	(0.029)	(0.030)	(0.029)	
Observations	1,988	994	994	

3.4 Methodology

To evaluate the hypotheses requires a more formal analysis of the data. The methodology of Abrell *et al.* (2011) is closely followed. However, this paper additionally researches trends in emission reductions in the post-treatment period (2013-2018) and uses different outcome variables for measuring financial performance. The EU ETS has been introduced in 2005 to reduce carbon emissions in the EU. Now, in 2020, it is reasonable to expect that significant progress should have been made. However, it is challenging to evaluate whether the EU ETS led to emissions reductions and what emissions would have been in the absence of the ETS. It is not observable what emissions would have been when the EU ETS had not been introduced in 2005. Studies like Abrell *et al.* (2011) have examined the effectiveness of the EU ETS by comparing the development of emission reductions in Phase I to Phase II. Anderson and Di Maria (2011) also evaluated the effectiveness of the EU ETS in Phase I by testing whether companies reduced or inflated their emissions during this pilot phase. This paper contributes to the debate by comparing emissions reductions in Phase II to Phase III. As the counterfactual of the emissions reductions due to the EU ETS is not observable, this paper examines the transition of Phase II to Phase III in January 2013 and assesses the possibility whether emission reductions have accelerated after the start of Phase III. One of the goals of this paper is thus to analyze whether companies changed their emission reduction strategy from the period 2013-2018 relative to 2011-2012. To test Hypothesis 1: "The EU ETS has accelerated carbon emission reductions in Phase III relative to Phase II", the below regression (1) is performed. To assess the effectiveness of the newly adopted regulation in Phase III this regression tests whether there has been an acceleration in emission reductions in Phase III relative to Phase II. To control for other plausible factors that may have induced emission reductions, the regression includes several control variables. For example, the economic environment or a company's individual performance could have led to some companies reducing their emissions. To control for a company's individual performance the regression includes a variable for revenue. On the other hand, to control for the economic environment the regression includes the growth in gross value added (GVA) for every sector for every year. Besides, to control for a company's size the number of employees is used. As many companies in the sample operate in labor intensive industries, the number of employees serves as a fair measure for size. A robustness check has been performed by taking the logarithm of the verified emissions to check for outliers. To control for outliers in the sample, a robust regression is performed (Huber, 1964; Verardi and Croux, 2009). To simply eliminate, trim or winsorize outliers would be a draconian measure as these outliers are part of the sample and there is a reason why they exist. Preferably, these outliers should be included in the sample so that it represents the full sample. Therefore, in a robust regression, the outliers are reweighted such that some receive weights smaller than 1. In order to test whether there has been an acceleration in emissions reductions in Phase III (Hypothesis 1), the following regression is formulated:

$$y_{i,t,s} = \beta_0 + \beta_1 \times \text{Year}_t + \beta_2 \times Firm\ Performance_{i,t} + \beta_3 \times Size_{i,t} + \beta_4 \times Economic\ Environment_{i,t,s} + \gamma + \lambda_s + u_{i,t,s} \quad (1)$$

Where $y_{i,t,s}$ is the variable reflecting the log order verified emissions of firm *i* operating in sector *s* in year *t*. $Year$ is a variable for every year in the sample period (2012, 2013, 2014, 2015, 2016, 2017, 2018). The $Firm\ Performance$ takes the revenue growth for company *i* between t and $t-1$, and thus uses revenue growth as a measure of firm performance. This variable is expected to have a positive relationship as well-performing and growing firms are expected to increase verified emissions as a result of higher output. $Size$ is measured by the number of employees and literature has not found conclusive results on whether the size of a company has an impact on its emissions. In absolute terms larger companies will have higher verified emissions, however in relative terms no evidence has been found. $Economic\ Environment$ controls for economic activity in the sector that a company operates in and is measured by the Gross Value Added. The sign is expected to be positive, because in a favorable economic environment firms tend to grow and increase output and as a result also emissions. Country-fixed effects denoted by γ are used to control for systematic differences in the financial environment across countries. Industry-fixed effects denoted by λ_s should control for systematic differences in financial environment across sector types. To control for heteroskedasticity the model uses robust standard errors. Finally, to assess whether the EU ETS has improved its effectiveness in Phase III, the emission reductions in Phase III are directly compared to the emission reductions in Phase II. Additionally, the same is done for all years in Phase III (2013, 2014, 2015, 2016, 2017, 2018) to examine whether the transition to Phase III induced short- or long-term effects. To make a direct comparison between two different periods, the third difference of Equation 1 is compiled. First, the differential in emission reductions for Phase II is calculated:

$$\mathbf{2012}\text{: } \log(emissions_{2012}) - \log(emissions_{2011}) = emission\ growth\ rate_{2012}$$

Then, the same is done for all years in Phase III (2013-2018):

$$\mathbf{2013}\text{: } \log(emissions_{2013}) - \log(emissions_{2012}) = emission\ growth\ rate_{2013}$$
$$\mathbf{2014}\text{: } \log(emissions_{2014}) - \log(emissions_{2013}) = emission\ growth\ rate_{2014}$$
$$\dots$$
$$\mathbf{2018}\text{: } \log(emissions_{2018}) - \log(emissions_{2018}) = emission\ growth\ rate_{2017}$$

The third difference in the emission growth rate between every year in Phase III (2013-2018) and emission growth rate in 2012 is:

$$\mathbf{2013}\text{: } \Delta^3 y_{2013} = emission\ growth\ rate_{2013} - emission\ growth\ rate_{2012}$$
$$\mathbf{2014}\text{: } \Delta^3 y_{2014} = emission\ growth\ rate_{2014} - emission\ growth\ rate_{2012}$$
$$\dots$$
$$\mathbf{2018}\text{: } \Delta^3 y_{2018} = emission\ growth\ rate_{2018} - emission\ growth\ rate_{2012}$$

Therefore, the third difference of Equation 1 translates into Equation 2, which estimates whether there has been an acceleration in emission reductions in Phase III relative to Phase II, and thus tests Hypothesis 1:

$$\Delta^3 y_{i,t,s} = \beta_0 + \beta_1 \times \Delta^3 Firm\ Performance_{i,t} + \beta_2 \times \Delta^3 Size_{i,t} + \beta_3 \times \Delta^3 Economic\ Environment_{i,t,s} + \gamma + \lambda_s + \Delta u_{i,t,s} \quad (2)$$

Where $\Delta^3 y_{i,t,s}$ is the variable reflecting the difference in verified emissions between the years in Phase III and Phase II. After taking the third difference of Equation 1, the parameter of interest becomes β_0 which captures the change of behavior in emissions by firm *i*. β_0 captures whether a firm has increased emission reduction efforts in Phase III opposed to Phase II. Although emissions are meant to be reduced as a result of the EU ETS, emissions may sometimes also increase. Therefore, a two-sided test must be performed to capture both emissions reductions as increases.

As explained in Section 3.1, some companies are underallocated and some are overallocated. This is expressed by the Allocation Factor (AF), which is AF>1 for overallocation and AF<1 for underallocation. It is expected that underallocated companies have a higher incentive to increase their emission reduction efforts as they incur higher costs from purchasing extra allowances on the market relative to overallocated companies. Therefore, to test Hypothesis 2: "Underallocated companies accelerated emission reductions by more than overallocated companies", Equation 2 is regressed on sub-samples of under- and overallocated companies.

Although the EU ETS may have a positive impact on the environment through emission reductions, it is unclear whether the companies under regulation experience a negative effect on their competitiveness relative to companies that are not regulated. In order to examine Hypothesis 3: "The EU ETS negatively affects financial performance of the companies under regulation", one must study the effect of participating in the EU ETS on a company's financial performance. *Ex-post* literature does hardly find any significant effects of the EU ETS on the competitiveness of the participating firms (See section 2.5). However, most of this literature was published before 2015 and examines only Phase I, Phase II and the beginning of Phase III. The regulation imposed for Phase III probably needs some time to become effective and therefore it is important to examine the effects of the EU ETS for the remainder of Phase III. Phase III regulation further limited the amount of free allocated allowances, which resulted in companies having to cut emissions even further or buy more allowances on the market. Prior research in this field shows that a difference-in-difference (DiD) model is highly suitable (Wagner and Patrick, 2014; Anger and Oberndorfer, 2007; Abrell *et al.,* 2011). DiD is a tool to estimate treatment effects comparing the pre- and post-treatment differences in the outcome of a treatment and a control group. Drawing on prior research, a difference-in-difference framework will be applied. The baseline specification of a DiD is the following (Roberts and Whited, 2011):

$$y = \beta_0 + \beta_1 \times d \times p + \beta_2 \times d + \beta_3 \times p + u \qquad (3)$$

The DiD estimator can also be obtained using differences of variables. With two periods, one pre- and one post-treatment, a cross-sectional regression of the change in outcomes, Δy, on a treatment group indicator variable d and the change in control variables, if any, will recover the treatment effect, β_1 (Roberts and Whited, 2011):

$$\Delta y = \beta_0 + \beta_1 \times d + \Delta u, \qquad (4)$$

where d is treatment assignment variable equal to one if a firm is in the treatment group and p is the post-treatment indicator equal to one after the policy change. Equation 3 translates into Equation 5 for this study:

$$y_{i,t} = \beta_0 + \beta_1 \times EU\ ETS_{i,t} \times Phase\ III_{i,t} + \beta_2 \times EU\ ETS_{i,t} + \beta_3 \times Phase\ III_{i,t} + u_{i,t} \quad (5)$$

Where $y_{i,t}$ is the dependent variable for financial performance and is measured by ROE, profit margin and the number of employees. $Phase\ III$ equals 0 for the pre-treatment period (Phase II: 2011-2012) and equals 1 for the post-treatment period (Phase III: 2013-2018), with $t = 2012, 2013, 2014, 2015, 2016, 2017, 2018$. $EU\ ETS$ acts as a treatment group indicator, assigned a positive value of 1 for companies under EU ETS regulation and 0 for unregulated companies. Then $Phase\ III$ is interacted with the group indicator. The use of a treatment and control group means the analysis is robust to omitted variables that would equally impact either group. To control for plausible factors that may have an effect on competitiveness, the regression should include several control variables. The estimate of the treatment effect β_1 is more efficient with additional exogenous controls, because these controls reduce the error variance (Roberts and Whited, 2011). Building on Equation 4, control variables are added to the equation. The $Firm\ Performance$ takes the revenue growth for company *i*, and thus uses revenue as a measure of firm performance. $Size$ is measured by the number of employees in 2012. $Economic\ Environment$ controls for economic activity in the sector that a company operates in and is measured by the Gross Value Added. The sign is expected to be positive, because in a favorable economic environment firms tend to grow. Country-fixed effects denoted by γ are used to control for country-specific factors, while industry-fixed effects denoted by λ_s control for industry-specific factors. To control for heteroskedasticity the model uses robust standard errors. The model below, Equation 6, includes a treatment and a control group, which examines how the treatment group performed relative to the control group, and whether this effect changes after the transition to Phase III. A control group is necessary as the counterfactual is not observable. To reduce the selection bias created by assigning a non-participating firm to each participating, firm, a propensity score matching is used. Using propensity score matching is a common way to 'correct' the estimation of participation effects while controlling for other factors that might have been an influence (Abrell *et al*., 2011). The basic idea behind this model is that selection bias is reduced when the treatment and control group are as similar as possible. Adding control variables for *Size, Firm Performance* and *Economic Environment*, as well as country-fixed effects and industry-fixed effects to Equation 5, gives the following equation:

$$y_{i,t,s} = \beta_0 + \beta_1 \times EU\ ETS_{i,t} \times Phase\ III_{i,t} + \beta_2 \times EU\ ETS_{i,t} + \beta_3 \times Phase\ III_{i,t} + \beta_4 \times Firm\ Performance_{i,t} + \beta_5 \times Size_{i,t} + \beta_6 \times Economic\ Environment_{i,t,s} + \gamma + \lambda_s + u_{i,t,s} \quad (6)$$

Finally, to test Hypothesis 3: "The EU ETS negatively affects financial performance of the companies under regulation", the first difference of Equation 6 is formulated – just like is done in Equation 4. This allows for a direct comparison between the years after the policy change in 2013 (Phase III) and 2011/2012 (Phase II):

$$\Delta y_{i,t,s} = \beta_0 + \beta_1 \times EU\ ETS_{i,t} + \beta_2 \times \Delta Firm\ Performance_{i,t} + \beta_3 \times \Delta Size_{i,t} + \beta_4 \times \Delta Economic\ Environment_{i,t,s} + \gamma + \lambda_s + \Delta u_{i,t,s} \quad (7)$$

$\Delta y_{i,t,s}$ is the outcome variable in log value which can be profit margin, ROE or number of employees and $\Delta y_{i,t,s}$ is the first difference between any year in Phase III (2013-2018) and 2012:

$$\mathbf{2013}: \Delta y_{i,t} = y_{2013} - y_{2012},$$

$$\mathbf{2014}: \Delta y_{i,t} = y_{2014} - y_{2012}$$

$$\ldots$$

$$\mathbf{2018}: \Delta y_{i,t} = y_{2015} - y_{2012}$$

$u_{i,t,s}$ is a time variant error term. The parameter of interest in this equation is β_1, as it shows the effect of being under EU ETS regulation after the transition to Phase III on the 1st of January 2013. β_1 captures the change in competitiveness between a company under EU ETS regulation and an unregulated company for every given year after the transition to Phase III. As a company's financial performance may be affected both positively and negatively as a result of being under EU ETS regulation, a two-sided test will be performed.

To test Hypothesis 4: "Underallocated companies underperform relative to overallocated companies", Equation 6 is performed on subsamples of under- and overallocated companies, as relative allocation of emissions may have an impact on the firm's behavior. The model examines the first difference between any given year in Phase III (2013-2018) and Phase II (2011-2012).

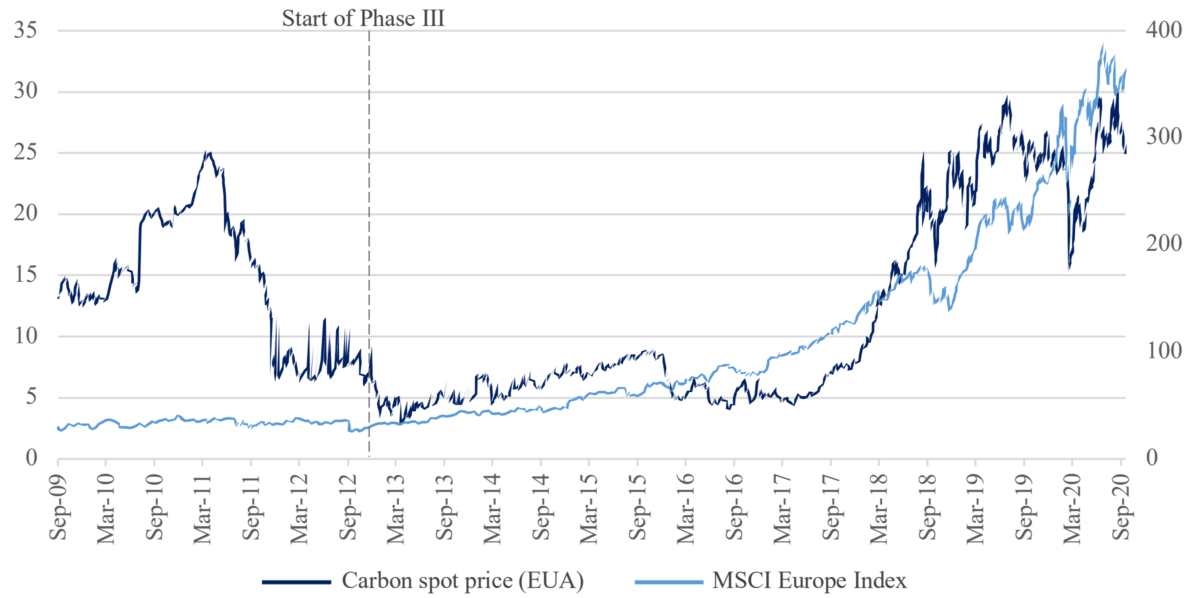
4. Results

Before looking into the results, it is important to understand the background of the EU ETS. The EU ETS consists of three phases: Phase I (2005-2007), Phase II (2008-2012) and Phase III (2013-2020). Over the course of these phases new regulation was adopted to increase the effectiveness of the system. Part of the new regulation intended to reduce the amount of free allocated allowances and to further cut back on emissions. Therefore, we first look into the general performance of the EU ETS. Thereafter, this paper will analyze whether the EU ETS led to emission reductions and addresses the effects of the EU ETS on the competitiveness of the firms under regulation.

4.1 General performance of the EU ETS

As discussed in the Theoretical Framework, during Phase I and II the initial allocation of allowances was decided upon by EU Member States via National Allocation Plans, which had to be approved by the European Commission (Abrell *et al.*, 2011). There was great variation between different countries in the allocation plans. Also, a majority of the emissions allowances were allocated for free to installations through a process called 'grandfathering', which was based on historical emissions (see Section 2.2.2). Key features of the new regulation imposed in Phase II were a 6.5% lower cap on allowances compared to 2005 and the proportion of free allocation fell to approximately 90% (European Commission, 2020). As the data on verified annual emission data from Phase I was now available, the cap on allowances was reduced in Phase II. However, the 2008 economic crisis led to higher than expected emissions reductions, which lead to a large surplus of allowances. This had a large impact on the carbon price throughout Phase II (European Commission, 2020). The EU ETS was criticized as the low EUA price would not motivate companies enough to curb carbon emissions. Companies would rather buy cheap EUA allowances than invest funds in strategies to decrease their verified emissions.

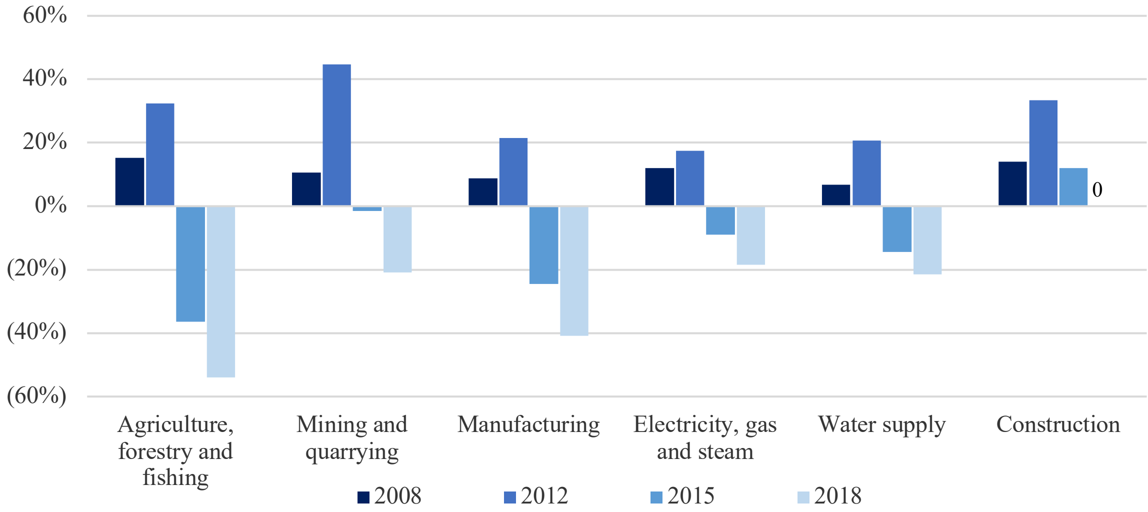
Figure 1: Weekly Closing Price EUA spot and MSCI Europe Index



From the start of Phase III, EUA prices consistently remained below €10/tCO2e due to the lack of mechanisms to address the surplus of allowances resulting from the aftermath of the economic crisis and high import of international credits (World Bank, 2019). The EU ETS was not able to effectively respond to unexpected economic conditions, like the financial crisis of 2008. New regulation imposed in Phase III includes the following key features: (i) auctioning will progressively replace free allocation and (ii) the introduction of a single, EU-wide cap on emissions instead of the previous system of national caps (European Commission, 2009). The EU emissions cap will linearly decrease with 1.74% every year (IETA, 2010). By 2020, these new measures should deliver an overall reduction of 21% of verified emissions compared to 2005. By introducing these new measures, EU lawmakers tried to address the surplus since 2014, however carbon prices only started to significantly increase after the post-2020 (Phase IV) reforms had been adopted in 2018. Especially the announcement of the Market Stability Reserve (MSR) led to this sudden increase. The MSR began operating in January 2019 and improves the system's resilience to major shocks by adjusting the supply of allowances to be auctioned. Due to the rising demand for emission allowances and the soon-to-be limitation of supply, the price of EUAs increase sharply. Figure 1 shows that the carbon spot price only tracks the MSCI Europe to some extent. The drop after April 2011 was caused by the backlash of the financial crisis in 2008 and the oversupply of allowances. However, after April 2013 the carbon spot price has moved relatively in the same direction until January 2018. The drop in March 2020, for both the carbon spot price and the MSCI Europe, can be explained by COVID-19 crisis. Both drops are identical, however the carbon spot price recovered stronger. As one of the goals of the MSR was to improve the system's resilience to major shocks, we may believe that the MSR has been effective in doing so.

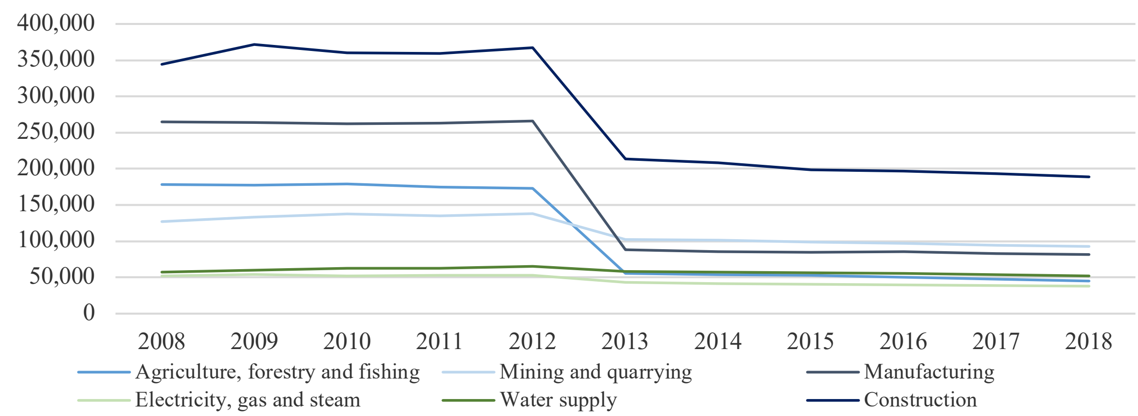
The trends in emissions and free allocation of allowances differ between sectors. Allowances are allocated either by free allocation, where installations receive allowances for free, or via auctioning. During Phases I (2005-2007) and II (2008-2012), most allowances were allocated for free, while during Phase III the majority of allowances will be provided via auctioning (European Commission, 2015). Since the start of Phase III, a benchmarking approach is used for the free allocation of allowances. Unlike grandfathering, benchmarking allocates allowances based on companies' production performance instead of their historical emissions. Under the benchmarking approach, highly efficient installations receive more free allowances relative to GHG-intensive installations. Thus, increasing the incentive for inefficient installations to take action to reduce emissions (European Commission, 2020). Figure 2 shows the excess allocation by sector. This shows that after the transition to Phase III in January 2013, the excess allocation in all sectors has dropped significantly to an extent where there is no more overallocation of allowances after 2018, on average. This means that, on average, all sectors will be net buyers of EUAs by the end of Phase III.

Figure 2: Excess allocation by sector



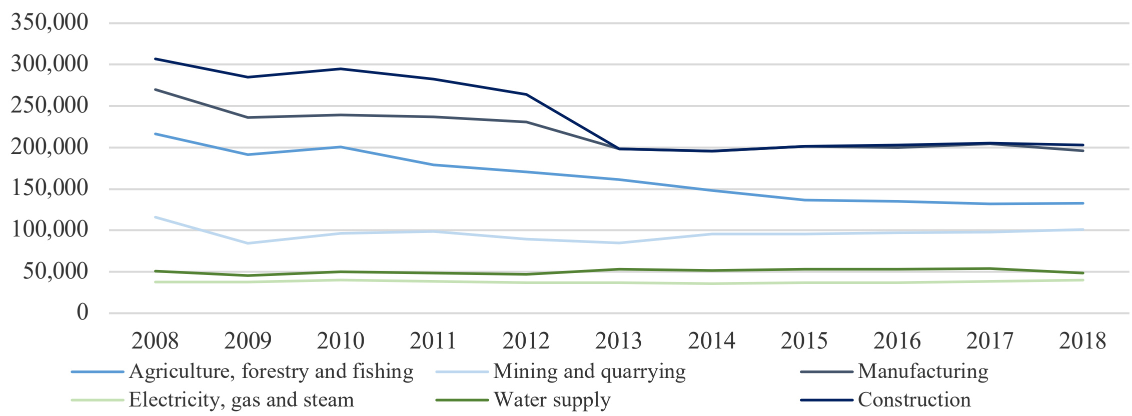
The graphs below add to Figure 2 by showing the yearly development of verified emissions, allocation of allowances and the excess allocation over the period 2008-2018. Figure 3 depicts the development of the allocation of allowances. The drop in 2013 is very much expected, as in Phase III auctioning will progressively replace free allocation. During Phases I (2005-2007) and Phase II (2008-2012), most allowances were allocated for free, while during Phase III the majority of allowances will be provided via auctioning (European Commission, 2015). The largest drops are experienced in the construction, manufacturing and agriculture sectors. This can be explained by the benchmarking approach, which allocates allowances based on companies' production performance. This suggests that, on average, the construction, manufacturing and agriculture sectors operate relatively GHG-intensive installations. By allocating less allowances for free, these sectors are forced to take action to cover their excess emissions.

Figure 3: Average allocation of allowances per company in each sector



The drop in free allocated allowances is steeper than the drop in verified emissions, as can be seen when comparing Figure 3 and Figure 4. However, it is evident that, on average, companies operating in the construction, manufacturing and agriculture sectors have been gradually reducing their verified emissions from the start of 2008. These sectors reported the highest verified emissions and therefore it is a success that these companies have been reducing their carbon emissions. However, verified emissions after 2013 have remained relatively constant until 2018. This is in line with the allocation of allowances decreasing with a small percentage each year. Nevertheless, this might suggest that in order to accelerate the reduction of verified emissions, the amount of free allocated allowances should be reduced at a faster pace.

Figure 4: Average verified emissions per company in each sector



However, based on the above sources of information it is impossible to conclude whether the EU ETS led to a reduction of verified emissions, or whether the observed emission pattern represents business as usual. Companies in this sample could have already planned to reduce their carbon emissions without the EU ETS regulating them or the economic environment could have had an impact. However, to assess whether the EU ETS induced additional reduction efforts, one can analyze the effectiveness of adjustments to EU ETS regulation on emission reductions over the course of Phase II to Phase III. An analysis based on firm level data is carried out in the following section.

4.2 Does the EU ETS accelerate emission reductions?

This section examines hypotheses 1 and 2, which are both based on the effectiveness of the EU ETS in accelerating emission reductions. Hypothesis 1 is formulated as "The EU ETS has accelerated carbon emission reductions in Phase III relative to Phase II." Table 4 presents the differential in mean growth in emission reductions for Phase III relative to Phase II, and thus simply compares both phases in general. Phase III will experience significant differences from Phase I and II, as it will (i) incorporate more industrial sectors and greenhouse gasses, (ii) auctioning will progressively replace free allocation and (iii) the introduction of a single, EU-wide cap on emissions instead of the previous system of national caps (European Commission, 2009).

Table 4: Differential in mean growth in emission reductions for Phase III relative to Phase II
Table 4 presents the results from the difference-in-difference regression for examining an acceleration in emissions reduction efforts by participating companies. The table presents the differential in mean growth in emission reductions for Phase III (2013-2018) relative to Phase II (2011-2012). The dependent variable is the log value of verified emissions for company i in year t. β_0 is the parameter of interest and captures the change of behavior in emissions by EU ETS regulated firms after the transition to Phase III on the 1st of January 2013. A two-sided test is performed on β_0, as emissions can both increase as decrease in any given year. Columns 2 and 3 present the results from the regression on the sub-samples of underallocated and overallocated companies, respectively. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses. Note: The Adjusted R-squared for Column 2 is much higher than for Columns 1 and 3. This is due to Novo Nordisk, an underallocated company, drastically reducing verified emissions in the period 2013-2018. This finding could be excluded as it may be considered an outlier. However, for this research we are examining emission reductions and if one company legitimately reduces their emissions by a substantial amount, we should include this finding in the dataset as this is the ultimate goal of the EU ETS. A robustness check will be performed in Table A.2 which excludes Novo Nordisk from the dataset.

Phase III (2013-2018) relative to Phase II (2011-2012)			
	(1) All companies	(2) Underallocated companies (AF<1)	(3) Overallocated companies (AF>1)
β_0 (cons)	0.5562	-1.3989**	-0.3408
	(0.4510)	(0.6434)	(0.6857)
Firm Performance	0.0137*	0.0192	-0.0001
	(0.0078)	(0.0134)	(0.0005)
Size	-0.0015	-0.0183	-0.0005
	(0.0042)	(0.0095)	(0.0044)
Economic Environment	0.0496**	0.1141**	0.0289
	(0.0242)	(0.0507)	(0.0265)
Country FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adj R-squared	0.0042	0.8079	0.0100
Sample (N)	821	349	472

Column 1 reports a significant positive relationship (coefficient 0.0137*) between firm performance and changes in emissions. This is a predictable interaction as a company's emissions are likely to decline if revenue decreases, due to lower output for example. Furthermore, Column 1 reports no significant relationship between size and changes in emissions. This is expected as in absolute terms larger companies will usually have higher emissions, however in relative terms there should be no difference. The economic environment has a significantly positive effect on the change in emissions. This is an expected result as in a favorable economic environment, companies will grow and increase output – as a result, emissions will also increase. The parameter of interest, β_0, captures the change of behaviour in emissions by the firm after the transition to Phase III on the 1st of January 2013. First, it is important how to interpret this variable. When $\beta_0 < 0$, then companies have increased their reduction efforts and when $\beta_0 > 0$ for companies that have not increased their reduction efforts. Column 1 shows that for the full sample, when controlling for firm performance, size, economic environment, country-fixed effects and industry-fixed effects, the differential in emission growth rates is 0.5562 higher for Phase III, suggesting that there was no acceleration in emission reduction efforts. However, based on a two-sided test, this finding is not statistically significant. Nonetheless, we may consider this finding to be economically significant as the coefficient is relatively high compared to the other coefficients in Column 1. To examine more thoroughly whether the transition to Phase III induced an acceleration in emissions reductions, Table A.1 presents the differential in mean growth in emissions reductions for every year in the period 2013-2018 (Phase III). The regression is run on the (A) full sample of companies, (B) underallocated companies and (C) overallocated companies. This model gives a more detailed analysis of the effectiveness of the EU ETS in reducing carbon emissions after the transition to Phase III. Again, the parameter of interest is β_0. For panel A, in 2013, β_0 is significantly positive and thus suggests that in 2013 companies did not increase their reduction efforts. However, except for 2017, all years between 2013 and 2018 show a negative differential in emissions growth rates. Nonetheless, these are not significant and therefore it cannot be concluded that the increased emission reduction efforts were a result of the transition to Phase III. Only in 2018, an acceleration in emission reductions is found, and this is significant at the 10% level. In general, based on Table 4, there has been no acceleration in carbon emission reductions in Phase III. Nonetheless, Table A.1 finds a significant emission reduction in 2018, which may be an indication that the new regulation introduced in 2013 for Phase III needed some time to finally induce a change in emission behaviour. However, the emission reduction in 2018 is still not enough to conclude that Phase III induced significant emission reductions relative to Phase II as indicated by Table 4. Therefore, we may reject Hypothesis 1.

Hypothesis 2 is formulated as "Underallocated companies accelerated emission reductions by more than overallocated companies". Again, the parameter of interest is β_0. When looking at the difference between underallocated and overallocated companies in Columns 2 and 3 in Table 4, there is only a significant acceleration in emission reductions for underallocated companies – at the 5% level. This result is expected as underallocated companies have a higher incentive to reduce carbon emissions to prevent making extra costs from buying additional allowances. Besides, there is no significant result found for overallocated companies increasing emission reduction efforts. This is also an expected result, as the incentive for overallocated companies is much lower. It is also interesting to examine the difference between underallocated and overallocated companies, as one would expect that underallocated companies would have a higher incentive to reduce emissions. Panel B of Table A.1 shows that underallocated companies accelerated their emissions reductions in 2015, 2016 and 2018. However, for 2015 and 2016 these findings are not significant and can therefore also be explained by company output changes or the economic environment. In 2018, underallocated companies significantly accelerated their emission reductions. As the model controls for company output changes, size and the economic environment, it can be concluded that the emission reductions in 2018 were also due to the shift from Phase II to Phase III. Again, this may be an indication that the new regulation introduced in 2013 for Phase III needed some time to finally induce a change in emission behaviour. Overallocated companies receive more free allocated allowances than their verified emissions. Therefore, their incentive to reduce emissions is much lower as they do not incur any additional costs from buying allowances on the market. The results from panel C in Table A.1 support this expectation. Overallocated companies have reduced their emissions in the period between 2014 and 2018, however these companies did not accelerate their emissions reduction efforts relative to Phase II. This indicates that overallocated companies have a lower incentive to reduce their emissions and thus did not increase their emission reduction efforts in the years after Phase II. Based on the above findings, Hypothesis 2 may be accepted as we may conclude that the transition to Phase III lead to an acceleration in emission reductions for underallocated companies, while overallocated companies did not increase emission reduction efforts. For the EU ETS to stimulate emission reduction efforts, the scheme should limit the amount of freely allocated allowances even further. Phase IV will address this issue as the overall number of emission allowances will decline at an annual rate of 2.2% in Phase IV, compared to 1.74% in Phase III. This will tighten the market for allowances. The system of free allocation will be prolonged until 2030 and has been revised to only focus on sectors at the highest risk of relocating their production outside of the EU. These sectors will receive 100% of their allocation for free. For other, less exposed sectors free allocation will be phased out after 2026 to 0 at the end of Phase IV. This will probably further increase the acceleration of emission reductions, as more companies become underallocated. The lack of flexibility in Phases I, II and III is one of the main shortcomings, which led to a structural allowance surplus. This allowance surplus is still present today, however measures as the Market Stability Reserve (MSR) have been put into place to reduce this surplus. As a result of strengthening the MSR in Phase IV, by doubling its allowance intake rate to 24% for the first five years of Phase IV, the market will be tightened even more. This will speed up the restoration of the supply-demand balance by reducing the existing surplus twice as fast. All these measures should make the EU ETS more effective in reducing carbon emissions.

There is also a large difference in free allocation between sectors. Equation 1 is also performed on every sector. Figure 2 (Chapter 4.1) shows that the sectors Agriculture, Forestry & Fishing and Manufacturing were underallocated by over 40% (AF=0.6), while the Construction sector fully covered its verified emissions by the free allocated allowances (AF=1). This would suggest that companies in the Construction sector had less incentive to increase emission reductions. The parameter of interest in Table 5, β_0, shows that after controlling for firm performance, size, economic environment, country-fixed effects and sector-fixed effects, companies in all six sectors, on average over the period 2013-2018, did not increase their emission reduction efforts after the transition to Phase III. A reason to explain this may be that these companies had high levels of verified emissions during Phase I and II. After the introduction of the EU ETS in 2005 and stricter regulation after 2008, companies had to drastically reduce their emissions, so that their verified emissions did not excessively exceed the allocated allowances. At the beginning of Phase III, these companies might had already reached the right balance between free allocated allowances and verified emissions. During Phase III, the overall number of emission allowances declines at an annual rate of 1.74%. As a result, companies that have reached the desired balance may only reduce their verified emissions by 1.74%. In Phase IV, the annual rate will increase to 2.2% and in 2026 many companies will not receive any allowances for free anymore. This should increase reduction efforts for many companies as they will have to choose between simply reducing their carbon emissions or buying more allowances to compensate their verified emissions, which could have an impact on its competitiveness due to higher costs. As Table 5 does not show results per industry for every single year in the sample period, Figures A.1-A.6 (Appendix) give an additional visualisation of the behavioural change in emission reductions by industry for the period 2013-2018.

Table 5: Differential in mean growth in emission reductions by industry classification for Phase III relative to Phase II

Table 5 presents the results from the difference-in-difference regression for examining an acceleration in emissions reduction efforts for participating companies per sector. The table presents the differential in mean growth in emission reductions for Phase III (2013-2018) relative to Phase II (2011-2012). The dependent variable is the log value of verified emissions for company *i* in year *t*. β_0 is the parameter of interest and captures the change of behavior in emissions by EU ETS regulated firms after the transition to Phase III on the 1st of January 2013. A two-sided test is performed on β_0, as emissions can both increase as decrease in any given year. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses.

	By industry					
	(1) Agriculture, forestry and fishing	(2) Mining and quarrying	(3) Manufacturing	(4) Electricity, gas and steam	(5) Water supply	(6) Construction
β_0 (cons)	2.8043***	0.0716	0.5694	0.4819	0.5960	3.8479
	(0.8515)	(0.2580)	(0.4312)	(0.2874)	(0.6707)	(.)
Firm Performance	0.0254	0.1818	0.0103	0.0090	-0.0502	-1.7605
	(0.0229)	(0.1203)	(0.0090)	(0.0365)	(0.0483)	(.)
Size	0.0043	0.0090	-0.0006	0.0143	0.1123**	-0.1479
	(0.0350)	(0.0208)	(0.0044)	(0.0410)	(0.0488)	(.)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0757	0.0266	0.0064	0.0279	0.0517	1.0000
Sample (N)	94	24	587	24	78	8

4.3 Does the EU ETS affect company performance?

As described in Section 3.2, this study measures a company's performance by ROE, profit margin and the number of employees (Hypothesis 3). As differences in performance are expected between under- and overallocated companies, the analysis is also performed on these sub-samples (Hypothesis 4). Underallocated companies are possibly affected to a larger extent than overallocated companies, as they must buy additional allowances, while overallocated companies can sell their surplus on the market. Tables 6 (ROE), 7 (Employees) and 8 (Profit margin) show the results for testing Hypothesis 3: "The

EU ETS negatively affects financial performance of the companies under regulation." Tables 9 (ROE), 10 (Employees) and 11 (Profit margin) are used to test Hypothesis 4: "Underallocated companies underperform compared to overallocated companies". The parameter of interest in these tables is *EU ETS,* which captures the change in the growth rate of financial performance – measured by ROE, profit margin and number of employees – for EU ETS regulated firms after the transition to Phase III on the 1st of January 2013 relative to the control group.

Thus, to either reject or accept Hypothesis 3 we must look at Tables 6, 7 and 8. Table 6 reports a significant positive relationship between firm performance and the ROE growth rate, which is an expected result. Larger companies (size is measured by the number of employees in 2012) seemed to realize a higher growth rate in ROE than smaller companies. A possible explanation for the relatively higher ROE growth rates of large companies is that they own land, buildings, factories, human capital, expertise and other assets that are on their "books" at a fraction of the price that new, smaller competitors would have to pay to obtain similar assets. The economic environment does not have a significant relationship with the ROE and the direction of the signs is not consistent per year. Table 6 shows that companies under EU ETS regulation experienced a significantly higher ROE in 2014, 2016, 2017 and 2018 relative to the control group. Table 9 shows that this due to overallocated companies significantly growing their ROE, while underallocated companies experience no significant effect of being under EU ETS regulation.

Table 6: Change in ROE growth rate by year for Phase III relative to Phase II

Table 6 presents the results from the difference-in-difference regression for examining the effect on financial performance of participating companies for every year in the sample period measured by ROE. The table presents the change in growth rate of the ROE for every year in the period 2013-2018 relative to the growth rate from 2011/2012. Thus, the dependent variable is the change in the *ROE* growth rate between $year_{t/t-1}$ and $year_{2012/2011}$. A two-sided test is performed on *EU ETS*, as ROE growth rate can increase and decrease. The variable *EU ETS* captures the change in *ROE* growth rate for EU ETS regulated firms after the transition to Phase III on the 1st of January 2013 relative to the control group. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses.

	ROE					
	All companies					
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
EU ETS	-0.0095	0.0365*	0.0340	0.0492*	0.0757***	0.0510**
	(0.0240)	(0.0212)	(0.0259)	(0.0295)	(0.0245)	(0.0249)
Firm Performance	0.2223***	0.2351***	0.2146***	0.1997***	0.2272***	0.1687***
	(0.0850)	(0.0488)	(0.0412)	(0.0341)	(0.0371)	(0.0243)
Size	0.0041	0.0160*	0.0100	0.0163*	0.0219**	0.0183**
	(0.0086)	(0.0083)	(0.0085)	(0.0085)	(0.0094)	(0.0082)
Economic Environment	1.1318	-2.9987**	-0.0760	2.1076	-0.4261	-0.4646
	(1.1326)	(1.5223)	(2.8403)	(3.4503)	(1.4306)	(0.7463)
Cons	-0.0593	-0.1867**	-0.1724*	-0.1608*	-0.1332	-0.1358
	(0.1269)	(0.0874)	(0.0918)	(0.0943)	(0.1745)	(0.0869)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0040	0.0300	0.0248	0.0282	0.0400	0.0462
Sample (N)	1984	1984	1984	1984	1984	1984

Table 7 reports a significant positive relationship between firm performance and the growth in number of employees, which is an expected result as well performing companies may grow their profit margin. It also reports a significantly negative relationship between size in 2012 and the number of employees in future years, which means that larger companies have reduced their workforce since 2012 as a result of becoming more efficient and new developing new technologies. As the companies in the dataset mostly operate in labor intensive sectors, new technologies to partly replace the manual work may have an impact on the number of employees. Again, there is no significant relationship between the economic environment and the growth in number of employees. This may be explained by the possibility that companies usually only make large cuts in their workforce when the economy is in deep recession and not when there is a small downturn. Table 7 does not report any significant results on the growth in number of employees for any year. Being in the treatment group resulted in more employees relative to the control group. However, as these results are not significant it cannot be concluded that this was a result of being under EU ETS regulation.

Table 7: Change in growth rate of number of employees by year for Phase III relative to Phase II
Table 7 presents the results from the difference-in-difference regression for examining the effect on financial performance of participating companies for every year in the sample period measured by the number of employees. The table presents the change in growth rate of the number of employees for every year in the period 2013-2018 relative to the growth rate from 2011/2012. Thus, the dependent variable is the change in *number of employees* growth rate between $year_{t/t-1}$ and $year_{2012/2011}$. The variable *EU ETS* captures the change in growth rate of employees for EU ETS regulated firms after the transition to Phase III relative to the control group. A two-sided test is performed on *EU ETS*. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses.

	Employees					
	All companies					
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
EU ETS	0.0191	0.0280	0.0186	0.0368	0.0320	0.0220
	(0.0168)	(0.0212)	(0.0232)	(0.0232)	(0.0237)	(0.0253)
Firm Performance	0.2729***	0.3135***	0.3648***	0.3758***	0.4259***	0.4722***
	(0.0448)	(0.0342)	(0.0483)	(0.0391)	(0.0357)	(0.0295)
Size	-0.0149**	-0.0239**	-0.0249***	-0.0336***	-0.0374***	-0.0429***
	(0.0075)	(0.0095)	(0.0096)	(0.0101)	(0.0103)	(0.0107)
Economic Environment	-0.3479	1.4604	-0.4333	-0.7341	0.4325	-2.2542
	(0.5975)	(1.1929)	(0.5165)	(2.2832)	(0.9841)	(2.5591)
Cons	0.1435*	0.2093*	0.3753***	0.4277***	0.4069**	0.4469***
	(0.0834)	(0.1101)	(0.1259)	(0.1283)	(0.1590)	(0.1268)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0620	0.0734	0.1155	0.1454	0.1806	0.2102
Sample (N)	1984	1983	1984	1984	1983	1984

Table 8 reports a significant positive relationship between firm performance and the growth in profit margin, which is an expected result as well performing companies may grow their profit margin. It also reports a negative relationship between size and profit margin, which means that larger companies realize lower growth in profit margin. However, this finding is only significant in 2015 and 2017. This finding may be explained by the possibility that large, developed companies have less room to grow the profit margin opposed to smaller companies. Smaller companies may have more room to cut costs and have more room to increase revenues. Table 8 shows that companies subject to EU ETS regulation realized a significant higher growth in profit margin than the control group for all years between 2014 and 2018. This is counterintuitive as one would expect companies subject to EU ETS regulation to rather experience negative effects on profit margin. However, as explained by Table 11, this is a result of some companies benefitting from the overallocation of allowances. Nevertheless, we may conclude that the EU ETS had no negative effect on the financial performance of regulated companies and thus Hypothesis 3 may be rejected – it actually had a positive effect on financial performance.

Table 8: Change in profit margin growth rate by year for Phase III relative to Phase II

Table 8 presents the results from the difference-in-difference regression for examining the effect on financial performance of participating companies for every year in the sample period measured by profit margin. The table presents the change in growth rate of the profit margin for every year in the period 2013-2018 relative to the growth rate from 2011/2012. Thus, the dependent variable is the change in *profit margin* growth rate between $year_{t/t-1}$ and $year_{2012/2011}$. The variable *EU ETS* captures the change in *profit margin* growth rate for EU ETS regulated firms after the transition to Phase III on the 1st of January 2013 relative to the control group. A two-sided test is performed on *EU ETS*. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses.

	Profit Margin					
	All companies					
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
EU ETS	0.0012	0.0134**	0.0219***	0.0354***	0.0380***	0.0362***
	(0.0047)	(0.0053)	(0.0056)	(0.0063)	(0.0060)	(0.0065)
Firm Performance	0.1187***	0.0983***	0.0891***	0.0857***	0.0826***	0.0777***
	(0.0156)	(0.0143)	(0.0133)	(0.0135)	(0.0102)	(0.0104)
Size	-0.0000	-0.0018	-0.0039*	-0.0028	-0.0042*	-0.0032
	(0.0018)	(0.0018)	(0.0020)	(0.0024)	(0.0022)	(0.0021)
Economic Environment	0.1938	-0.2629	0.6008**	2.1143**	-0.8238**	0.3139
	(0.2766)	(0.4034)	(0.2758)	(1.0211)	(0.4082)	(0.2781)
Cons	-0.0319	-0.0099	-0.0802***	0.0161	0.1632***	0.1192***
	(0.0229)	(0.0209)	(0.0258)	(0.0296)	(0.0475)	(0.0257)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0581	0.0627	0.0880	0.0728	0.0959	0.0970
Sample (N)	1984	1984	1984	1984	1984	1984

As it is expected that underallocated companies will experience a larger negative effect on financial performance than overallocated companies, we must test Hypothesis 4: "Underallocated companies underperform compared to overallocated companies." Therefore, one must look at the sub-samples for under- and overallocated companies for the different measures of financial performance. All relationships between control variables *Firm Performance, Size* and *Economic Environment* and the outcome variables *ROE, Number of Employees* and *Profit Margin*, are similar to the relationships explained in Tables 6, 7 and 8 and will therefore not be explained again in this section. For the ROE (Table 9), as the coefficients are negative for the full period, underallocated companies realized a lower growth in ROE than companies in the control group. However, as this result is not significant it cannot be concluded that this is a direct result from being under EU ETS regulation. Overallocated companies realize a higher growth rate than the control group for the full period, and these results are significant in 2014, 2015, 2017 and 2018. For these years, we can therefore conclude that overallocated companies realized a higher growth in ROE as a result of EU ETS regulation. These overallocated companies had a surplus of allowances, which could have been sold on the carbon market, resulting in improved financial performance.

Table 9: Change in ROE growth rate by year for Phase III relative to Phase II (Under- and overallocated companies)

Table 9 expands on Table 6 by examining sub-samples of under- and overallocated companies. Therefore, it also presents the results from the difference-in-difference regression for examining the effect on financial performance (measured by ROE) of under- and overallocated companies for every year in the sample period. The table presents the change in growth rate of the *ROE* for every year in the period 2013-2018 relative to the growth rate from 2011/2012. Thus, the dependent variable is the change in *ROE* growth rate between $year_{t/t-1}$ and $year_{2012/2011}$. A two-sided test is performed on *EU ETS*, as ROE growth rate can increase and decrease. The variable *EU ETS* captures the change in *ROE* growth rate for EU ETS regulated firms after the transition to Phase III on the 1st of January 2013 relative to the control group. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses.

Underallocated companies (AF<1)						
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
EU ETS	-0.0102	0.0126	-0.0251	0.0365	0.0577	0.0372
	(0.0297)	(0.0358)	(0.0435)	(0.0400)	(0.0387)	(0.0344)
Firm Performance	0.2010	0.2542**	0.1890***	0.1926***	0.2543***	0.1603***
	(0.1478)	(0.1063)	(0.0716)	(0.0499)	(0.0710)	(0.0393)
Size	0.0173*	0.0109	0.0076	0.0050	0.0065	0.0030
	(0.0095)	(0.0088)	(0.0107)	(0.0105)	(0.0118)	(0.0085)
Economic Environment	2.9973	-5.8439	-3.1432*	-2.6991	-2.6436	-1.2720
	(2.7841)	(3.8719)	(1.7163)	(4.8270)	(3.5428)	(0.8792)
Cons	-0.1351	0.1930	0.1347	0.0233	0.2318	0.0721
	(0.1144)	(0.1215)	(0.1001)	(0.0941)	(0.3500)	(0.0831)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0022	0.0166	0.0148	0.0252	0.0470	0.0198
Sample (N)	832	832	832	832	832	832
Overallocated companies (AF>1)						
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
EU ETS	-0.0115	0.0553**	0.0804**	0.0651	0.0999***	0.0757**
	(0.0357)	(0.0262)	(0.0327)	(0.0410)	(0.0308)	(0.0361)
Firm Performance	0.2339**	0.2236***	0.2307***	0.2041***	0.1932***	0.1758***
	(0.1059)	(0.0449)	(0.0474)	(0.0461)	(0.0383)	(0.0324)
Size	-0.0046	0.0191	0.0100	0.0204	0.0240*	0.0231*
	(0.0133)	(0.0131)	(0.0131)	(0.0128)	(0.0138)	(0.0132)
Economic Environment	0.5251	-2.4538	0.9031	2.5349	0.4973	-0.5293
	(1.3269)	(1.5013)	(3.9422)	(4.1155)	(1.7888)	(1.0317)
Cons	0.0424	-0.2174*	-0.1805	-0.2092	-0.2760	-0.2016
	(0.1831)	(0.1316)	(0.1386)	(0.1388)	(0.2289)	(0.1334)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0012	0.0326	0.0332	0.0315	0.0466	0.0633
Sample (N)	1152	1152	1152	1152	1152	1152

Table 10 suggests that underallocated companies have increased the number of employees in every year. However, these findings are only significant for 2017 and 2018. An explanation may be that underallocated companies are often the companies with higher than average verified emissions and are thus still growing their business. As a result, these companies also need to increase the number of employees. No significant relationship has been found for overallocated companies.

Table 10: Change in growth rate of number of employees by year for Phase III relative to Phase II (Under- and overallocated companies)

Table 10 expands on Table 7 by examining sub-samples of under- and overallocated companies. Therefore, it also presents the results from the difference-in-difference regression for examining the effect on financial performance (measured by number of employees) of under- and overallocated companies for every year in the sample period. The table presents the change in growth rate of the *Number of Employees* for every year in the period 2013-2018 relative to the growth rate from 2011/2012. Thus, the dependent variable is the change in *Number of Employees* growth rate between $year_{t/t-1}$ and $year_{2012/2011}$. A two-sided test is performed on *EU ETS*, as the growth rate of *Number of Employees* can increase and decrease. The variable *EU ETS* captures the change in *Number of Employees* growth rate for EU ETS regulated firms after the transition to Phase III on the 1st of January 2013 relative to the control group. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses.

			Underallocated companies (AF<1)			
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
EU ETS	0.0550	0.0575	0.0534	0.0680	0.0894*	0.0933**
	(0.0339)	(0.0423)	(0.0457)	(0.0460)	(0.0455)	(0.0468)
Firm Performance	0.3228***	0.3247***	0.3216***	0.3106***	0.3880***	0.4490***
	(0.0724)	(0.0639)	(0.0739)	(0.0486)	(0.0457)	(0.0420)
Size	-0.0280*	-0.0409**	-0.0353*	-0.0421**	-0.0522***	-0.0674***
	(0.0163)	(0.0194)	(0.0192)	(0.0193)	(0.0195)	(0.0203)
Economic Environment	-2.2545**	3.6075*	0.8338	4.5220	-1.8086	-7.5418
	(1.0168)	(2.1194)	(0.9284)	(3.6634)	(1.5780)	(8.1754)
Cons	0.2043**	0.1200	0.1331	0.1703	0.4256**	0.2878**
	(0.0915)	(0.0938)	(0.0970)	(0.1136)	(0.1950)	(0.1219)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0616	0.0839	0.0983	0.1170	0.1699	0.2091
Sample (N)	832	831	832	832	831	832
			Overallocated companies (AF>1)			
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
EU ETS	0.0016	0.0086	-0.0048	0.0206	-0.0060	-0.0240
	(0.0164)	(0.0219)	(0.0257)	(0.0244)	(0.0261)	(0.0286)
Firm Performance	0.2425***	0.3057***	0.4003***	0.4299***	0.4579***	0.5054***
	(0.0546)	(0.0383)	(0.0619)	(0.0563)	(0.0517)	(0.0395)
Size	-0.0064	-0.0125	-0.0178*	-0.0275**	-0.0269**	-0.0240**
	(0.0059)	(0.0094)	(0.0102)	(0.0113)	(0.0116)	(0.0117)
Economic Environment	0.2302	0.3098	-0.9261	-2.2424	1.0784	0.0608
	(0.8123)	(1.5918)	(0.7123)	(3.0184)	(1.2654)	(0.7667)
Cons	0.0341	0.1221	0.3378**	0.4198***	0.2727	0.3033**
	(0.0697)	(0.1261)	(0.1415)	(0.1514)	(0.1800)	(0.1465)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0670	0.0670	0.1233	0.1665	0.1900	0.2337
Sample (N)	1152	1152	1152	1152	1152	1152

Finally, the results for the changes in profit margin (Table 11) yield some interesting conclusions. For underallocated companies, the growth in profit margin was significantly lower in 2013 and 2014 – at the 10% level. This result is expected as underallocated companies incur higher costs due to buying additional allowances to cover their excess of verified emissions. In 2017, underallocated companies appeared to realize significantly higher growth in profit margin than the control group. The growth in profit margin for underallocated companies is counterintuitive as it was expected that underallocated companies would incur higher costs as a result of buying additional allowances, and hence a decrease in profit margin. However, as the EU ETS targeted to reduce the negative effects on competitiveness for the participating companies from the start of Phase II, this may well be a sign that the European Commission succeeded.

Table 11: Change in profit margin growth rate by year for Phase III relative to Phase II (Under- and overallocated companies)

Table 11 expands on Table 8 by examining sub-samples of under- and overallocated companies. Therefore, it also presents the results from the difference-in-difference regression for examining the effect on financial performance (measured by number of employees) of under- and overallocated companies for every year in the sample period. The table presents the change in growth rate of the *Profit Margin* for every year in the period 2013-2018 relative to the growth rate from 2011/2012. Thus, the dependent variable is the change in *Profit Margin* growth rate between $year_{t/t-1}$ and $year_{2012/2011}$. A two-sided test is performed on *EU ETS*, as the growth rate of *Profit Margin* can increase and decrease. The variable *EU ETS* captures the change in *Profit Margin* growth rate for EU ETS regulated firms after the transition to Phase III on the 1st of January 2013 relative to the control group. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses.

			Underallocated companies (AF<1)			
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
EU ETS	-0.0127*	-0.0128*	-0.0017	0.0160	0.0193**	0.0104
	(0.0067)	(0.0075)	(0.0078)	(0.0106)	(0.0093)	(0.0102)
Firm Performance	0.1001***	0.0931***	0.0707***	0.0831***	0.0694***	0.0655***
	(0.0232)	(0.0203)	(0.0207)	(0.0218)	(0.0143)	(0.0157)
Size	0.0009	0.0009	-0.0057*	-0.0042	-0.0079**	-0.0044
	(0.0033)	(0.0030)	(0.0033)	(0.0046)	(0.0037)	(0.0032)
Economic Environment	-0.2888	-0.4176	0.1278	2.5135*	-1.4158**	0.4952
	(0.4524)	(0.6486)	(0.3645)	(1.4273)	(0.6889)	(0.4694)
Cons	-0.0026	0.0216	0.0470**	0.0558	0.1727**	0.0285
	(0.0263)	(0.0221)	(0.0238)	(0.0339)	(0.0683)	(0.0281)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0482	0.0588	0.0490	0.0387	0.0543	0.0535
Sample (N)	832	832	832	832	832	832
			Overallocated companies (AF>1)			
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
EU ETS	0.0104	0.0308***	0.0365***	0.0467***	0.0491***	0.0528***
	(0.0064)	(0.0071)	(0.0079)	(0.0080)	(0.0078)	(0.0084)
Firm Performance	0.1295***	0.1005***	0.1000***	0.0843***	0.0871***	0.0836***
	(0.0210)	(0.0195)	(0.0163)	(0.0168)	(0.0136)	(0.0139)
Size	-0.0014	-0.0039	-0.0037	-0.0028	-0.0028	-0.0031
	(0.0021)	(0.0024)	(0.0028)	(0.0026)	(0.0027)	(0.0028)
Economic Environment	0.2336	-0.1183	0.7951**	1.9759	-0.5890	0.2430
	(0.3557)	(0.5219)	(0.3714)	(1.2983)	(0.4917)	(0.3481)
Cons	-0.0269	0.0040	-0.0887***	0.0051	0.1229**	0.1107***
	(0.0270)	(0.0266)	(0.0339)	(0.0346)	(0.0569)	(0.0338)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.0758	0.0820	0.1282	0.1036	0.1388	0.1321
Sample (N)	1152	1152	1152	1152	1152	1152

In addition, underallocated companies may have increased efficiency in their business operations as a result of being under EU ETS regulation. In order to comply to EU ETS regulation, underallocated companies had to decide whether to reduce yearly carbon emissions in general or to buy additional allowances without having to curb emissions. The companies that decided to reduce yearly carbon emissions may have found a way to become more efficient in their production process, supply chain and business in general. For example, reducing employee travel and using renewable energy sources for installations and offices will reduce carbon emissions, and as a result allows the company to cut costs. This could also have increased the profit margins of underallocated companies. For overallocated companies, the growth in profit margin was significantly higher for all years in the period 2014-2018 – at the 1% level. This suggests that overallocated companies benefited from their participation in the EU ETS and increased their profit margins in Phase III relative to the control group, which can be explained by the fact that overallocated companies are allowed to sell their surplus of allowances to other companies – thus, generating extra income. Finally, Table 11 shows that underallocated companies underperform relative to overallocated companies, although, based on the profit margin, underallocated companies also seemed to benefit from their participation in the EU ETS in 2017. Nevertheless, it becomes clear that underallocated companies have a significantly lower growth in profit margin than overallocated companies. Also, for the ROE, in 2014, 2015, 2017 and 2018, a significant higher growth rate in ROE is found for overallocated companies. Therefore, Hypothesis 4 may be accepted as underallocated firms underperform relative to overallocated companies.

The overall conclusion is that participating companies did not experience any significant loss of competitiveness. Actually, overallocated companies seemed to benefit from their participation in the EU ETS by increasing their profit margins and ROE. The results show that overallocated companies outperform underallocated companies. The reason why some companies are overallocated free allowances is due to carbon leakage. Producers that face competition from countries not imposing a price on GHG emissions are at a competitive disadvantage and risk losing market share. This can lead production to move to countries without or with lower CO2 costs. As a result, this may increase overall global emissions, which is the exact opposite of what the EU ETS is trying to accomplish. To tackle carbon leakage in Phase IV, the system of free allocation will be extended until 2030 and has been revised to only focus on sectors at the highest risk of relocating their production outside of the EU. These sectors will receive 100% of their allocation for free (European Commission, 2020). However, the European Commission should be aware that when a company's freely allocated allowances exceed its verified emissions, it has a surplus of allowances. This surplus can be sold to other companies on the carbon market and thus benefits overallocated companies. It is difficult to say whether this is a favourable situation. When companies get allocated 100% of their allocation for free, this means that a company can only be overallocated when it reduces it verified emissions. This is favourable because it means that overallocated companies are actually increasing their emission reduction efforts and thus reducing its carbon footprint. On the other side, it creates a competitive advantage for overallocated companies over its competitors that are not under regulation, as these companies can generate additional income by selling their surplus of allowances. Just as the European Commissions should not create a competitive disadvantage for participating companies, it should also not create a competitive advantage for these companies. However, the European Commission wants to succeed in its goal to reduce carbon emissions. A solution to this problem could be to introduce new regulation in which overallocated companies are not allowed to sell their surplus of allowances on the carbon market.

4.4 Robustness Checks

Table 4 presents the results from the difference-in-difference regression for examining an acceleration in emissions reduction efforts by participating companies. The table presents the differential in mean growth in emission reductions for Phase III (2013-2018) relative to Phase II (2011-2012). Many, most often underallocated, companies have significantly reduced their yearly verified emissions over the course of Phase III. One of these companies, Novo Nordisk, has significantly reduced its emissions: in 2013 its verified emissions were 1.1x allocated allowances, while in 2018 verified emissions were only 0.001x allocated allowances. In 2015, Novo Nordisk set a target for all production sites to use electricity from renewable sources by 2020. The company has signed up to the RE100 initiative, a coalition of companies, committed to 100% renewable electricity led by The Climate Group in partnership with CDP, a not-for-profit organisition that runs the global disclosure system for environmental impacts. Over the course of Phase III, Novo Nordisk went from a underallocated company to a heavily overallocated company, which is fully supported by their commitment to become carbon neutral by 2030. As this study examines the effect of EU ETS regulation on emission reductions, it would be wrong to simply eliminate this outlier since the case of Novo Nordisk is exactly the result that the EU ETS tries to accomplish. However, as a robustness check Novo Nordisk is eliminated from the sample to validate the results from Table 4. Table A.2 presents the results from the difference-in-difference regression for examining an acceleration in emissions reduction efforts by participating companies, excluding Novo Nordisk. The results appear to be robust as the coefficients do not change by much and stay significant. The Adj. R-squared of Column 2 drops to 0.0814 and thus has less explanatory power.

Unfortunately, for this study it is not possible to check the internal validity of the results by repeating the difference-in-difference on pre-event years – prior to 2011. In European Union Transaction Log (EUTL) there is no emissions data available for the years prior to 2008, so it is not possible to examine the change from Phase I to Phase II. Also, many others, like Abrell *et al.* (2011) and Anger and Oberndorfer (2008), have already studied the effectiveness of the EU ETS in reducing carbon emissions, as well as the impact on financial performance, in Phases I and II. However, financial performance in this study is measured by three different by three different outcome variables, y: ROE, number of employees and profit margin. This serves as a type of robustness check as the model examines the effect on different measures of financial performance. To validate the robustness of the control group, the matching process between the treatment group and the control group was randomized. Every company in the treatment group is matched one-on-one to a company in the control group based on a Propensity Score Matching in STATA. However, sometimes the matching is dependent on how the data is sorted and can lead to inconsistent matching. Therefore, the data is randomized in such a way that the data is always randomized in the same way. By randomly randomizing the data, one can assure that the matching process between the treatment and the control group is independent of how the data is sorted. Table 3 (Section 3.3) presents the baseline descriptives between the treatment and the control group. Since the difference (Column 4) is not significant, the parallel trend assumption holds, which assumes a parallel trend between the control group and the treatment group in the pre-treatment period, thus allowing a causal effect to be inferred. Conforming to the parallel trend assumption suggests that the matching procedure was conducted properly.

Conclusion

This paper researches the effectiveness of the EU ETS on reducing carbon emissions in Europe and its effect on the financial performance of participating companies. A sample of 994 European companies was used to study the change in emission behavior after the transition to Phase III on the 1st of January 2013. This paper builds upon the scarce empirical literature on the effectiveness of the EU ETS in Phase III and its effect on the financial performance of the companies under regulation. As climate change is one of the most important global issues, it is very important that schemes as the EU ETS are put into place. This paper assesses the largest Emission Trading System – the EU ETS – in the world. The performance and effectiveness of the EU ETS is not only really important for reducing carbon emissions in Europe, but also around the world as it is considered as precursor for many currently operating ETSs around the world (China, California, Australia, Canada, etc.).

The hypotheses discussed below serve as a foundation to answer the research question: *"Is the EU Emissions Trading System successful in reducing carbon emissions and what is the impact at a firm-level?"* The analysis on the effectiveness of the EU ETS in reducing carbon emissions presented the following findings. Hypothesis 1: "The EU ETS has accelerated carbon emission reductions in Phase III relative to Phase II" is rejected as the analysis finds no significant results for an acceleration in emission reductions. However, we may accept Hypothesis 2: "Underallocated companies accelerated emission reductions by more than overallocated companies" for the following reasons. The analysis suggests that the EU ETS induced an acceleration in emission reductions in Phase III relative to Phase II for underallocated companies. This result is expected as underallocated companies have a higher incentive to reduce carbon emissions to prevent making extra costs from buying additional allowances. Overallocated companies did not increase their emission reduction efforts. This is also an expected result as the incentive for overallocated companies is much lower. Therefore, we can conclude that the transition to Phase III only lead to an acceleration in emission reductions for underallocated companies. After studying the effects of the EU ETS at firm-level, Hypothesis 3: "The EU ETS negatively affects financial performance of the companies under regulation" may be rejected. In general, participating companies did not experience any negative effects on ROE and their number of employees. However, participating companies, on average, realized a higher profit margin, which was mostly caused by a significantly higher profit margin for overallocated companies. Based on all three measures for financial performance, the conclusion is that participating companies did not experience a significant loss of competitiveness. As overallocated companies seemed to benefit financially from their participation in the EU ETS relative to underallocated companies, Hypothesis 4: "Underallocated companies underperform compared to overallocated companies" may be accepted. The EU ETS seemingly creates a competitive advantage for overallocated companies over its underallocated and unregulated competitors, as overallocated companies can generate additional income by selling its surplus of allowances. Just as the European Commissions does not want to create a competitive disadvantage for participating companies, it should also not create a competitive advantage for these companies. However, the European Commission does want to succeed in its goal to reduce carbon emissions. Considering the above findings, we may conclude that the EU ETS led to a reduction of carbon emissions in Europe. However, as new regulation was imposed for Phase III, one would expect that the new regulation would induce an acceleration in emission reductions in Phase III relative to Phase II. The results clearly show that only underallocated companies accelerated emission reductions over the course of Phase III. Overallocated companies did not show any increased efforts to reduce emissions. As a result, on average, regulated companies in Phase III did not accelerate emission reductions. Finally, the results above allow for answering the research question. We may argue that Phase III regulation did not have the desired effect. Although, the EU ETS did induce carbon emission reductions, it did not, on average, accelerate the reduction efforts of participating companies in Phase III relative to Phase II. Therefore, we may conclude that the EU ETS was only partly successful in reducing carbon emissions. The European Commission should learn from this and further limit freely allocated allowances, as a result creating more underallocated companies, which do seem to accelerate emission reductions. At a firm level, participating companies did not experience any negative effects on financial performance. Actually, overallocated companies seemed to benefit financially from their participation in the EU ETS. The European Commission should take note from this, as the results shows that while overallocated companies did not accelerate emission reductions, they did benefit financially from participating in the EU ETS.

The conclusions of this paper are similar to existing literature. Demailly and Quirion (2008) study the impact of the ETS on production and profitability for the steel and iron sector and only find modest competitiveness losses. Abrell *et al.* (2011) study the effect of the ETS on the added value, the profit margin and employment of participating firms and find no evidence that the EU ETS affects these measures of competitiveness. A comparable study by Anger and Oberndorfer (2008), compares overallocated firms, which were practically exempt from payments under the EU ETS, to underallocated firms which had to purchase additional permits at a cost. They find evidence that the EU ETS allocation mechanism did not have a significant impact on revenues and employment of the participating firms. This suggests that, for Phase I, initial over-allocation or under-allocation of EUAs does not affect a firm's competitiveness based on employment and firm revenue. By examining firm-level micro data, Wagner and Petrick (2014) find that German manufacturing firms have reduced emissions due to being subject to EU ETS regulation, while the same firms have not experienced any competitiveness effects. According to Arlinghaus (2015), most *ex-post* literature on the competitiveness effects of the EU ETS finds no causal effects of the EU ETS on employment, profits or output. While these studies do not find any evidence for competitiveness effects, they do find substantial emissions abatements. This suggests that the EU ETS was binding and strict enough to induce significant emission reductions, while not leading to competitive disadvantages for participating firms (Arlinghaus, 2015).

However, opposed to existing literature, this study finds a significant positive effect on the financial performance of overallocated companies.

The study attributes to the scarce efforts in academic literature to empirically test the effectiveness of the EU ETS and the effect at firm-level during Phase III. Existing literature conducted studies mainly during Phase II and compared Phase II to Phase I. The methodological procedure of this study is based on previous literature by Anger and Oberndorfer (2008), Abrell *et al.* (2011) and Wagner and Patrick (2014). However, data on emissions is difficult to find and even more difficult to match to financial data, which may also explain the scarce empirical literature in this field. Abrell *et al.* (2011) retrieved emissions data from the Community Independent Transaction Log – the precursor of EUTL – and had to match companies based on addresses, which is prone to errors. Nowadays, EUTL data includes company registration numbers, which allowed for a more reliable matching procedure between company emission data and financial data from Orbis. Databases like Orbis should include emissions data as it will become more and more important for companies to be transparent about their carbon footprint. This would also allow for even better matching procedures as many more companies could be included in the dataset. As Phase III has not yet been completed, it is not possible to conclude whether the transition to Phase III in 2013 had the desired effect, as the regulation could turn out to only be effective on the longer-term. To make a fair assessment of Phase III, future research should build on this study by examining Phase III after its completion. It would be interesting to conduct the same study in 2025 or 2030 to research whether the regulation in Phase IV actually induced an acceleration in emission reduction efforts from all companies and not only from underallocated companies. This study uses ROE, number of employees and profit margin as measures for financial performance as a large majority of the companies in the dataset are private companies. For further research, it may be interesting to only study listed companies as these companies receive more investor attention and this would allow authors to use more reliable measures for financial performance as Tobin's Q and stock returns.

The world is reaching the tipping point beyond which climate change may become irreversible. Fortunately, governments, businesses and individuals are finally starting to realize the dangerous implications of climate change. The Paris Agreement sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C by 2050 (with 1.5°C as a target) (UNFCCC, 2015). The Paris Agreement is the first-ever universal, legally binding global climate change agreement. It is crucial that countries, governments and businesses all work together to bring a halt to global warming. The EU ETS is a mechanism to limit carbon emissions. It is essential that the public debate is well informed about the dangers of global warming and the measures taken by governments and businesses to bring a halt to this. The time to act is now.

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Appendix

A. Tables

Table A.1: Differential in mean growth in emission reductions by year for Phase III relative to Phase II

Table A.1 presents the results from the difference-in-difference regression for examining an acceleration in emissions reduction efforts by participating companies for every year in the sample period. The table presents the differential in mean growth in emission reductions for every single year in the period 2013-2018 relative to the growth from 2011/2012. The dependent variable is the log value of verified emissions for company *j* in year *t*. β_0 is the parameter of interest and captures the change of behavior in emissions by EU ETS regulated firms after the transition to Phase III on the 1st of January 2013. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses.

(A) All companies						
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
β_0 (cons)	1.8460***	-0.0680	-0.0707	-0.0382	0.0185	-0.2265*
	(0.1583)	(0.1258)	(0.1222)	(0.1220)	(0.1519)	(0.1158)
Firm Performance	0.2035***	0.3632***	0.2139***	0.2897***	0.2224***	0.3177***
	(0.0297)	(0.0265)	(0.0265)	(0.0258)	(0.0238)	(0.0256)
Size	0.0058	0.0175	0.1063***	0.0383	0.0717**	0.0211
	(0.0289)	(0.0275)	(0.0259)	(0.0274)	(0.0307)	(0.0232)
Economic Environment	-10.5629***	3.4764	1.9065*	0.6513	-0.7121	0.6217
	(1.8596)	(2.3594)	(1.1038)	(3.3745)	(1.1296)	(0.8183)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.1682	0.1815	0.1380	0.1324	0.1127	0.1640
Sample (N)	989	987	988	986	986	944
(B) Underallocated companies (AF<1)						
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
β_0 (cons)	1.6259***	0.0187	-0.0120	-0.0307	0.0430	-0.2904**
	(0.1985)	(0.1799)	(0.1635)	(0.1432)	(0.2357)	(0.1334)
Firm Performance	0.2990***	0.3428***	0.1304***	0.2276***	0.1932***	0.1923***
	(0.0465)	(0.0463)	(0.0412)	(0.0362)	(0.0399)	(0.0368)
Size	0.0025	0.0676	0.1416**	-0.0212	0.0424	0.0237
	(0.0357)	(0.0539)	(0.0593)	(0.0435)	(0.0460)	(0.0251)
Economic Environment	-21.8883***	3.6594	-0.2371	-2.9284	-0.1476	1.6993
	(2.9653)	(4.5281)	(1.9862)	(5.2275)	(1.9585)	(1.3419)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.3104	0.2189	0.0464	0.1578	0.2736	0.1037
Sample (N)	415	413	411	411	412	397
(C) Overallocated companies (AF>1)						
	(1) 2013	(2) 2014	(3) 2015	(4) 2016	(5) 2017	(6) 2018
β_0 (cons)	-0.0399	0.3990**	0.4064**	0.5154***	0.4787**	0.4467**
	(0.2432)	(0.1834)	(0.1845)	(0.1944)	(0.2226)	(0.1866)
Firm Performance	0.1927***	0.3624***	0.2723***	0.3108***	0.2097***	0.4024***
	(0.0399)	(0.0346)	(0.0367)	(0.0375)	(0.0327)	(0.0370)
Size	0.2139***	0.0075	0.0923***	0.2832***	0.1500***	0.0242
	(0.0440)	(0.0334)	(0.0306)	(0.0366)	(0.0442)	(0.0447)
Economic Environment	-8.6552***	3.0585	2.2415	1.5867	-0.2046	-0.2880
	(2.4717)	(2.9112)	(1.4091)	(4.5787)	(1.5253)	(1.1010)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.1186	0.1858	0.3712	0.2163	0.1525	0.2196
Sample (N)	574	574	576	574	574	544

Table A.2: Differential in mean growth in emission reductions for Phase III relative to Phase II (Robustness check to Table 4 – Eliminating outlier Novo Nordisk)

Table A.2 serves as a robustness check for Table 4, as Table 4 includes a large outlier – Novo Nordisk – which may have an impact on the results. Table A.2 excludes this outlier and presents the results from the difference-in-difference regression for examining an acceleration in emissions reduction efforts by participating companies. The table presents the differential in mean growth in emission reductions for Phase III (2013-2018) relative to Phase II (2011-2012). The dependent variable is the log value of verified emissions for company *j* in year *t*. β_0 is the parameter of interest and captures the change of behavior in emissions by EU ETS regulated firms after the transition to Phase III on the 1st of January 2013. Column 2 and 3 present the results from the regression on the sub-samples of underallocated and overallocated companies, respectively. 1, 5 and 10% significance levels are indicated by ***, **, *, respectively. Robust standard errors are reported in parentheses.

Phase III (2013-2018) relative to Phase II (2011-2012)			
	(1) All companies	(2) Underallocated companies (AF<1)	(3) Overallocated companies (AF>1)
β_0 (cons)	0.5559	-1.3989**	-0.3408
	(0.4505)	(0.6434)	(0.6876)
Firm Performance	0.0137*	0.0192	-0.0001
	(0.0078)	(0.0134)	(0.0005)
Size	-0.0015	-0.0183*	-0.0005
	(0.0042)	(0.0095)	(0.0044)
Economic Environment	0.0496**	0.1141**	0.0290
	(0.0241)	(0.0507)	(0.0265)
Country FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adj R-squared	0.0012	0.0814	0.0099
Sample (N)	820	349	471

B. Figures

Figure A.1 - Behavioral change in emission reductions (Agriculture, forestry and fishing)
Figure A.1 is an addition to Table 5 and presents the behavioral change in emission reductions for every year in the period 2013-2018 relative to the growth rate from 2011/2012 for the agriculture, forestry and fishing sector. The y-axis presents the behavioral change in emission reductions and corresponds to parameter β_1 in Table 5.

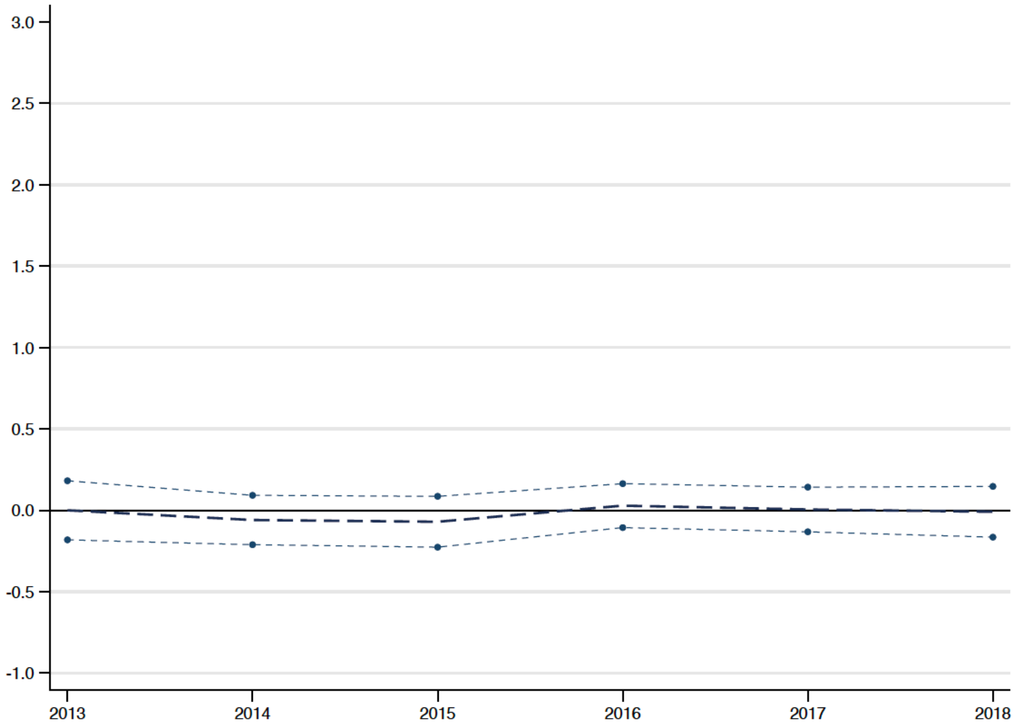

Figure A.2 - Behavioral change in emission reduction (Mining and quarrying)
Figure A.2 is an addition to Table 5 and presents the behavioral change in emission reductions for every year in the period 2013-2018 relative to the growth rate from 2011/2012 for the mining and quarrying sector. The y-axis presents the behavioral change in emission reductions and corresponds to parameter β_1 in Table 5.

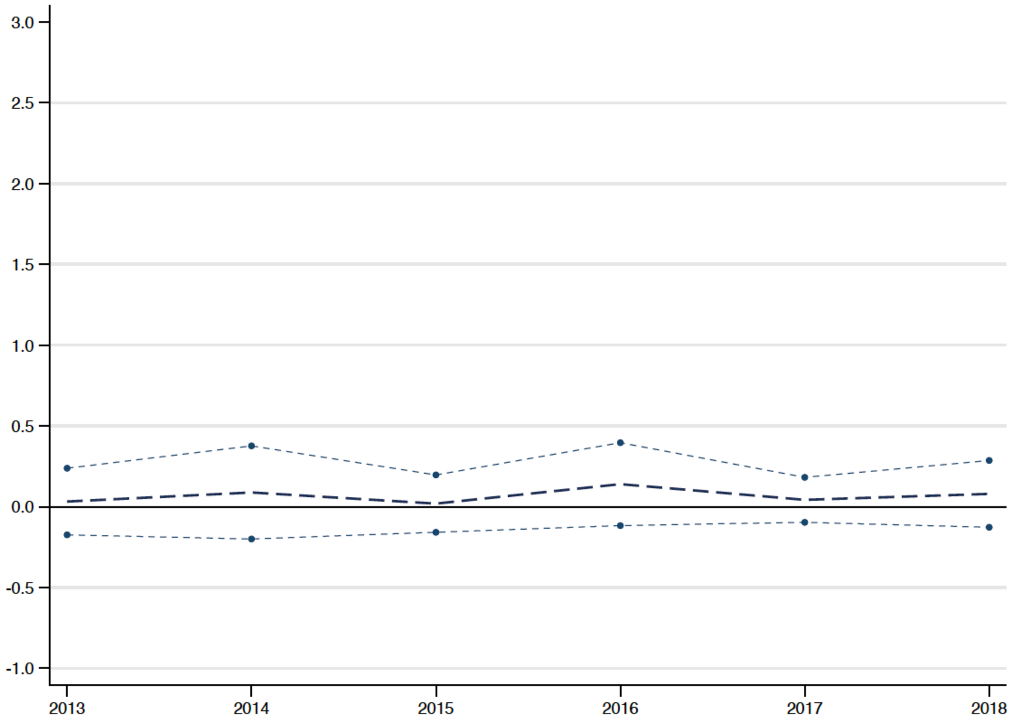

Figure A.3 - Behavioral change in emission reduction (Manufacturing)
Figure A.3 is an addition to Table 5 and presents the behavioral change in emission reductions for every year in the period 2013-2018 relative to the growth rate from 2011/2012 for the manufacturing sector. The y-axis presents the behavioral change in emission reductions and corresponds to parameter β_1 in Table 5.

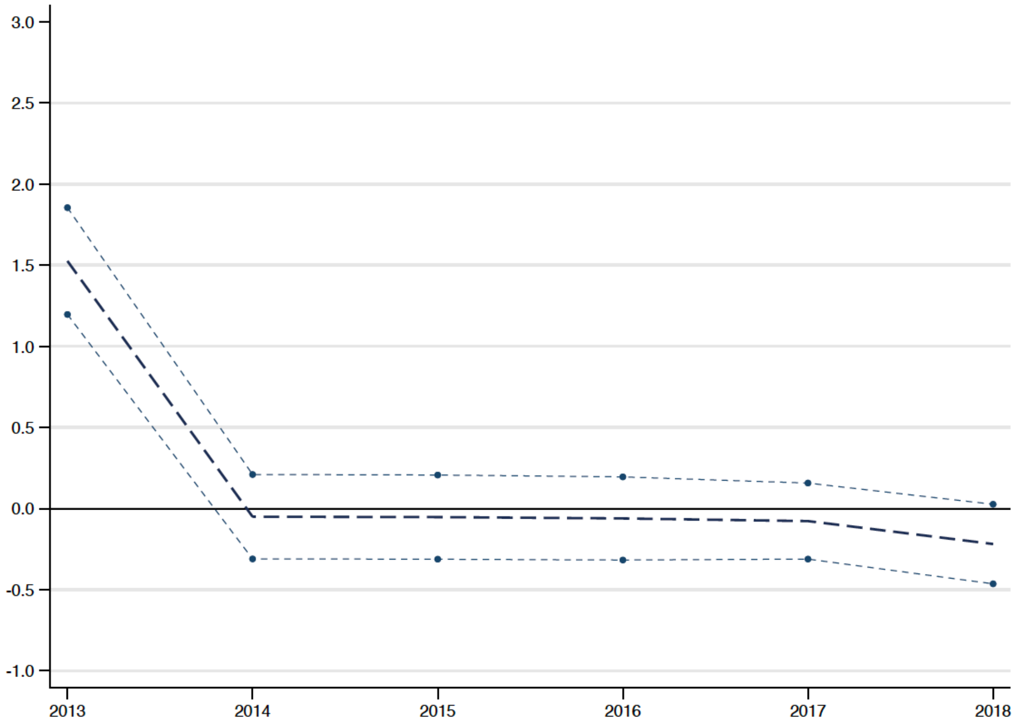

Figure A.4 - Behavioral change in emission reduction (Electricity, gas and steam)
Figure A.4 is an addition to Table 5 and presents the behavioral change in emission reductions for every year in the period 2013-2018 relative to the growth rate from 2011/2012 for the electricity, gas and steam sector. The y-axis presents the behavioral change in emission reductions and corresponds to parameter β_1 in Table 5.

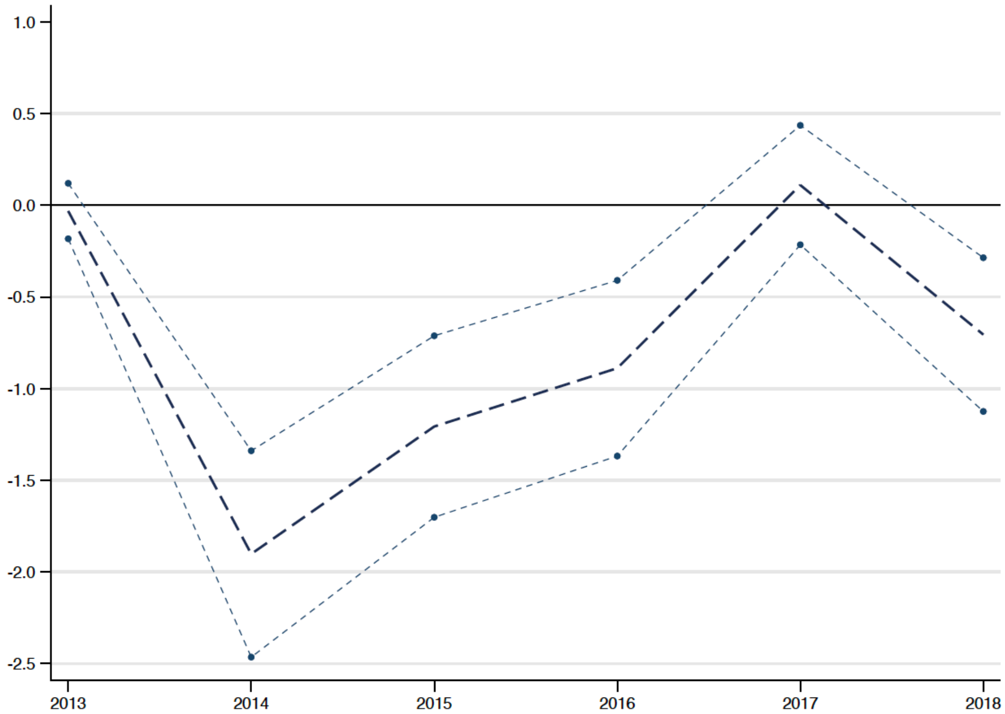

Figure A.5 - Behavioral change in emission reduction (Water supply)
Figure A.5 is an addition to Table 5 and presents the behavioral change in emission reductions for every year in the period 2013-2018 relative to the growth rate from 2011/2012 for the water supply sector. The y-axis presents the behavioral change in emission reductions and corresponds to parameter β_1 in Table 5.

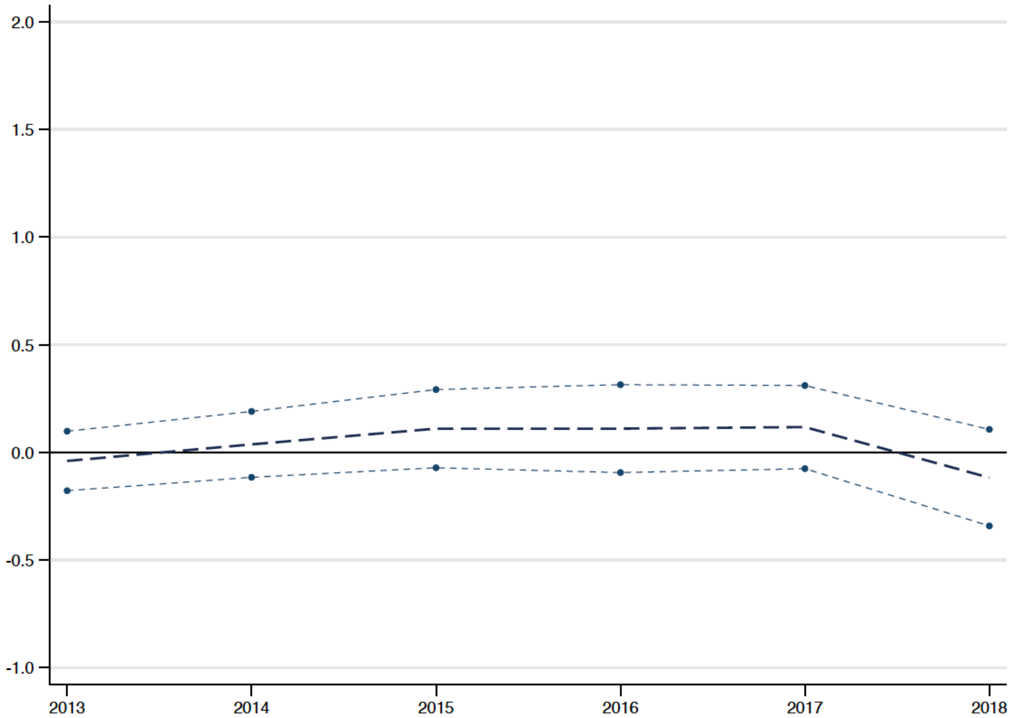

Figure A.6 - Behavioral change in emission reduction (Construction)
Figure A.6 is an addition to Table 5 and presents the behavioral change in emission reductions for every year in the period 2013-2018 relative to the growth rate from 2011/2012 for the construction sector. The y-axis presents the behavioral change in emission reductions and corresponds to parameter β_1 in Table 5.