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Does the Polluter Pay in the EU ETS, or does the EU ETS Pay the Polluter?

A firm-level analysis of the EU ETS and its impact on Norwegian firms' profitability and CO_2 emissions

En analyse på bedriftsnivå av EU ETS og dens innvirkning på norske bedrifters lønnsomhet og CO_2-utslipp

Anja Lund Jakobsen

Acknowledgements

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I take full responsibility for any errors and omissions.

Ås, 13 May 2014

Anja Lund Jakobsen

Abstract

This thesis provides insight into how the EU Emissions Trading Scheme (EU ETS) has affected firm profitability and CO_2 emissions in Norway since its inception in 2005. Using historical emissions and financial data of 111 Norwegian land-based industrial firms, both regulated and non-regulated by the ETS, I examine the regulative impact on the firms' profit margin, return on assets, absolute CO_2 emissions and emission intensity. By using econometric panel data methods, I find that the EU ETS has not had a statistically significant impact on firms' profitability. The results however suggest, although they are not statistically significant, that it is more likely that the aggregate effect has been positive rather than negative. In addition, I find that the firms' CO_2 emissions most likely have been reduced by the introduction of the ETS, but the size of this effect, especially regarding emission intensity, is very uncertain. Also, some sectorial variation was observed among industries in the sample, with firms in the "metals and minerals" industry seemingly contributing the least to emission reductions.

Sammendrag

Denne oppgaven gir et innblikk i hvordan det europeiske klimakvotemarkedet (EU ETS) har påvirket norske bedrifters lønnsomhet og CO_2-utslipp siden oppstarten i 2005. Ved å bruke historiske utslipps- og regnskapsdata for 111 norske landbaserte industrielle bedrifter, både regulerte og ikke-regulerte av EU ETS, undersøkes henholdsvis reguleringseffekten på bedriftenes profittmargin, totalkapitalrentabilitet, totale CO_2-utslipp og utslippsintensitet. Ved hjelp av økonometriske metoder, finner jeg først at EU ETS ikke har hatt en betydelig innvirkning på bedriftenes lønnsomhet. Resultatene kan imidlertid tyde på at det er mer sannsynlig at den aggregerte effekten er positiv enn at den er negativ. Den andre hovedkonklusjonen i denne oppgaven er at bedriftenes CO_2-utslipp mest sannsynlig har blitt redusert som følge av ETS, men størrelsen på denne effekten, særlig når det gjelder utslippsintensitet, er svært usikker. Det ble i tillegg observert noen forskjeller blant industrisektorene, blant annet tyder resultatene på at bedrifter innenfor mineral- og metallindustrien har bidratt aller minst til de utslippsreduksjonene som ble funnet.

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1. Introduction

According to the latest IPCC report, annual CO_2 emissions must decrease by 40-70% within 2050 to keep global warming below 2 degrees Celsius (IPCC 2014). While it may not look like we are on the right track yet, several countries have made mitigation pledges and efforts in order to avoid severe damages due to climate change. Still, the major initiator has been the EU, with their Emission Trading Scheme (EU ETS) being the largest emission-trading program in the world. Norway has been linked to the EU ETS since the start in 2005, but became officially part of it in 2008. Since nine years have passed since emission trading was introduced in Norway, it seems about time to assess the impacts the trading scheme has had on the regulated firms. The main objective of this thesis is therefore to shed light on how the ETS has affected land-based[1] Norwegian firms, with respect to both profitability and emissions, during the two first phases of the ETS (2005-2012) using econometric methods. While there have been several studies analyzing the firm-level effect in the EU, this is to my knowledge the first quantitative study using Norwegian data. The panel used contains 111 Norwegian firms, where the ETS regulated firms in the sample cover approximately 20% of all land-based CO_2 emissions in Norway[2].

Hence, the first research question this thesis addresses is:

Has the EU ETS had a significant effect on Norwegian firms' profitability?

With environmental regulation there is always a conflict between the interests of firms and the interests of the regulatory imposing the regulation. This is mainly because firms are afraid the regulation will harm their competitiveness, and thus perhaps decrease their profitability. In the case of EU ETS most of the permits have so far been allocated for free[3], making it more likely that some firms could have benefited from the

[1] For simplicity reasons, the offshore industry is excluded in this analysis.
[2] In comparison, all EU ETS regulated land-based plants in Norway stand for approximately 56% of all land based CO_2 emissions.
[3] The reasons why permits were allocated for free are discussed in sections 2.1.1 and 3.1.2.

regulation. Hence, the net effect of the ETS could go both ways. While it may not harm the effectiveness of an environmental regulation that some firms could profit from it, it violates the "polluter pays principle" and is therefore more of an ethical dilemma. The profit margin and the return on assets for the individual firms will be used as measures of profitability.

Furthermore, the second research question addressed in this thesis is:

Have Norwegian firms' CO_2 emissions decreased significantly due to the EU ETS?

Norway has quite ambitious goals about decreasing carbon emissions, and have decided that 2/3 of the committed reductions should happen domestically[4]. With two phases of the ETS behind us, it is therefore of great interest to examine if the regulation has actually led to significant reductions in CO_2 emissions. On one hand, emissions should have been reduced significantly since the introduction of the ETS, since this is the main objective of the regulation. On the other hand, CO_2 prices have been lower than expected almost the entire time, which is mainly a result of the financial crisis. In combination with a generous allocation of permits, at least in the first phase, this might have reduced firms' incentives to decrease their emissions. It is therefore uncertain if the ETS has led to significant emission reductions among the regulated firms. To answer the second research question I will look at both absolute emissions and emission intensity of the individual firms.

The thesis is structured as follows: chapter 2 describes the three phases of the EU ETS, accompanied with a short discussion on EUA prices and a literature review. Chapter 3 reviews relevant economic theory and presents a simple microeconomic model of a profit-maximizing firm in an ETS. Chapter 4 describes the data used and presents the econometric models and methods, while the results of the analyses is presented and discussed in chapter 5. Finally, chapter 6 concludes and makes suggestions for further research.

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[4] See e.g. the national budget 2010: http://www.regjeringen.no/nb/dep/fin/dok/regpubl/stmeld/2009-2010/meld-st-1-2009-2010/3/8/1.html?id=579807

2. Background

The first international cooperative agreement with the aim of stabilizing greenhouse gas (GHG) emissions was a fact in June 1992, when the United Nations Framework Convention on Climate Change (UNFCCC) was negotiated at the Earth Summit in Rio de Janeiro. No quantitative targets for emission reductions were agreed on, but the agreement laid the foundation for further international cooperation. The Conference of Parties (COP) to the UNFCCC was held on a yearly basis from 1995 to discuss the climate change issue, and at the third COP in Kyoto in 1997 binding emission targets for Annex B countries were finally set. These emission targets varied greatly between states. The EU member states committed to reducing their GHG emissions by 8% in the commitment period 2008-2012 compared to 1990 levels, while Norway committed to limit its emissions to a 1% increase (UNFCCC 2008). New commitments for 2020 have later been added, and the EU has now through their 20-20-20 targets committed to decrease GHG emissions by 20% compared to 1990 levels while Norway has committed to decrease by 30% (EC 2014).

2.1. EU ETS

Emission trading was introduced as one of the flexible mechanisms in the Kyoto protocol, together with Joint Implementation (JI) and the Clean Development Mechanism (CDM). This inclusion was the very start of the EU ETS. Six months after COP3 in Kyoto, the EU burden sharing agreement (BSA) came in place in June 1998. At that point the EU consisted of fifteen member states, which through the BSA agreed to varied national targets that together would cover the 8% Kyoto target of the EU (Ellerman et al. 2010). At approximately the same time, the European Commission decided to set up an internal trading scheme, namely the EU ETS, by 2005. The reasons for setting up the scheme two years before the Kyoto commitment period were that it would give "practical familiarity and even a leading edge to the European Union in using the instrument" (Ellerman et al. 2010 p.18).

Hence, the ETS was EU's chosen instrument to meet the Kyoto requirements, and the first phase was launched in 2005. The second phase coincided with the commitment period of the Kyoto protocol and lasted from 2008 until 2012. There is no end date in the EU ETS directive, and we are therefore now in the third phase which will last until 2020, and the fourth period is already in planning. In the rest of this section I will briefly go through the first three phases, with emphasis on the two first phases and the differences between the EU and Norway. A short discussion of the permit prices is also included at the end of this section.

2.1.1. 2005-2007

As mentioned, the first phase of the EU ETS (2005-2007) was a trial phase, where the main objective was to introduce the trading scheme and to learn from the system so that they would be more prepared when the Kyoto commitment period started. The regulated emissions in this phase were the power industry and energy-intensive industrial sectors (production and processing of ferrous metals, minerals and pulp, paper and board), and most of the allowances were given away for free[5]. A penalty for non-compliance was set at 40 euros per ton CO_2 (Directive 2003/87/EC 2003).

There are two main reasons why EU wanted to grandfather most of the permits instead of auctioning them. First, it was to protect firms from large costs and possible bankruptcy. It was also to get the firms on board in order to have a smooth transition; if everyone had to buy permits there would be massive protests from the industrial sectors and thereby more difficult to implement regulations. Second, it was to prevent carbon leakage, which is that a decrease in emissions in regulated countries leads to an increase in emissions in unregulated countries. Carbon leakage is highly possible in competitive, carbon-intensive industries (Bye & Rosendahl 2012).

Norway established their own emissions trading scheme in 2005-2007, which was harmonized, but not directly linked to the European system. All the 51 regulated firms in this period received free allowances (Norwegian Ministry of Environment 2007). The Norwegian trading system covered the same emissions as the EU ETS, with the

[5] The EU had an upper limit of 5% for auctioning of permits, but there was no lower limit, meaning that 100% of the permits could be given for free (Ellerman et al. 2010). The end result after the first phase was close to 99% grandfathering of permits.

exception of industries already covered by the existing CO_2 tax. The industries already covered by the tax in the first period were the pulp and paper industry, fishmeal processors and offshore oil and gas facilities. Approximately 10% of all Norwegian CO_2 emissions were ETS regulated in the first period.

Figure 2.1 presents the aggregated allowances allocated and aggregated verified CO_2 emissions of EU ETS regulated Norwegian firms in the first period of the trading scheme. It is evident from the figure that there was an aggregated surplus of allowances each year. Just by looking at the graph it is however impossible to say if this surplus was actually due to abatement or to an over-allocation of permits[6] – for that further analysis is required. Still, the figure coincides with Ellerman & Buchner's (2008) findings for the EU (which will be returned to in section 2.2).

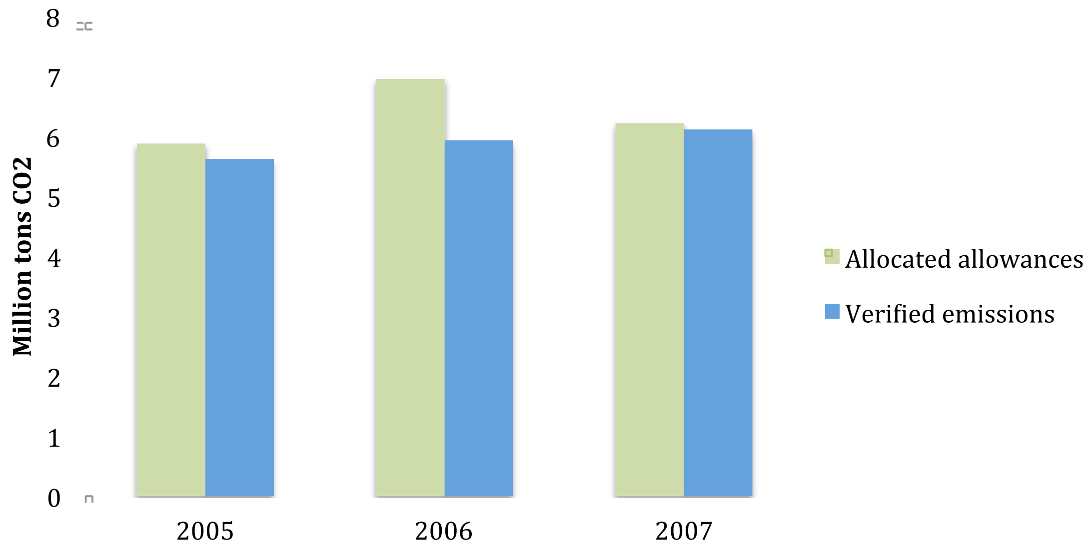

Figure 2.1: Aggregated allocated allowances and verified CO_2 emissions from regulated Norwegian firms 2005-2007, in million tons. *Source*: Norwegian Environment Agency.

[6] Over-allocation of permits could be defined in many ways, but the most used definition (which also Ellerman and Buchner (2008) used in their research) is that over-allocation occurs when there is handed out more permits than the BAU emissions.

2.1.2. 2008-2012

In 2008 the Kyoto commitment period started, which meant that the Annex B countries would have to meet their emission targets by the end of 2012. Several changes were made compared to the first phase: the lower limit of free allocation shrank from 95% to 90%, the penalty for non-compliance was increased to 100 euros per ton CO_2 and Nitrous Oxide (N_2O) emissions was included as a GHG gas in several member states (Directive 2003/87/EC 2003). As a response to the major EUA price decline in the first phase, the cap was also reduced by approximately 6.5% compared to 2005. Furthermore, in 2008 the three European Free Trade Association (EFTA) states – Norway, Iceland and Liechtenstein – were also included in the EU ETS.

The agreement between the European Commission and the EFTA states to join the EU ETS was official in October 2006, and Norway was then directly linked to the trading scheme. Consequently, Norway had to include several sectors that had not been regulated in the past. These new sectors included pulp and paper installations, fishmeal and fish oil facilities, mineral-processing installations and offshore oil and gas installations (Ellerman et al. 2010). This inclusion resulted in a modification of the existing CO_2 tax, since most of these sectors already paid tax for their emissions. Hence, the pulp and paper together with the fishmeal industries were exempted from the tax, and became instead regulated by the EU ETS with free allowances. The petroleum industry was still bound by the CO_2 tax, but the tax was reduced by almost 50% (Ellerman et al. 2010). However, in the ETS agreement the EFTA states got one exemption from the directive; they got exempted from article 10, meaning that they could auction off more permits than 10%. This was especially important for Norway, since they then avoided having to give free permits to the offshore industry (since the permit system would partially replace the existing carbon tax). The petroleum industry, including offshore, would then have to buy permits in the market from 2008.

The second phase covered about 40%[7] of Norwegian GHG emissions and around 115 regulated firms (Norwegian Environment Agency 2014). The aggregated allowances allocated and verified CO_2 emissions from EU ETS regulated Norwegian firms, excluding

[7] This is including offshore. When only considering land-based CO_2 emissions, the ETS covers approximately 56%.

offshore, in the second phase of the ETS are displayed in figure 2.2. From this figure it is clear that the regulated Norwegian land-based firms were aggregate net short of allowances each year in the second trading period.

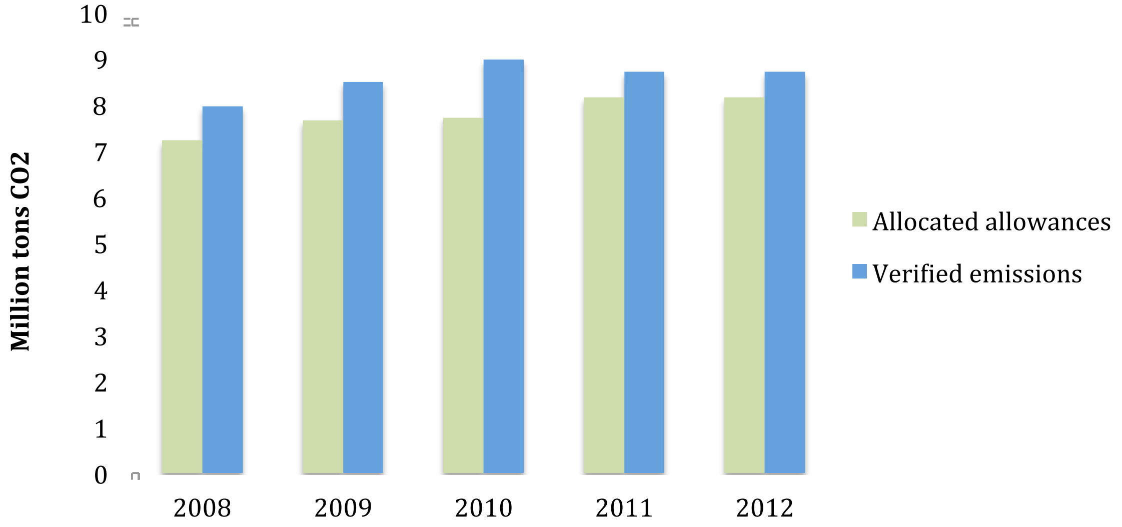

Figure 2.2: Aggregated allocated allowances and verified CO_2 emissions from EU ETS regulated land-based Norwegian firms in 2008-2012, in million tons. *Source*: Norwegian Environment Agency

The last addition to the EU ETS in the second phase came in January 2012 when airlines was included, making it the first international policy measure setting a binding cap on emissions from aviation. Originally, all aircraft operators arriving to or departing from European Economic Area (EEA) airports would have to submit allowances equivalent to their emissions. However, massive international opposition followed[8] and the European Parliament (EP) eventually had to fully exempt flights between EEA- and non-EEA countries from regulation in 2012 and 2013 (Proposal 2013/0344(COD) 2013). The plan was that non-EEA airlines would start paying for their emissions inside the EEA from 2014, but it may however look like the international pressure is too strong and non-EEA airlines may get exempted on a more permanent basis[9].

[8] The opposition has been mostly driven by USA, China and Russia. China went as far as banning airlines from paying for their emissions (The Telegraph 2012)

[9] See e.g. http://www.europeanvoice.com/article/2014/march/eu-surrenders-on-aviation-in-ets/79909.aspx

2.1.3. 2013-2020

We are now in the third phase of the ETS, which will last until 2020. In this period the rules are much more harmonized for all countries involved, which led to significant changes. There now exists a single EU-wide cap on emissions, which is not made up based on national allocation levels as in the two first periods. The allocation rules for free permits are harmonized and a few more sectors and gases are included, mainly PFCs in aluminum production. In addition, the share of auctioned permits has increased; the power sector has to buy all permits, while the industries most exposed to carbon leakage get as much as before. The remaining industries will receive gradually less towards 2020. The plan is to evolve towards a system where auctioning of permits is the rule, and grandfathering is the exception.

Since the rules of the scheme are much more harmonized than before, some sectorial changes have had to be made in Norway. One of the biggest changes in the third phase for Norway is that the offshore industry has now been given free permits, which is consistent with EU regulations. There are also now some land-based industries that have to buy the permits, with the largest example being the power sector. Altogether, 140 Norwegian firms that stand for about 50% of GHG emissions in Norway are now regulated through the EU ETS.

2.1.4. EUA prices

While the EU ETS have succeeded in establishing a market for emission trading and actually setting a price on carbon, it is somewhat questionable if it has succeeded in reaching and maintaining a reasonable price level. The price development of European Union Allowances (EUA) is displayed in figure 2.3.

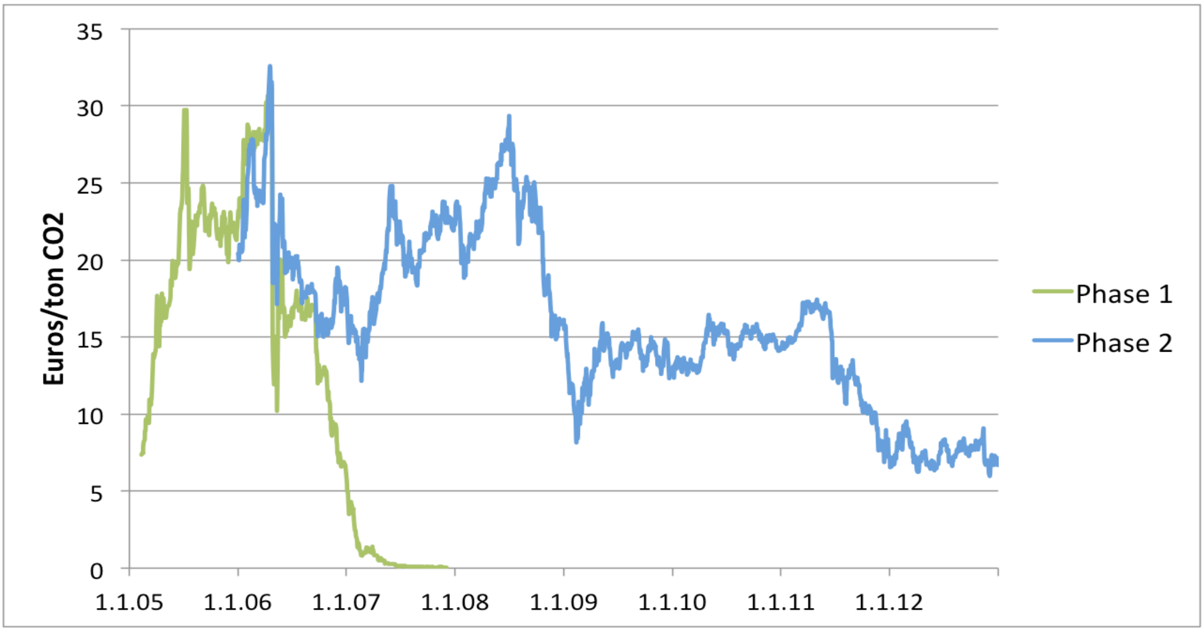

Figure 2.3: Development of EUA prices (in euros/ton CO_2) in the period 2005-2012. *Source*: Nord Pool

From the beginning in 2005 and until mid 2006 the EUA price was relatively high, with the highest (phase 1) price being approximately 30 euros/ton. Since then, large price fluctuations are evident, with a decreasing trend. The first price crash came in the beginning of 2007, and the price eventually reached nearly zero in March the same year. The reasons for this crash are many, but the research points towards over-allocation of permits, due to a lack of reliable historical emission data, combined with non-banking of permits as the main contributors (Ellerman & Buchner 2008). In the first phase, permits could not be saved and used in the next trading period, which meant that the surplus permits were of little value in 2007. One lesson apparently learned, because from 2008 EU ETS regulated firms were given permission to bank permits between phases.

Since the cap on emissions became tighter in the second phase, EUA prices increased and almost reached 30 euros/ton again. The second price crash, although the price did not drop as much as in 2007, was in the beginning of 2009. This time it was a result of the financial crisis, since decreased production volumes led to decreased demand of emission permits. Since then, despite some positive fluctuations, there has been a negative trend in EUA prices.

How much a firm is able to profit, or stand to lose, from being regulated by the EU ETS is highly dependent on the permit price. If the price is very low, it is less likely that a firm is able to abate at a lower marginal cost than the permit price, in order to sell excess permits. The profit from selling excess permits would of course also be relatively low if the price is low. Thus, it would ruin the inherent incentives of reducing emissions beyond the cap that was given to the firm, and total emissions would be higher than they would be if the price was high.

2.2. Literature review

In this section, a literature review of previous studies of the impact of the EU ETS will be given. A literature review of more theoretical concepts relevant to the topic is integrated in chapter 3, when discussing economic theory.

When it comes to EU ETS and the effect on firms' performance, a number of ex-post assessments have been conducted, and most of them conclude that the trading system have had little impact. There have also been several ex-post studies of emission reduction efforts due to the EU ETS, but most of them only evaluate the first phase. The lack of literature on emission impacts after 2008 might be due to the complexity of the financial crisis, making it difficult to isolate factors influencing CO_2 emissions. This difficulty is reflected in the uncertainty of the few studies conducted of the second phase.

Anger and Oberndorfer (2008) examined if the allocation factor (allowances allocated divided by verified emissions) had an impact on revenues and employment of German firms, and they found no significant evidence that the allocation factor contributed to the performance of firms. However, they acknowledged the fact that they only looked at the first year of the EU ETS, and that the impacts might come later in time. Kenber et al. (2009) conducted a qualitative study of nine large European firms regulated by the EU ETS, and they also found that the trading scheme did not significantly affect the firms' costs or competitiveness. One exception was however the aluminum industry, which experienced a loss in performance due to the increased electricity costs (due to the passing on of carbon price by power producers onto the consumers).

A study Abrell et al. (2011), covering the entire EU, and looking at both regulated and non-regulated firms from 2005-2009, also supports the findings above. Using added value, profit margin and employment as dependent variables they found no significant evidence that regulated firms experienced losses in competitiveness compared to non-regulated firms. When examining the effect on emissions however, they found significant emission reductions in 2007/2008 due to the ETS corresponding to about 3.6 percentage points. They also reported major sectorial differences; while the metals and minerals industry contributed to emission reductions the electricity and heat industry did not make a significant contribution.

While the studies mentioned above all found no significant impact of the EU ETS on firms' profitability, there exist some studies that found a significant effect. On one hand, Commins et al. (2011) found that the first phase of EU ETS had a negative effect on productivity and profits of European firms. On the other hand, Bushnell et al. (2013) investigated the daily stock returns of firms after the decline in permit prices in 2006, and argued that some firms have been making profits from the regulation.

The most famous study of the EU ETS effect on emission reduction efforts is probably Ellerman and Buchner (2008). They examined verified emissions and allowance allocation for the first two years of the ETS, to determine if abatement had really occurred or if the aggregated surplus of allowances was just a result of over-allocation. Their main finding was that some abatement had occurred in the energy and industrial sectors, despite over-allocation in some countries (especially the Baltic countries) and to some sectors. In 2005-2006 they estimated that total CO_2 emissions in ETS-sectors in

Europe had declined by approximately 2-5% due to the EU ETS. Egenhofer et al. (2011) continued the study of Ellerman and Buchner, and looked at 2008-2009 as well. They found higher abatement due to the EU ETS in 2008 and 2009 compared to previous years, and estimated a decline in emission intensity between 2.8% and 5.4% in 2009.

None of the studies mentioned above include Norway in their analyses and there has generally been very little literature on the effects of EU ETS on Norwegian firms. However, Holm et al. (2014) conducted recently a qualitative study of 18 Norwegian firms that own 64 EU ETS regulated plants, to see how the permit price affected their strategic decisions. One of the main insights was that the low EUA price level is not an important factor for the industries when they consider abatement investments, since they anyway assume that emissions in the future will be more costly than today. Another interesting insight is that most firms interviewed do not sell their excess permits, as they will rather save it in case of a production increase in the future. The low permit prices were also reported as a reason why they did not want to sell their permits; the gains from trade were not large enough.

3. Economic theory

In this chapter, the most relevant economic theory when it comes to emission trading will be reviewed. First, there will be a discussion regarding emission trading versus other environmental economic instruments. Second, a short review of grandfathering and auctioning is provided. Third, we will see how a profit-maximizing firm behaves (according to microeconomic theory), both unregulated and regulated by an ETS. Last, a simple model of a profit-maximizing ETS-regulated firm is presented.

3.1. Prices versus quantities

In environmental policy there are three main economic instruments; emission standards, emission taxes (and subsidies) and tradable emission permits. While the first is a command-and-control strategy, the two latter are defined as incentive-based strategies since they give the polluter economic incentives to reduce emissions further (Field & Field 2009). Emission trading and emission standards are both instruments that control the quantity of emissions, and apart from the fact that emission trading might create incentives to reduce emissions beyond the cap of the individual firm, the two different instruments do not differ when it comes to the end result, which is total emissions. They do however differ with respect to costs; emission trading is cost-effective while emission standards are not, since emission trading satisfies the equimarginal principle. This means that the total costs of achieving the emission reductions needed are minimized such that the abatement costs are equalized at the margin between the firms (Field & Field 2009).

Figure 3.1 illustrates the cost savings in an ETS with, for simplicity reasons, two firms. Firm A has relatively high marginal costs of abatement, while firm B has relatively low marginal abatement costs (MAC). In a case with emission standards, the authorities would set a standard, in this case a uniform standard for simplicity, which in the figure is represented by Q_0. This means that both firms have to abate the same amount, regardless of their marginal costs. Since firm A has a very steep MAC curve compared to firm B, firm A would have to abate at a much higher cost. If instead of an emission standard the two firms would be a part of an ETS they would both be gaining from this trade. Firm A would buy permits from firm B up until its MAC would equal the market price of permits, which would reduce firm A's abatement level to Q_A. Firm B would gain from selling its permits at a price higher than their MAC, and would thus increase abatement efforts up until Q_B. Hence, the end result with respect to emissions would be unchanged from the emission standard, but it would be achieved in a cost-effective way.

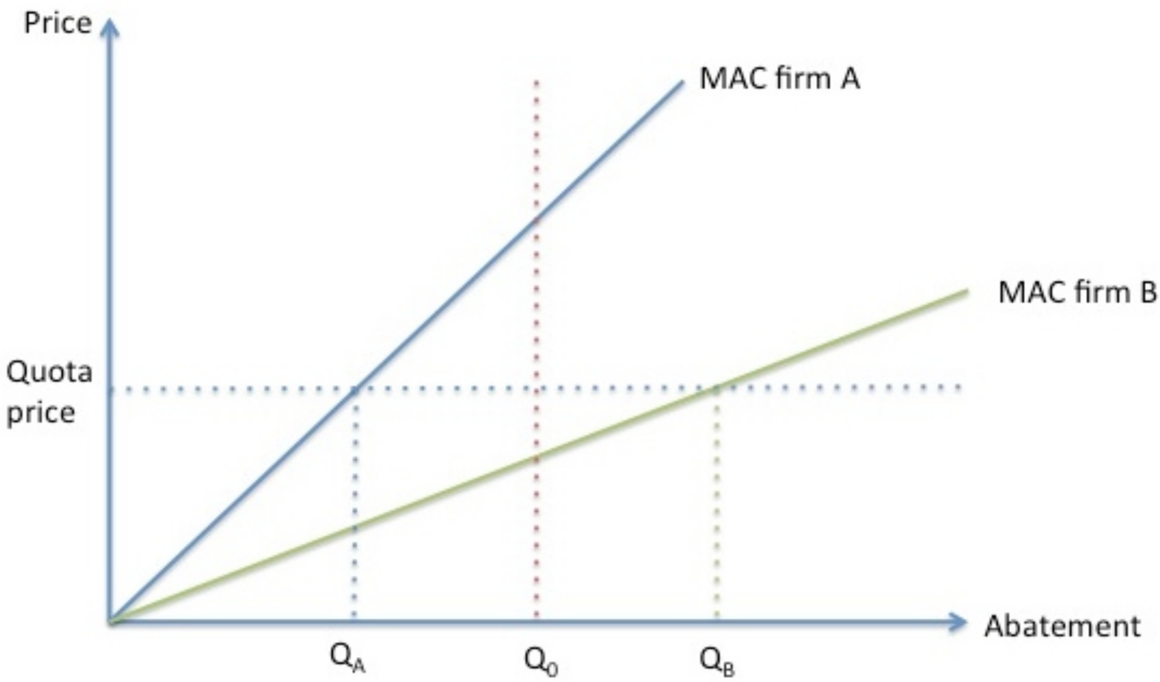

Figure 3.1: The gains from tradable permits compared to command-and-control

An emission tax is an alternative to tradable permits, which also satisfies the equimarginal principle and is thereby cost-efficient. Taxes and quotas can therefore lead to the same optimal outcome, given some conditions (e.g. no uncertainty). Weitzman (1974) is probably the most known addition to the debate regarding taxes and quotas, where he discussed when to regulate prices (taxes) and quantities (standards and quotas) in the presence of uncertainty. His conclusion was that we should regulate price if the marginal abatement costs grow at a higher rate than the marginal benefits (MB) of abatement. Conversely, quantities should be regulated when the MB curve is steeper than the MAC curve. However, since this conclusion was based on a model with uncertainty, this conclusion would not hold without uncertainty.

If the Weitzman proposition were to be applied to the climate change problem, the solution would be to regulate price and thus set a carbon tax. The intuition behind this is that climate change is happening rather slowly (the major damages are far away in time), while the costs increase a lot if reductions are large. Hence, the MAC curve is steeper than the MB curve. This is however not what we see happening in the real world. While some countries do have domestic emission taxes, it has not been introduced as a multinational instrument to reduce carbon emissions. One reason for this is probably that it is more difficult to get political acceptance for taxes than for quotas. As an example, the EC did in fact propose an EU-wide carbon tax in 1992, but they ultimately had to withdraw the proposal five years later due to massive opposition from the member states[10] (Ellerman et al. 2010).

3.2. Grandfathering and auctioning

The success of a trading scheme depends a lot on how the permits are allocated. In addition to setting the total cap on emissions right, a lot of the allocation issues concern whether or not the emission permits should be given out freely (grandfathered) or auctioned off. In principle both methods could lead to cost-efficient allocation, as long as the free permits are given as a lump sum, which is when the firms have no impact on the quantity of permits they receive (Böhringer & Lange 2005; Montgomery 1972). In that case, grandfathering would only differ from auctioning through generating public revenue, which could be used to reduce distortionary taxes. This means that auctions would provide efficiency gains that free allocation could not (Fischer et al. 2003).

While grandfathering may be cost-efficient, there exist some issues concerning equity and the incentive structure of free allocation. One ethical issue that arises in the context of free allocation of permits is that it violates the “polluter pays principle”, as the polluters would not pay for their negative externalities (Böhringer & Lange 2005). In addition, if the firm receives permits that exceed its real demand, the excess permits can be sold and the firm may profit from the regulation. As a result, the firm would receive a

[10] The two main sources of this resistance was, according to Ellerman et al. (2010), the fear that the EC would diminish the state autonomy regarding fiscal policy and strong opposition from the industry lobbies.

subsidy instead of actually paying for emissions. Grandfathering could also give perverse incentives to the regulated firms if the allocation is conditional on something that the firms themselves affect. If firms believe that future permits will be distributed based on current emissions, it may give them incentives to increase emissions beyond BAU-levels in order to get more permits in the future (Rosendahl 2008).

Considering the issues mentioned concerning free allocation, one could argue that auctioning in theory is the preferred mechanism of distributing emission permits. Auctions tend however to stir political unwillingness due to opposition from the affected industries, just like taxes as discussed in the previous section. It is therefore unlikely to get political acceptance for an ETS that is mainly based on auctioning as the allocation mechanism. A hybrid system would therefore be more likely to happen (Ellerman et al. 2010).

3.1. The profit maximizing firm

According to economic theory (Silberberg & Suen 2001; Varian 1992), the objective of a firm is to maximize profits. A profit maximizing firm will therefore produce up until the cost of producing one more unit of output equals the revenues from selling one more unit, that is when MC = MR. In figure 3.2 the behavior of such a firm in the short run is demonstrated. Full competition in the market the firm is operating in is assumed, meaning that the firm is a price taker and cannot affect the exogenous market price.

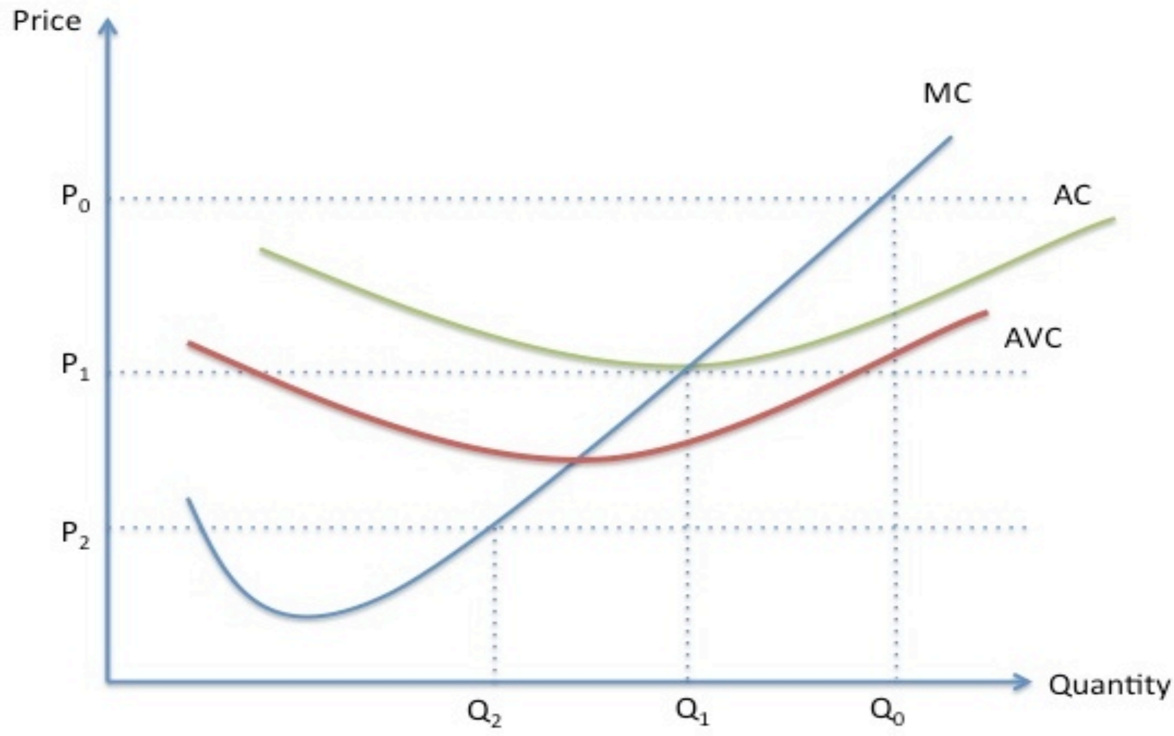

Figure 3.2: A non-regulated profit maximizing firm´s behavior under full competition

As mentioned, the profit-maximizing firm will adjust where the marginal cost of production equals the marginal revenue, which is the market price in a market with full competition. In figure 3.2 we see the marginal costs (MC), average costs (AC) and average variable costs (AVC) of a profit-maximizing firm under full competition. *(Q_0, P_0)* is the profit maximizing equilibrium when the firm does not face any environmental regulation and the market price is P_0. The price is illustrated above the average cost curve, meaning that the firm will in the short run make a profit. According to theory, this profit will however not be sustained in the long run, since new entrants will then have incentives to enter the market. This entrance will increase the supply, and hence decrease the market price and the profits will vanish. Nevertheless, markets are not always perfectly competitive in real life and there may exist barriers making it difficult for new firms to enter the market.

Thus, a firm's profitability depends on the changes in market price. If the price falls below the AC curve (for instance to P_1), the firm will not be able to cover all costs in the short run. Since fixed costs are considered sunk costs, the firm will in the short run not stop producing until the price falls below the AVC curve (for instance to P_2). After this point it is more profitable to stop production than to keep producing.

3.2. The profit maximizing firm in an emission trading scheme

Section 3.1 considered a profit-maximizing firm not subject to any environmental regulation. In this section we will see what happens when the firm enters an ETS. First, the change in costs and producer surplus is shown graphically (3.2.1), and second a theoretical model explaining a firm's behavior under an ETS is presented (3.2.2).

3.2.1. The effect on marginal costs and producer surplus

Figure 3.3 shows the changes in producer surplus when a firm becomes regulated by an ETS. For simplicity reasons it is assumed that there are many identical firms that initially have an aggregate production of Q_0, at the market price P_0. *D* denotes the total market demand the firms face. The extra costs of emissions shifts the marginal cost curve outwards from MC_0 to MC_1, which changes the profit maximizing equilibrium from (Q_0, P_0) to (Q_1, P_1). Demand is assumed to be unaffected by the ETS, and the emission rate is assumed constant for all levels of production. Emission rate is here defined as emissions per output, which is then assumed unchanged by the ETS. The difference between MC_0 and MC_1 is therefore the costs of emissions, i.e. the quota price. As a consequence of the shift outwards in the MC curve, the producer surplus will be reduced from area C+D to area A, which will most likely affect the firm's profitability in a negative way.

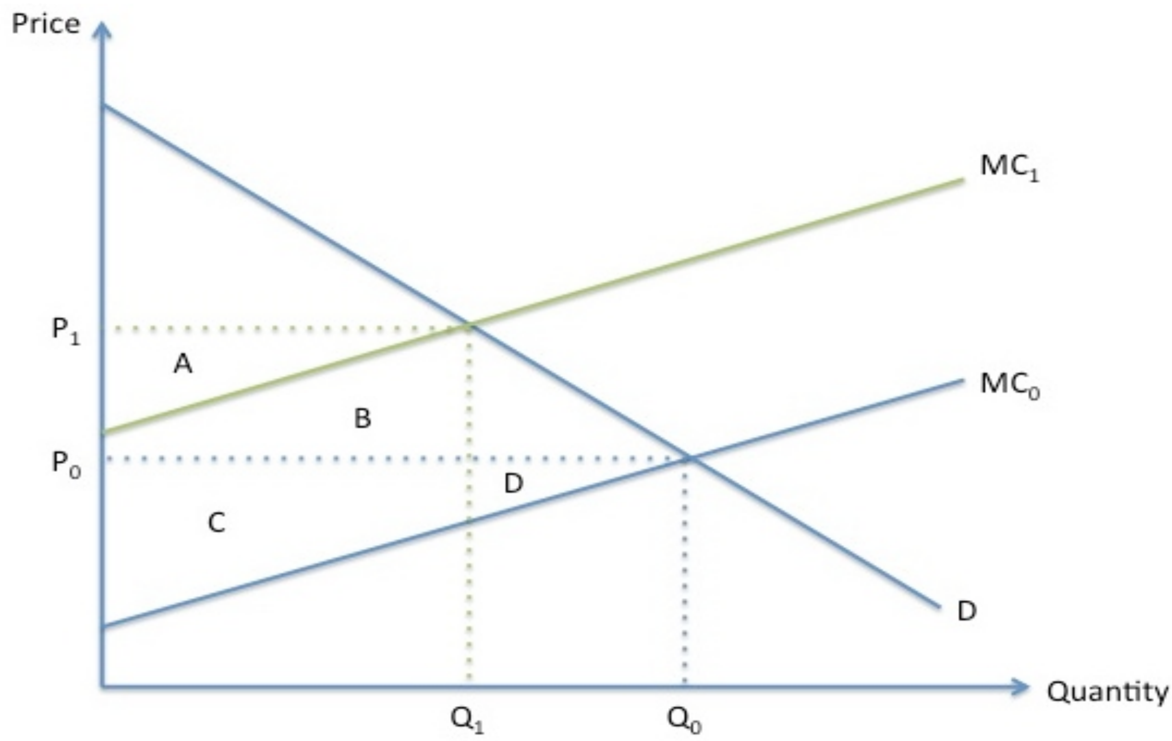

Figure 3.3: Changes in producer surplus when a firm enters a tradable permit system

However, the reduction in producer surplus from C+D to A is only true when permits are auctioned off. Hence, the net effect on producer surplus (and profitability) depends on the allocation of emission permits. If for example regulated firms received permits equivalent to 100% of their ex-post emissions, corresponding to production level Q_1, the free allocation would lead to a transfer of area C+B. Altogether, the regulated firm would then lose area D and gain area A+B, comprising the total producer surplus to area A+B+C, which might offset the costs from regulation. However, if allocation is based on ex-ante emissions, corresponding to Q_0, it is almost certain that the producer surplus would increase (Bushnell et al. 2013).

While also other factors contribute to a firm's profitability, figure 3.3 shows that it is possible for a firm to profit from environmental regulation. This could also be the case when permits are auctioned, if the firm is able to pass on the increased costs on to the consumers or if the firm has very cheap abatement possibilities. Nevertheless, profitability would likely decrease on an aggregate level if all permits were auctioned off.

3.2.2. Theoretical model

In this section a simple theoretical model will be presented. We are looking at a profit-maximizing firm that produces two kinds of outputs, "good" and "bad" outputs. The "good" outputs represent the physical products they produce and sell in a market, while the "bad" outputs represent the emission of pollutants. These two kinds of outputs are of course always produced, regardless if the firm faces environmental regulation or not. However, with regulation there has become a price on pollution that now needs to be included in the profit maximization problem of the firm. The theoretical model is a combination of classic microeconomic producer theory (e.g. Varian 1992) and a model by Bushnell et al. (2013).

Consider a profit-maximizing firm producing the "good" output y, which is a function of inputs x_1 and x_2. In this case the two different inputs may be considered "clean" and "dirty" inputs, so that x_1 could for example be clean inputs (e.g. labor) and x_2 could be fossil fuels. The reason for differentiating these inputs is that it makes it possible for a firm to reduce emissions without having to reduce production, but instead by changing the composition of inputs. The firm's revenue is the output y multiplied with the output price, p. As always the firm faces production costs, which is the level of inputs, x_1 and x_2, times the price of inputs, w_1 and w_2.

So far, the function resembles a regular profit function. However, since this firm is subject to environmental regulation it also needs to take into consideration the cost of its "bad" output, namely emissions. Emissions, e, is a function of the dirty input x_2 and the level of abatement efforts, z. $k(z)$ represent the costs of abatement, which is investments in cleaning technology (this could for example be carbon capture, although it has not yet been an option). The firm is regulated by a cap and trade system, and it may therefore possess emission allowances. The allowances the firm might own, which is the initial allocation before sales and purchases, is a, while the market price of allowances is b. The allocation of allowances is assumed to be exogenous in this model, meaning that a is not a function of y or other variables that the firm can influence. This makes ab the value of permits allocated to the firm, and $be(x_2, z)$ the cost of emissions. Altogether, the profits of a firm in an ETS may be represented as:

$$\pi = pf(x_1, x_2) - w_1x_1 - w_2x_2 + ab - k(z) - be(x_2, z) \quad \text{(Eq. 3.1)}$$

The first order condition with respect to input x_1 is:

$$\frac{\partial \pi}{\partial x_1} = p\frac{\partial f}{\partial x_1} - w_1 = 0 \quad \text{(Eq. 3.2)}$$

By rewriting we get:

$$p\frac{\partial f}{\partial x_1} = w_1 \quad \text{(Eq. 3.3)}$$

Equation 3.3 represent a classic optimization in producer theory; a profit maximizing firm will use the clean input x_1 up until the marginal revenue from the input equals the input price, which is MR=MC.

The first order condition with respect to input x_2 is:

$$\frac{\partial \pi}{\partial x_2} = p\frac{\partial f}{\partial x_2} - w_2 - b\frac{\partial e}{\partial x_2} = 0 \quad \text{(Eq. 3.4)}$$

By rewriting we get:

$$p\frac{\partial f}{\partial x_2} = w_2 + b\frac{\partial e}{\partial x_2} \quad \text{(Eq. 3.5)}$$

From equation 3.5 we see that a profit maximizing firm in an ETS will use the dirty input x_2 up until the revenue per unit of additional input equals the marginal price of the input, w_2, plus the costs of emission per additional unit x_2. In other words, when the firm is deciding how much to use of x_2 in order to maximize profits it now needs to consider the cost of emissions as well, which is the quota price multiplied with emissions.

The last first order condition is found by maximizing profits with respect to abatement, z:

$$\frac{\partial \pi}{\partial z} = -\frac{\partial k}{\partial z} - b\frac{\partial e}{\partial z} = 0 \quad \text{(Eq. 3.6)}$$

By rewriting:

$$\frac{\partial k/_{\partial z}}{-\,\partial e/_{\partial z}} = b \qquad \text{(Eq. 3.7)}$$

The left side of equation 3.7 may be interpreted as a firm's marginal abatement costs (MAC), which consists of both the marginal costs of investments in abatement technology and the marginal reduction in emissions of increasing abatement by one unit. On the right side of the equation we find the quota price, b. According to equation 3.7, a firm in an ETS will therefore reduce emissions until the MAC equals the quota price. This finding follows the intuition from section 3.1.1 and figure 3.1.

All in all, within this theoretical model (eq. 3.1) emissions can be reduced in three ways. First, the firm can reduce output, y, and thereby decrease the dirty input that cause emissions. Second, the firm can replace the dirty input, x_2, with the clean input, x_1, and hence reduce emissions without reducing output. In a more complex model the dirty input could consist of two inputs: one extra dirty input (e.g. coal), and one less dirty input (e.g. gas). In that case, switching between the two dirty inputs could also reduce emissions, which has been a common way of reducing carbon emissions. For simplicity reasons, this option was not included in this model. The third way of reducing emissions in this model is to invest in abatement technology. In practice, CO_2 emission reductions happen mostly through the first two options. While abatement technology has been applied when it comes to other GHG gases (e.g. N_2O), little CO_2 emission reduction is yet happening through investments in abatement technology. Still, it is interesting to include abatement technology in the model, especially since it is likely that it, e.g. carbon capture, will be a viable option in the future.

4. Methodology

The most relevant theory and background material concerning the EU ETS has now been reviewed, and the foundation for further analysis is laid. We will therefore move on to the empirical part of the thesis. Chapter 4 will first present and discuss the data used in the econometric analyses. Second, variables and expectations regarding coefficient signs will be discussed. Last, the econometric methods used will be presented.

4.1. Data

The main purpose of this thesis is to examine the effect the EU ETS has had on Norwegian firms' profitability and emissions. In order to estimate that effect, the counterfactual must be defined, which is what would have happened in absence of the regulation. The true counterfactual is of course unknown, since we cannot observe a firm in two states (regulated and non-regulated) at the same time. The counterfactual can however be estimated using a "treatment" group and a control group (Ravallion 2005). In this case, the treatment group is EU ETS regulated firms and the control group is non-regulated firms, which includes both regulated firms before they became regulated and firms that never have been EU ETS regulated.

The firm level emission data and EU ETS data was obtained from the Norwegian Environment Agency, and the emission data I received from them contained all Norwegian plants with permission to emit CO_2 (which are firms that are both regulated and not regulated by the EU ETS). The emission data was then matched with firm level economic performance data obtained from the database of "Proff Forvalt". All firms could not be matched, i.e. not all firms with permission to emit could be found in the "Proff Forvalt" database, and could thus not be a part of the sample. The reasons behind this are unknown[11], and it is therefore difficult to say whether the left out firms were omitted in a systematic way or not. If there was a systematic underlying reason why

[11] It could be that some annual reports are not publicly available due to various reasons, for example because some plants are owned by the government and therefore falls under national/municipal budgets.

those firms could not be found in the database, it could lead to attrition bias (Ravallion 2005). The same reasoning holds when the issue is missing data, which also a problem in the dataset. Not all firms have complete data for all years, making the dataset unbalanced. Again, this is not a big problem if the reasons why they are missing are unsystematic. In this case, some of the data is missing because all firms did not exist during all 12 years. Some firms went out of business before that (or perhaps merged with another firm), and some did not start operating before after 2001. I can only assume that the startup and closure of firms was random, and that it does not cause attrition bias.

The firm-invariant control variables, which are variables that change over time but are equal for all firms, were attained from two different places. Data on Brent crude oil prices were obtained from the BP Statistical Review of World Energy 2013, while electricity prices are taken from Statistics Norway. Ideally, energy prices should also be at firm level, but this was not publicly available. Electricity prices do however differ between power intensive industries[12] and non-power intensive industries, since firms defined as power intensive are faced with lower electricity prices than other firms. All prices were converted to fixed prices (using the producer price index from Statistics Norway), and prices in foreign currency were converted to NOK using the historical exchange rate.

One of the biggest issues I had when building this dataset was that I was not able to get economic performance data on the same firm level as emission data. A firm may own several plants, and while the emission data was at the plant level, the economic data was at the firm level. The plant level emission data therefore had to be collapsed to the firm level in order to match the financial data, thus decreasing the number of observations. As a result of the mismatch in data, some firms also had to be removed from the sample because they did not fit in either the regulated group or the control group. The reason for this was that they had some plants that were regulated by the EU ETS, while they had other plants that were not regulated. It is therefore difficult to say

[12] Power intensive industry is industry that uses large amounts of electric power in their production, and is in Norway limited to production of pulp and paper, basic chemicals, basic iron and steel products and non-ferrous metal production (e.g. aluminum production)(Holstad 2010).

what the net effect on the entire firm would be. As a rule of thumb I therefore found it best to leave out firms that owned both regulated and non-regulated plants and had less than half of their plants regulated by the EU ETS. Firms were therefore assumed to belong to the treatment group if 50% or more of their plants were regulated[13]. Again, it is assumed that the exclusion was random and thus did not cause attrition bias, though it could be a systematic error since firms with many plants typically tend to be large firms. It is therefore something that needs to be kept in mind when analyzing the results.

The final dataset consist of a panel of 111 land-based Norwegian CO_2-emitting firms in the period 2001-2012, and contain one "treatment group" (firms regulated by the EU ETS) and one control group (firms not regulated by the EU ETS). The distinction between the two groups is represented by the dummy variable *ets*, which is equal to 1 when a firm is regulated and 0 otherwise. The regulated group in the panel stands for about 20% of all CO_2 emissions from land-based plants in Norway (Norwegian Environment Agency 2014). During the four first years of the panel (2001-2004), none of the firms were regulated since this was pre EU ETS. In the first period of the ETS (2005-2007) the panel contains 24 regulated firms, and thus 87 non-regulated firms. As mentioned in section 2.1.2 the firms previously exempted from the ETS due to the CO_2 tax were included in 2008, thus increasing the number of firms regulated. In this dataset 11 more firms were regulated in phase 2, comprising the regulated group to 35 firms out of the total 111 firms. In figure 4.1 allocated allowances and verified CO_2 emissions of the 35 firms in the dataset is shown.

[13] In the dataset, there are 8 firms that have some plants (but less than 50%) not regulated by the EU ETS. I tested the effect of excluding these firms, and it did not alter the main conclusions.

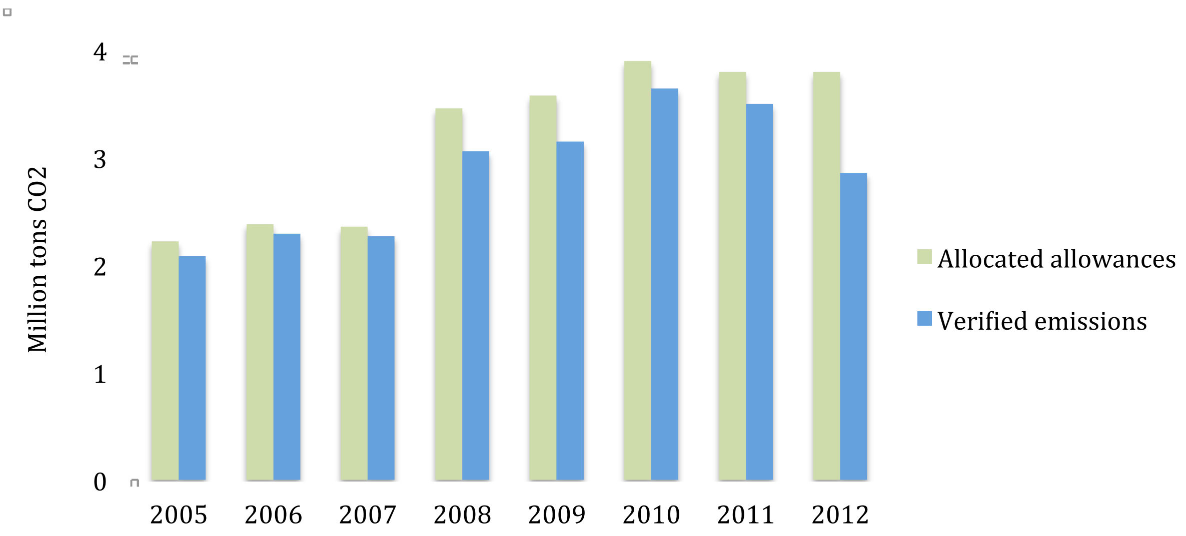

Figure 4.1: Aggregated allocated allowances and verified emissions from EU ETS regulated firms in the data sample, 2005-2006, in million tons CO_2

When comparing figure 4.1 to figure 2.1 and 2.2, which displays all of the regulated land-based firms in Norway, it is visible that the sampled firms differ some from the overall picture. While 2005-2007 looks quite similar, the sampled firms are aggregately net long of permits in the second trading period, while the overall firms in figure 2.2 are aggregately net short. The reason for this is probably that a lot of the firms that I was unable to find sufficient data[14] on belonged to the two-digit NACE code 35, which is "electricity, gas, steam and air conditioning supply", and most of the firms within that group are EU ETS regulated. This is a flaw in the dataset, since it makes this sector underrepresented. As a result, the dataset might suffer from attrition bias and the results of the econometric analysis might not be transferrable to the entire group of EU ETS regulated firms. If figure 4.1 is divided up into sectors (figures are enclosed in appendix A), we find that the "electricity and heat" sector has overall been a net buyer of permits. If this result is transferable to the entire power sector in Norway, it is clear that the underrepresentation of it in the data sample is what is causing figure 4.1 to be different from figure 2.2.

The sectorial distribution of all firms in the panel is shown in table 4.1. Using two-digit NACE Rev. 2 code, firms in the panel have been categorized into seven different industry

[14] For many of these firms I was only able to find emission data from 2008-2012, but not any on economic performance or emissions prior to 2008. This would not be enough for the analysis (since STATA would see it as missing data and omit the observations anyway), so I had no choice but to leave those firms out.

sectors. Since Norway is a small country, the number of regulated firms is not high (particularly since the panel is at firm level instead of plant level), and I therefore included firms from all sectors with permission to emit CO_2 to get the largest possible sample. As a result, two industry sectors do not contain any EU ETS regulated firms. The control group should ideally be similar to the treatment group in order to get correct estimates, and with the sectorial distribution below it could be problematic. I will however perform additional regressions using just the industries containing regulated firms, as a robustness test. If the results are similar the sectorial differences are probably not that big, which would mean that the entire sample could be used.

Table 4.1: Sectorial distribution of CO_2-emitting firms in the dataset

Industry	NACE codes	Frequency (%)	# of firms	# of ETS regulated firms
Mining	07, 08	3.60	4	0
Food and textiles	10, 11, 13, 14	20.72	23	5
Wood, pulp and paper	16, 17	9.91	11	9
Chemicals and pharmaceuticals	20, 21	22.52	25	8
Metals and minerals	23, 24, 25	29.73	32	9
Other manufacturing	30, 32	6.30	7	0
Power production and waste	35, 36, 38	8.40	9	4
Total		**100**	**111**	**35**

From table 4.1 we see that the largest industry within the panel is "metals and minerals", covering almost 30% of sampled firms. Other industries that are highly representative are "food and textiles" and "chemicals and pharmaceuticals". Within each industry sector there is an overweight of non-regulated firms, except for "wood, pulp and paper" where nine out of total eleven firms are EU ETS regulated.

4.2. Variables and model specification

The variables that were found relevant for the econometric models are displayed in the table 4.2, together with the expected coefficient signs. The choice of variables is discussed further in sections 4.2.1 and 4.2.2.

Table 4.2: Description of variables to be used in the econometric analysis

Variable	Description	Exp. effect on profitability	Exp. effect on absolute emissions	Exp. effect on emission intensity
pm	Profit margin	Dep. variable	Not used	Not used
roa	Return on assets	Dep. variable	Not used	Not used
emis	Absolute CO_2 emissions	Not used	Dep. variable	Not used
emisint	CO_2 emission intensity	+/-	Not used	Dep. variable
ets	Dummy variable for EU ETS	+/-	-	-
empl	Number of employees	+	Not used	Not used
emplint	Employment intensity	Not used	-	-
revenue	Operating revenue	Not used	+	Not used
ci	Capital intensity	+/-	+	+
oilp	Brent crude oil prices	-	-	-
elprice	Electricity prices	-	+/-	+
ind1	Industry dummy for "mining"	+/-	+/-	+/-
ind2	Industry dummy for "food and textiles"	+/-	+/-	+/-
ind3	Industry dummy for "wood, pulp and paper"	-	+/-	+/-
ind4	Industry dummy for "chemicals and pharmaceuticals"	+/-	+	+/-
ind5	Industry dummy for "metals and minerals"	+/-	+	+/-
ind6	Industry dummy for "other manufacturing"	+/-	+/-	+/-

In the regressions, log-log model will be used when investigating emissions, meaning that all variables (except dummy variables of course) will be taken the logarithm of.

This is convenient, since the coefficients then can be interpreted as direct elasticities. In addition, when plotting the variables in a Kernel density estimate it was clear the logarithmic variables followed a much more normal distribution. When analyzing the effect of EU ETS on profitability, a lin-log model will be used, meaning that only the right side of the equation will be logarithmic. This is because the dependent variables *pm* and *roa* have some negative values and can therefore not be log-transformed.

In table 4.3 we see the descriptive statistics of the dependent and independent variables, with mean, standard deviation, minimum and maximum values. We see that the variables have the expected range, but there are substantial differences among firms. This is reflected in the min/max values and the large standard deviations.

Table 4.3: Descriptive statistics of relevant variables, except dummy variables. Prices are in NOK, and revenue is in 1000 NOK.

Variable	Mean	Std. deviation	Min. value	Max. value
pm	5.334	17.500	-293.107	71.257
roa	9.828	16.152	-171.4	133.5
emis	93080	341014	0.1	6036000
emisint	0.141	0.968	6.07e-07	30.927
empl	437.266	1967.271	2	61164
emplint	0.0013	0.0177	0.00002	0.6035
ci	2117.427	6559.008	1.3529	116362
oilp	308.335	73.342	204.97	411.93
elprice	18.189	4.429	10.77	26.57
revenue	1265702	3752603	305.793	4.83e+07

4.2.1. Model specification and expectations when examining profitability

When estimating the effect of the EU ETS on firms' profitability two different outcome variables are used: profit margin and return on assets. These are time- and firm variant, and the same independent variables are used for both models. For simplicity reasons, a linear relationship between the parameters is assumed (an assumption that will be tested later). The lin-log model explaining firms' profitability can thus be expressed in the following matter:

$$\boldsymbol{Y}_n = \beta_0 + \delta_0 ets_{it} + \beta_1 lnempl_{it} + \beta_2 lnci_{it} + \beta_3 lnemisint_{it} + \beta_4 lnoilp_t + \beta_5 lnelprice_t + \delta_1 ind2_i + \delta_2 ind3_i + \delta_3 ind4_i + \delta_4 ind5_i + \delta_5 ind6_i + \delta_6 ind7_i + u_t$$

where $\boldsymbol{Y}_n = pm_{it}, roa_{it}$

In addition to the variables above, year dummies will be added and tested for statistical significance. Year dummies for each period control for changes over time that affects everyone in the sample, and is often recommended in panel data regressions (see e.g. Wooldridge 2002). In this setting it could for example be the financial crises, and it thus seems reasonable to include in the model. Since the year dummies capture changes in the macro environment, it is difficult to state expectations about the coefficients. It might also be that the year dummies overlap with energy prices, since they are both capturing the firm-invariant changes over time. This would especially be the case with oil prices, since this variable is completely firm invariant. One year dummy is left out, here 2001, in the regression to avoid perfect collinearity, and that year is used as the benchmark for the other years.

The rest of chapter 4.2.1 will discuss the choice of variables included, and the expected signs of the coefficients of independent variables.

Profit margin

One of the dependent variables used when investigating the effect of the EU ETS on Norwegian firms' profitability is the profit margin, which is a common measure of profitability. The profit margin is a measure of how much of the revenue that translates into profits, with the following formula:

$$Profit\ Margin = \frac{Profit}{Revenue} \cdot 100\%$$

Profit is here defined as the earnings before interest and taxes (EBIT), also called operating income or operating profit. If the profit margin of a firm is for example 10% it means that the profit represents 10% of the total revenue. A profit margin of 3-4% is considered satisfying, and it is considered very good if it is above 7% (Hoff & Bjørnenak 2010). The average annual profit margin of firms in the panel used in this thesis is 5.3%, with a range from -293.1% to 71.3% (c.f. table 4.3).

Return on assets

The second profitability measure and dependent variable used is return on assets (ROA), which also is a key figure in profitability analyses. ROA can be calculated the following way, where average total assets is the sum of total liabilities and equity:

$$ROA = \frac{Profit\ before\ tax + interests}{Average\ total\ assets} \cdot 100\%$$

ROA therefore expresses the profit a firm generates as a share of its total assets, and the higher this share is the more profitable the firm is. While the acceptable value for ROA depends on the industry, a rule of thumb is that is should be above 5% (Hoff & Bjørnenak 2010). In the data sample the average annual ROA is 9.8, with a range from -171.4 to 133.5.

EU ETS dummy

The first, and most important for this research, explanatory variable is the EU ETS dummy. Following the intuition from section 3.2, it is possible that some firms have profited from being regulated by the EU ETS. The regulated firms have received, perhaps too generously (cf. findings for Europe in the first phase by e.g. Ellerman & Buchner (2008)), free emission permits that they have been able to sell in the market if they had excess permits. If most of the regulated firms have been subject to an "over-allocation" of permits, the coefficient sign would be expected to be positive, or at least neutral. However, there is little doubt that the ETS have had a negative effect on some firms' profitability, and it is difficult to tell how many firms it concerns. The net effect of the ETS on firm's profitability could therefore go both ways.

Considering previous research on European firms (cf. section 2.2), it is most likely that the EU ETS have not had a significant impact on profitability. If the recent qualitative study by Holm et al. (2014) is taken into account as well, where Norwegian firms stated that they were cautious about selling excess permits, it is less likely that firms have profited from the regulation. If firms do not sell their excess permits, additional profit due to regulation will most likely not be generated[15], probably making the regulation profit-neutral. All in all, the coefficient sign of the EU ETS dummy could be both negative and positive, but given previous research it is expected to be small and perhaps insignificant.

Employees

The number of employees can be a measure of firm size, and is therefore an important and commonly used determinant of firm performance. Beard and Dess (1981) for instance, argued that firm size is one of the most influential variables in explaining firm profitability (in that paper measured as return on total investments and on equity), and states that the correlation generally is positive. While it is not always the case, larger firms are presumed to be more profitable. The sign of the coefficient of *lnempl* is therefore expected to be positive.

Capital intensity

Capital intensity (K/L) is here defined as the ratio of total annual fixed assets to the number of employees. If a firm is capital intensive, it is more dependent on expensive equipment and raw materials to produce output, rather than labor. The higher the ratio between fixed assets and labor, the more capital intensive a firm is. Since the panel in this case consists of industrial firms, it is reason to believe that most firms are relatively capital intensive. Still, there are big differences among firms, and capital intensity is therefore considered an important explanatory variable. Whether the relationship between capital intensity and profitability is positive or negative, is however unsure. According to Beard and Dess (1981) the correlation is usually negative, but they also report that some studies have shown a positive relationship. The expectations are therefore ambiguous.

[15] This would depend on how the banked permits are included in the firms' accounts. If it is considered as some kind of "unrealized" revenue, the excess permits would have the same positive effect on profits as if they had been sold on the market.

Emission intensity

In this paper, CO_2 emission intensity is defined as the ratio of a firm's annual CO_2 emissions to its annual revenue. That is:

$$Emission\ intensity = \frac{Absolute\ emissions}{Revenue}$$

Ideally, emission intensity should be the ratio of emissions to the production level (output), but since I was not able to get such data revenue is used as a proxy for activity level. One problem with using revenue as the denominator is that the EU ETS may have affected revenue per output, which could lead to endogeneity issues in the model. However, one of the panel data regression methods that will be used (FE) tolerates to some degree endogeneity, so it might not necessarily lead to any bias. Another alternative to using revenue as the denominator could be to use energy use as a proxy instead. We would then get the carbon intensity, which would not capture the effects of reducing energy per produced unit that we get by using revenue as proxy. Revenue was therefore considered the most appropriate proxy for production level in this case.

Expectations regarding the sign of the coefficient are ambivalent here as well. While more polluting firms are often "richer" than less polluting firms, which would imply a positive relationship, it does not automatically reflect the profitability of a firm. More efficient firms might be more profitable as well.

Oil prices

Since the data set only contain land-based industry, oil prices are considered inputs to firms, and therefore represent costs. When the price of an input increases, it is expected to have a negative effect on the profitability. It is however important to notice that oil price development is usually positively correlated with the overall economic performance in Norway, since Norway in total is an oil supplier. Thus, the effect on firms' profitability might be uncertain. Also, as mentioned earlier, it would be better to have oil prices on firm level instead of them being firm invariant, but that data was not publicly available. The overall prices of oil were therefore included instead as a proxy variable for fossil fuel prices, as it was considered important when looking at industrial firms' behavior.

Electricity prices

As with oil prices, electricity prices are for most firms in the sample considered as an input cost and the coefficient sign should therefore be expected to be negative. However, for power producers it is the price of their output and the price of electricity should therefore be correlated positively with profitability for those firms. Nevertheless, since power producers only make up a small part of the panel (cf. table 4.1), the positive effect of electricity prices is not expected to outweigh the negative effect.

Another interesting aspect about electricity prices is that it is often correlated with EUA prices, at least in the EU. Several studies, e.g. Kenber et al. (2009) and Holm et al. (2014), have shown that the increased electricity prices, due to the passing on of CO_2 costs onto the consumers by the power generators, have a larger effect on a firm's performance than the actual EUA price. This is especially the case for industries that require large amounts of electric power in their production, which is mainly the aluminum industry (Holm et al. 2014). In that case, the indirect effect of the EU ETS on electricity prices could be contributing to a negative coefficient sign. Nevertheless, it is questionable how big this effect has been in Norway, since most of the electricity produced stems from renewable hydropower and not fossil fuels. The electricity market in Norway is however partly connected to the EU market, so the increased electricity price in EU countries due to the ETS might have spillover effects in Norway as well.

Industry dummies

Since the panel consist of a rather diverse specter of firms, it is important to include industry dummies in order to correct for this diversity. Without these, the ETS dummy might capture an effect that in reality is due to the sectorial differences rather than the "treatment effect" of firms being regulated by the ETS. One industry dummy (here, *ind7*) is left out in the model, in order to avoid the "dummy variable trap", which is perfect collinearity. The industry dummy for "power production and waste" (*ind7*) is therefore functioning as the benchmark, meaning that the other industry dummies will be measured against it. The industry sectors, which are the same as in table 4.1, are relatively wide and it is therefore difficult to have any expectations about the signs of coefficients, especially since it is compared to the benchmark industry. However, one might expect the "wood, paper and pulp" industry to have a negative coefficient, since the industry has generally been suffering economically for several years.

4.2.2. Model specification and expectations when examining emissions

When investigating the effect of the EU ETS on firms' CO_2 emission levels, two different outcome variables will be looked at: absolute emissions and emission intensity. It is relevant to look at emissions in absolute form, because the main target of EU ETS is to decrease emissions in absolute terms. It is however also important to analyze the effect on emission intensity, since it gives us a more realistic picture of emission reduction efforts among firms. Again assuming linearity in the parameters, the log-log model explaining firms' absolute emissions can be expressed as:

$$lnemis_{it} = \beta_0 + \delta_0 ets_{it} + \beta_1 lnemplint_{it} + \beta_2 lnci_{it} + \beta_3 revenue_{it} + \beta_4 lnoilp_t + \beta_5 lnelprice_t + \delta_1 ind2_i + \delta_2 ind3_i + \delta_3 ind4_i + \delta_4 ind5_i + \delta_5 ind6_i + \delta_6 ind7_i + u_t$$

Since emission intensity is here defined as the ratio between a firm's total CO_2 emissions and their revenue, revenue cannot be included as an independent variable when emission intensity is the dependent variable. The log-log model explaining emission intensity can thus be expressed as:

$$lnemisint_{it} = \beta_0 + \delta_0 ets_{it} + \beta_1 lnemplint_{it} + \beta_2 lnci_{it} + \beta_3 lnoilp_t + \beta_3 lnelprice_t + \delta_1 ind2_i + \delta_2 ind3_i + \delta_3 ind4_i + \delta_4 ind5_i + \delta_5 ind6_i + \delta_6 ind7_i + u_t$$

The rest of section 4.2.2 will discuss the choice of variables and expected coefficient signs in the two models above. Definitions of the dependent variables will not be specified, since they were defined in section 4.2.1.

EU ETS dummy

The entire purpose behind the EU ETS is to reduce CO_2 emissions, and solely based on that we should expect significant negative coefficient signs of the EU ETS dummy on both absolute emissions and emission intensity. However, the size and significance of that negative effect is rather uncertain. First of all, since Norwegian firms are allowed to trade permits freely within the EU, it could be that emission reductions have not been that noticeable. Especially since the permit prices have generally been low, it might have been cheaper for many firms to buy permits from abroad rather than abate themselves. Second, there has been evidence of over-allocation of permits in the EU, at least in the first trading period (Ellerman & Buchner 2008), which also could reduce firms' incentives to abate. If firms have been allocated permits that exceeds their business-as-usual (BAU) emissions, the EU ETS dummy would most likely be insignificant, as the firms just would have continued their BAU production. However, in periods where the EUA price have been relatively high, for example in 2008, the EU ETS might have provided incentives to reduce emissions for firms with low abatement costs, as they then could have reduced emissions at a lower marginal cost than the price of permits. In that case, the coefficient of both absolute emissions and emission intensity could be negative and significant.

It is also important to notice that the financial crisis could make it harder to isolate the emission effect due to the EU ETS, especially in the case of absolute emissions. If this is not controlled for, a negative ETS coefficient could be due to reduced production because of the crisis rather than due to regulation. This problem is however tried eliminated by including the control group that also went through the financial crisis, although different sectors and firms may have been affected disproportionally. Revenue is therefore also included as an independent variable, to control for production level. Because of this it is more likely that a negative coefficient is actually due to the EU ETS, but there are still many factors affecting absolute emissions, making it difficult to isolate the ETS effect. The real effect may therefore be more visible in the emission intensity model. All things considered, the expected coefficient sign is negative both with absolute emissions and emission intensity. The effect is however expected to be rather small and perhaps insignificant, especially with absolute emissions.

Revenue

As mentioned earlier, revenue will only be used as an explanatory variable when examining absolute emissions, and not emission intensity. Since absolute emissions are a direct result of production, it seemed natural to include a production measure and because data on produced output was not available, revenue is used as a proxy. Since higher production is assumed to increase emissions, the relationship between revenue and absolute emissions is expected to be positive. It is however important to notice that a firm could also decrease emissions without decreasing production, by instead changing the input factors from dirty to more clean inputs. Larger, and then often richer, firms could also be able to use more efficient fuel than smaller firms, making them cleaner and less polluting. Still, the coefficient sign of *lnrevenue* is expected to be positive.

One problem with controlling for revenue, is that the effects of the ETS on emission reductions du to output reductions are not captured. Some firms could have reduced their production in order to meet the regulation instead of changing input factors (perhaps that option was not possible, or it would be too expensive), and this effect would then not be captured by *ets*. I will therefore run an additional regression where revenue is excluded, to test if the ETS dummy changes significantly by doing so. It is also important to perform an estimation without revenue in order to separate absolute emissions more from emission intensity, since revenue is also used as proxy for output when calculating emission intensity.

Capital intensity

The more capital intensive a firm is, the more machines and other equipment it owns relative to other inputs. A higher capital intensity generally implies increased emissions, and the relationship between capital intensity and absolute CO_2 emissions is therefore expected to be positive. Several studies (e.g. Cole et al. 2005) can back up this argument; industries that are more capital intensive generate more pollution than labor intensive industries. The same argument also applies to emission intensity, and a capital-intensive firm is expected to have higher emission intensity than a labor-intensive firm.

Employment intensity

When investigating absolute emissions and emission intensity, employment intensity is included as a determinant instead of employees. Here, employment intensity is defined as the ratio of workers to the firms' revenue, and is therefore partly an inverse to capital intensity. Employment intensity is first and foremost included in the absolute emissions model, because revenue and employees both represent the size of a firm and are thus highly correlated. Employment intensity and revenue is also correlated to a certain degree[16], but it is still a better alternative. Another reason for including employment intensity, in both emission models, is the same reason as why revenue may be problematic in the model (cf. section above about revenue). Since the number of employees can be seen as a measure of firm size we would also here control for "production level", so that the emission reductions achieved by reducing output would not be captured by the EU ETS dummy.

Workers can be seen as a substitute for capital, and capital is often positively correlated with energy and emissions. Therefore, if employment intensity increases emissions and emission intensity is expected to decrease. However, it might be that this effect is not so visible in this dataset, since we are looking at industrial firms that most likely are all quite capital intensive, but the coefficient is still expected to be negative.

Oil prices

Since oil prices here represent fossil fuel prices, this variable represents the cost of the dirty input that produces carbon emissions (w_2 in the theoretical model in section 3.2.2). It is therefore expected to have a negative relationship with both absolute emissions and emission intensity, since an increase in fossil fuel price would lead to increased production costs. When production costs increase due to fossil fuel price, the firm could either decrease production (since profit maximizing would give a lower optimal production level), or substitute the dirty input with a cleaner, less expensive, input. If a firm decreases production, without changing the input mix, it would yield lower absolute emissions, but the emission intensity would stay the same. However,

[16] The correlation between employment intensity and revenue is -0.45, while it is 0.85 between employees and revenue (see appendix B for correlation values between other variables as well).

since we correct for revenue in this model, the output reduction effect would not be visible in the oil price variable, but it would be evident in the model without revenue (cf. section about revenue). If a firm would change the input mix instead of reducing production, by substituting fossil fuel with a cleaner energy input (e.g. biofuel or perhaps electricity), it would yield a reduction in both absolute emissions and emission intensity. All in all, depending on the elasticity of energy prices for firms, the coefficients of oil price is expected to be negative.

Electricity prices

Although the production of electricity might not be clean, it may be considered a clean input for industrial firms compared to fossil fuels. Electricity could therefore in some cases work as a clean substitute for dirtier inputs, such as coal. In that case the coefficient would be positive, as a decrease in electricity price could decrease dirty inputs and thus change the input mix. This would decrease both absolute emissions and emission intensity. However, it might not be very likely that electricity can often work as a substitute for fossil fuels among the industrial firms as there may be lock-in on dirty fuel, at least in the short run. It is therefore questionable if there is a significant effect of electricity prices, but the coefficient sign would most likely be positive.

Industry dummies

Following the intuition from the section about industry dummies in chapter 4.2.1, it is generally difficult to establish expectations about the signs of their coefficients. However, when it comes to absolute CO_2 emissions, sectorial distributions of historical emissions could give a clue. Of land-based industry in Norway, it is the metal industry, followed by the chemical industry, that have had the highest CO_2 emissions (NVE Rapport 69/2013). Therefore, it is realistic to expect that the coefficients of *ind4* and *ind5* should be positive when estimating the effect on absolute emissions. When estimating the effect on emission intensity it is however more difficult to predict signs of coefficients, since it is also dependent on the production level.

4.3. Econometric methods

As mentioned, the data sample used in this thesis is a short unbalanced panel data set, describing 111 Norwegian firms over a time period of 12 years. Since panel data describes different units over time, heterogeneity is often inherent in the data set. This means that each unit has some unobserved characteristics, which generally is time-constant, that affect the outcome variable in all time periods. If this unobserved heterogeneity is not corrected for, it will lead to biased estimates (Wooldridge 2002).

Generally, an Ordinary Least Squares (OLS) regression is the starting point of any econometric analysis. This is also the case with panel data, only here the error u_{it} is likely to be correlated over time for each unit, and cluster-robust standard errors that cluster on the individual (here: firm) is therefore essential to use. A pooled OLS regression will also be the starting point in my analysis, with some post-estimation tests checking for linear functional form and the presence of unobserved heterogeneity. I will not test for heteroskedasticity and serial correlation, since it is often assumed in panel data. Cluster robust standard errors are therefore automatically used, which are robust against any type of heteroskedasticity and serial correlation (Wooldridge 2002).

If there are unobservable firm specific effects (unobserved heterogeneity), they will be a part of the error term, and they will most likely be correlated with the explanatory variables. If this is the case, we have a violation of one of the key assumptions in the classical linear regression model; the error term cannot be correlated with the explanatory variables. As a result, pooled OLS will give biased and inconsistent estimates. Other panel data methods, which take unobserved effects into consideration, are therefore needed. Fixed effects (FE) and random effects (RE) models are the most commonly used methods, and it is these methods that will be used in this thesis.

The FE model removes the unobserved effect by time-demeaning the variables, meaning that each variable is expressed as the deviation from its mean value, and then the time-demeaned variables are estimated using a pooled OLS (Wooldridge 2002). One big advantage with FE is that it allows the now time-invariant unobserved effect to be correlated with the explanatory variables, and thus allowing for limited endogeneity(Gujarati & Porter 2009). This is not the case with RE, which will be returned to in the next section, making FE more robust than RE. However, FE has one big drawback as well, which is that time-invariant variables are excluded from the regression. This makes sense since the unobserved effects can be correlated with the explanatory variables; it is impossible to differ the time-invariant observable (explanatory) variables from the time-invariant unobservable effects (since it is assumed that these are fixed). The exclusion of time-invariant variables is a weakness when it comes to our model, because the industry dummies will then be removed from the regression. RE regressions will therefore also be used.

RE estimation is done by a feasible generalized least-squares (FGLS) estimator, which accounts for the unobserved heterogeneity by letting each firm has its own intercept value. In the RE model, the unobserved effect is assumed to be purely random, unlike the FE model where it was assumed to be fixed. While this is a more realistic assumption since it makes more sense that it is random (Wooldridge 2002), it also comes with a stricter assumption than in the FE model; it implies that the unobserved effects are uncorrelated with the explanatory variables. Another assumption of the RE estimator is that it is assumed that the sample is a drawing from a larger population of firms. Since there might be a problem with attrition bias in my dataset, this assumption may be difficult to satisfy and FE might be more appropriate.

The Hausman test, which is a method for choosing between FE and RE, will be performed for each econometric model. The null hypothesis is that there is no systematic difference between RE and FE results, implying that the error term is not correlated with the explanatory variables. If the null hypothesis is not rejected, RE estimates can be used and are consistent and efficient. FE estimates are also consistent if it is not rejected, but they will not be efficient. If the null hypothesis is rejected, FE is most appropriate (Cameron & Trivedi 2010; Wooldridge 2002).

5. Results and discussion

As mentioned in chapter 4, it is likely that there are unobserved firm-specific effects in the panel. In that case, the pooled OLS estimates will be biased. I started performing pooled OLS regression on the four models, and the results are shown in appendix B (table B.2–B.5). Afterwards, I predicted the residuals of the OLS models, and then added the lagged residuals to the original model. This is a way of testing for serial correlation, which is a good indicator of firm-specific effects (Wooldridge 2002). If the lagged residuals turn out to be statistically significant, there is most likely serial correlation and unobserved heterogeneity in the model. In this case, the lagged residuals were highly significant in all four models. I therefore found it necessary to estimate the models using fixed effects and random effects estimators.

In order to test for model specification (whether a linear relationship between the parameters is a valid assumption or not), I created quadratic variables and included them in the FE regressions. This is one way of testing for functional form in panel data (Wooldridge 2002), and if the non-linear variables turn out to be statistically significant the model may have a problem with linearity. These test results are attached in appendix B (table B.6-B.9), and the quadratic variables are all over not significant. I therefore assume that there is not a big problem with functional form, and that using a model that is linear in parameters does not lead to any bias.

When discussing the results I will report results from both FE and RE, since they both provide insights that the other does not, especially when it comes to the time-invariant industry dummies.

5.1. The effect of EU ETS on firms' profitability

In this section results regarding firms' profitability will be presented. First, the results of the model using profit margin as the dependent variable will be discussed, and last the results using return on assets as the dependent variable is discussed. The results of fixed effects and random effects specifications are displayed in tables, with coefficient value, significance level and cluster-robust standard errors in brackets. In the bottom of the tables the R^2 value, number of observations (N) and the p-value of the Hausman test are reported. Coefficients of the year dummies will not be displayed, but it is commented on in the tables whether they are jointly statistically significant or not.

5.1.1. Profit margin

Table 5.1: Estimation results with profit margin as dependent variable

Variable	Fixed effects	Random effects
ets	0.9837 (1.8954)	2.2508 (1.8402)
lnempl	-7.0159 (5.6303)	-2.4101 (2.3049)
lnci	-2.2580 (2.2608)	-1.5571 (1.6218)
lnemisint	-0.8672* (0.5467)	-0.9944* (0.5228)
lnoilp	(omitted)	-5.5985 (3.9416)
lnelprice	-5.2910 (4.8421)	-3.6263 (4.1449)
ind1	(omitted)	-2.2469 (10.0368)
ind2	(omitted)	-13.5778* (8.3115)
ind3	(omitted)	-17.1341** (8.6616)
ind4	(omitted)	-18.4095* (10.1059)
ind5	(omitted)	-11.5163 (8.3617)
ind6	(omitted)	-24.0042*** (9.2996)
R^2	0.0476	0.0334
N	1065	1065
Year dummies	Insignificant	Significant
Hausman	p-value 0.0012	

* significant at 10%   ** significant at 5%   *** significant at 1%

First of all, it is obvious from table 5.1 that the R^2 is very low in both FE and RE, with respectively a percentage value of 4.76% and 3.34%. This means that the model is explaining little of the variation in the dependent variable, *pm*. However, while a low R^2 could imply a weakness in the model, it does not necessarily mean that the model is bad. In this case, the dependent variable is very complex; there are so many factors affecting firms' profitability. In addition, these factors could be affecting each firm differently. It is therefore common in cross-section data to have a relatively low R^2, and since panel data is cross-section data over time I do not consider it a big problem. According to the Hausman test the FE model is most appropriate, and the FE estimates should therefore be given more weight than the RE estimates.

The main variable of interest, *ets,* is positive but statistically insignificant in both FE and RE (with p-values of respectively 0.6 and 0.2). I did not have any particular expectations regarding the coefficient sign, since it could go both ways. The coefficient value of *ets* is 0.9837 in FE model, and 2.2508 in RE model. If the estimated parameter is correct, it would imply that the EU ETS has had a positive effect on profit margin corresponding to approximately one percentage point using the FE estimate (which the Hausman test suggests as the most appropriate estimate). The result is however uncertain, given the insignificance of the coefficient. One reason why the result is insignificant could be that the effect on profit margin may differ across firms and sectors. Some sectors might have profited, while others might have suffered from the regulation, making the net effect ambiguous and insignificant. An additional regression was therefore performed with interaction dummies, where the EU ETS-dummy was multiplied with the industry dummies, to see if the ETS effect differs across the industry sectors. The result is included in appendix B, in table B.11. Few of the interaction dummies are statistically significant, but according to FE it looks like firms in the "chemical and pharmaceuticals" and "power and waste" industries have benefited more from the EU ETS than firms in the "wood, pulp and paper" and "metals and minerals" have.

There are few statistically significant coefficients in the main model, especially in the FE estimation where *lnemisint* is the only significant variable. The coefficient of *lnemisint* is negative and significant at the 10% level, with a coefficient value of -0.8672. Since this is a lin-log model it means that when emission intensity increases by 1%, the profit margin will decrease by 0.0087 percentage points[17], keeping other variables constant. The expectations regarding sign of this coefficient were ambiguous, so the result does not confirm or disprove the expectations. All variables have expected signs, except for employees (*lnempl*), which I expected to be positive. It is however statistically insignificant, so there is really no point in discussing the parameter sign.

Oil prices are omitted in the FE model (and all the other FE models to come) due to collinearity, when the year dummies are included. If the year dummies are taken out, the coefficient of *lnoilp* is estimated and of similar value to the RE estimate. As mentioned briefly in section 4.2.1, the reason why oil prices are omitted in FE might be that the observations are highly correlated with the year dummies (i.e. that the time dummies is catching the effect of oil prices), and the FE estimator might therefore see a time-invariant effect in the oil price variable. This shows that it would be better with energy prices at the firm level. However, since the coefficient is not significant, I do not consider it a big problem that it is omitted.

It is also visible that the industry dummies are important to the model, with four out of six industry dummy variables being statistically significant. The signs of the coefficients are negative, implying that the "power and waste" industry is more profitable than the other industries in the sample. According to the estimates, it is "other manufacturing", "wood, paper and pulp" and "chemicals and pharmaceuticals" that are the least profitable. The year dummies are jointly statistically significant, but individually it is only 2004 that is significant (and positive), which means that the overall profitability was higher in 2004 than in the base year 2001.

[17] In lin-log models, the log-transformed coefficient needs to be divided by 100 to get the correct interpretation. This is not the case with dummy variables, since they are not log-transformed. Dummies are therefore interpreted directly as unit change.

5.1.2. Return on assets

Table 5.2: Estimation results with return on assets as dependent variable

Variable	Fixed effects	Random effects
ets	1.9437 (2.0647)	2.0981 (1.8163)
lnempl	-0.8060 (1.3840)	0.10138 (0.6614)
lnci	-0.8874 (1.2062)	-0.8783 (0.6730)
lnemisint	-0.7641* (0.4703)	-0.7333** (0.3266)
lnoilp	1.4143 (1.8639)	-1.6931 (3.1438)
lnelprice	-3.1517 (3.1196)	-0.7806 (2.7431)
ind1	(omitted)	5.1023 (7.3769)
ind2	(omitted)	-0.9500 (3.0961)
ind3	(omitted)	-7.6377* (4.6565)
ind4	(omitted)	-4.0418 (3.2268)
ind5	(omitted)	-3.9733 (3.1296)
ind6	(omitted)	-12.6796*** (3.8936)
R^2	0.0285	0.0798
N	1067	1067
Year dummies	Insignificant	Insignificant
Hausman	p-value 0.5678	

* significant at 10% ** significant at 5% *** significant at 1%

As with profit margin in the last section, the R^2 is really low and there is only one statistically significant variable in the FE estimation (which again is emission intensity). However, the Hausman test implies here that it is the RE that is the preferred method. Since the estimated coefficients are quite similar in both methods, I consider the RE estimates to be consistent and efficient. The R^2 is a bit higher in RE as well (almost 8%), probably due to the industry dummies, but the model still explains little of the variation in the dependent variable, *roa*.

The EU ETS dummy is not statistically significant in this model either, with a p-value of 0.35 in FE and 0.25 in RE, but the sign of the coefficient is still positive. The coefficient value of *ets* in RE is 2.0981, indicating a relatively large positive effect on profitability. However, since the p-value is 0.25, we cannot reject the null hypothesis that the coefficient is equal to zero, and the result can thus not be trusted. Still, it is reasonable to conclude that there is a bigger chance that the effect of EU ETS on firms' ROA has rather been positive than negative. As mentioned when discussing the result of the same variable in section 5.1.1, the reason why the coefficient is insignificant could be due to different effects among sectors. When adding the interaction dummies (cf. section 5.1.1 and appendix B), we get the same results as with profit margin. None are statistically significant, but firms in the "chemicals and pharmaceuticals" industry seem to have been more profitable due to the EU ETS, compared with other industry sectors.

Apart from emission intensity, which is negative and significant at the 5% level in both models (same finding as with profit margin in section 5.1.1), the only significant variables are the industry dummy variables *ind3* and *ind6.* As expected, they are both negative compared to the benchmark *ind7*. The interpretation of this is that the "wood, paper and pulp" and "other manufacturing" industries have lower ROA than the "power and waste" industry. The year dummies are insignificant in both models.

5.2. The effect of EU ETS on firms' emissions

The results of the main estimations using absolute emissions and emission intensity will be presented and discussed in this section. The estimates are displayed in tables 5.3 and 5.4 with coefficient values, significance level and cluster-robust standard errors in brackets.

5.2.1. Absolute CO_2 emissions

Table 5.3: Estimation results with absolute CO_2 emissions as dependent variable

Variable	Fixed effects	Random effects
ets	-0.2528 (0.1649)	-0.0128 (0.1675)
lnrevenue	0.6772*** (0.2098)	0.6021*** (0.1267)
lnemplint	0.3961** (0.1552)	0.2602* (0.1436)
lnci	0.1110 (0.1088)	0.3323*** (0.3266)
lnoilp	(omitted)	-0.0470 (0.4459)
lnelprice	-0.0475 (0.3068)	-0.10978 (0.2973)
ind1	(omitted)	-1.1855* (0.7453)
ind2	(omitted)	-1.6999** (0.6957)
ind3	(omitted)	-0.7081 (0.8097)
ind4	(omitted)	-0.8898 (0.7356)
ind5	(omitted)	0.3574 (0.7447)
ind6	(omitted)	-4.0671*** (0.8638)
R^2	0.0489	0.4012
N	1074	1074
Year dummies	Significant	Significant
Hausman	p-value 0.0000	
* significant at 10%	** significant at 5%	*** significant at 1%

First of all, there is a huge difference in R^2 between the FE model and the RE model in. While the FE model explains approximately 5.5% of the variation in absolute emissions, the RE model explains around 40% of the variation. Since FE excludes time-invariant variables, there is reason to believe that this difference is due to the industry dummies. This shows how important they are to the model, which makes it important to report RE results even though FE is the preferred approach according to the Hausman test.

Second of all, the main variable of interest *ets* is negative and statistically insignificant in both FE and RE. However, the p-value is 0.128 in the FE model, meaning that it is almost significant at the 10% level. I expected it to be negative, but to have low coefficient value and perhaps insignificant, meaning that the EU ETS have had little impact on firms' CO_2 emissions. The coefficient value is however -0.2528, implying that EU ETS regulated firms has approximately 22%[18] lower CO_2 emissions than what they would have if they had not been regulated. This is a very large effect, and it may seem rather unrealistic that regulated firms have reduced their absolute emissions by that much due to the ETS. In comparison, the RE model gives an estimate of -0.0128, which corresponds to a 1.27% emission reduction due to the ETS. This may be a more realistic estimate, especially when considering previous research (e.g. Ellerman & Buchner (2008) who found that EU emissions had decreased 2-5% due to the ETS), in spite of the statistical insignificance of the RE coefficient (the p-value is 0.939) and that FE is the preferred model. However, the RE model controls for the time-invariant industry dummies, which the FE model does not control for. Because of that, the industry effect might have been absorbed by the ETS effect instead, which could be why the FE produces such a high estimate. In that case, we could trust the RE estimate more, in spite of its lack of significance. It might also be that the financial crisis is not sufficiently corrected for, and that a part of the reduction in absolute emissions in FE model is due to the decreased demand rather than the EU ETS (although production level is corrected for by including revenue in the model). Nonetheless, both models point to a reduction in absolute emissions due to the EU ETS, but it is great uncertainty regarding the size of that effect.

As mentioned when discussing the results on profitability, the insignificance of the EU ETS dummy could be due to differences among sectors. Therefore, interaction variables, between EU ETS and industry sectors, were also added to the models examining emissions. The result is included in appendix B, in table B.12. The coefficient for firm in the "metals and minerals" sector is positive and significant at the 1% level in FE, implying that firms belonging to that sector has emitted more than would have without

[18]In order to get the coefficient value of a dummy variable in exact percentage change when the dependent variable is log-transformed, the formula is $(e^{coef}-1)*100\%$. In this case, $(e^{-0.2528}-1)*100\% = -22.24$

the ETS, compared to the benchmark sector “power and waste”. “Wood, pulp and paper” has the only negative coefficient of the interaction dummies, but it is insignificant.

Of the remaining explanatory variables in FE regression, *lnrevenue* and *lnemplint* are the only statistically significant variables. Revenue has the expected coefficient sign, while employment intensity is unexpectedly positive. It was expected to be negative, and it is also a bit odd that it has the same sign as capital intensity (since they are supposed to be almost inverses). *lnci* is significant in RE, but since the Hausman test clearly states that FE is the preferred method, the FE estimates are more trustworthy. The rest of the variables have the expected coefficient signs. The industry dummies in RE regression have all negative coefficients, with the exception of *ind5* that also was expected to be positive. Out of the six industry dummies *ind1, ind2* and *ind6* are statistically significant, implying that the *“mining”*, “food and textiles” and “other manufacturing” industries have lower absolute emissions than the “power and waste” industry. The year dummies are jointly statistically significant both in FE and RE and they have all positive coefficient signs except for 2007 and 2008 in RE. The years that are significant on their own are 2003, 2004, 2005 and 2006 in both models.

As mentioned in section 4.2.2, we will not be able to detect the effect of EU ETS on emission reductions achieved by reduced production level when revenue is corrected for. Therefore, an additional regression was performed with revenue excluded as an independent variable and the result is included in appendix B, table B.10. However, when taking out revenue, the results do not differ substantially, but the EU ETS dummy increases a bit in coefficient value (from -0.25 to -0.29), and becomes statistically significant at the 10% level in the FE model. Some emission reduction has therefore happened through decreased production, but whether this is due to the ETS or e.g. the financial crisis is hard to say. What is also interesting is that employment intensity has the expected coefficient sign (negative) when revenue is excluded, in contrast to the main estimation results. It is however only significant in the RE model, so we cannot really trust the estimate. Nevertheless, this additional regression does not alter the main findings about the effect of EU ETS on absolute emissions.

5.2.2. Emission intensity

The FE and RE estimation results using emission intensity, which here was defined as the ratio of CO_2 emissions to revenue, as the dependent variable is shown in table 5.4. It is easier to estimate the effect of the EU ETS on emission intensity than on absolute emissions, because a lot of factors may influence production. If a firm's CO_2 emission intensity decreases, it is likely to be due to the change of inputs (e.g. from dirtier fuel to cleaner fuel) or investments in abatement technologies.

Table 5.4: Estimation results with emission intensity as dependent variable

Variable	Fixed effects	Random effects
ets	-0.2389 (0.1642)	-0.0016 (0.1672)
lnemplint	0.6411*** (0.1559)	0.5737*** (0.1574)
lnci	0.1096 (0.1166)	0.3058*** (0.1013)
lnoilp	(omitted)	0.0349 (0.4488)
lnelprice	-0.0189 (0.3114)	-0.0489 (0.3020)
ind1	(omitted)	-1.7186** (0.7645)
ind2	(omitted)	-2.0045*** (0.7596)
ind3	(omitted)	-1.1348 (0.8116)
ind4	(omitted)	-1.3570* (0.7645)
ind5	(omitted)	-0.1394 (0.7704)
ind6	(omitted)	-4.4350*** (0.8480)
R^2	0.0604	0.2168
N	1078	1078
Year dummies	Significant	Significant
Hausman	p-value 0.0000	
* significant at 10%	** significant at 5%	*** significant at 1%

As with absolute CO_2 emissions, there is also a great difference in R^2 when analyzing the determinants of CO_2 emission intensity. While the model explains approximately 6% of the variation in emission intensity using the FE estimator, it explains 21.68% of the variation when the RE estimator is used. As mentioned previously, this difference is most likely because of the industry dummies. The p-value of the Hausman test is 0.0000, which strongly indicates that the unobserved firm-specific effects are correlated with the explanatory variables, and the FE estimator is preferred.

The EU ETS dummy is also here negative and statistically insignificant in both models. It is however significant at the 15% level in FE, with a coefficient value of -0.2389. When converted to percentage change (see footnote 18), the interpretation is that regulated firms have 21.25% lower emission intensity than they would without the EU ETS. This effect is also very large, which is not as expected (I expected it to be negative, but quite small and most likely insignificant). As with absolute emissions, the RE estimate might seem more realistic than the FE estimate, although it with a coefficient value of -0.0016 in practice means that the EU ETS have had no effect on emission intensity. Again, the coefficient is overwhelmingly insignificant in RE (p-value is 0.99), so it is beyond logic to discuss the coefficient at all. Still, a model with industry dummies might also be more trustworthy than one without. It also seems more likely that the EU ETS has had little or no impact on emission intensity, rather than it have had a massive impact and reduced emission intensity by over 20%. When adding the interaction variables (see table B.12 in appendix B), we see that "chemicals and pharmaceuticals" and "metals and minerals" have significantly higher effect on emission intensity, while "wood, pulp and paper" has insignificantly lower effect on emission intensity, than "power and waste" due to the EU ETS.

All of the variables have the expected coefficient signs, except for *lnemplint* that is positive. It is also significant at the 1% level in both models, meaning that a higher share of workers compared to revenue leads to increased emission intensity. Capital intensity is positive, and significant in RE with a coefficient value of 0.2060, which is as expected. It is however strange that it has the same sign as employment intensity. Also, all of the industry dummies have negative coefficients, suggesting that the "power and waste" industry has higher emission intensity than all other sectors. The coefficients of *ind3* and *ind5* are however not statistically significant, so these estimates might not be trusted. The year dummies are jointly significant, and all positive, but it is only the years 2003 and 2005 that have partial significance.

5.3. Robustness tests

Four additional robustness tests were performed, in order to check if the main estimation results are valid. The regression outputs, using FE and RE, from these tests are attached in appendix C, and the results will be briefly discussed in this section.

Estimations with lagged independent variables

The first robustness test is regressions with lagged (*t-1*) independent variables (except for industry dummies and year dummies). The lagged variables were included partially to avoid the potential problem of reversed causality that can occur when both dependent and independent variables are in time *t*, and partially because some variables (especially energy prices) might be "sticky" or inelastic in the short run. The effect of the EU ETS could also be sticky in the sense that it might take some time before the real effects of regulation are visible. For example, a firm does not necessarily have to sell their excess permits in the same year they are allocated. Hence, the gains from trade might come later in time. A sticky regulative effect could also be the case with emissions, even though an overall cap is set in an ETS. Abatement technology or the switching between dirty and less dirty fuel could also take time, and the effects of regulation might therefore not be visible instantly.

When comparing the results with lagged independent variables to the main estimation results showed earlier in chapter 5, there are overall no big changes. Some variables become more significant (especially when estimating the effect on emissions) and some lose their significance, but there is little change in coefficient signs. The most interesting findings from the lagged models are probably that the electricity price becomes highly statistically significant (and negative) in all profitability models, and that the EU ETS dummy is significant (and still positive) at the 10% level in RE when profit margin is the dependent variable. However, since the RE model may not be trusted this result must be taken with a grain of salt. The ETS dummy also becomes significant at the 10% in FE models of both absolute emissions and emission intensity. Allover, the results of the lagged models do not alter any of the conclusions drawn previously about the main estimation results.

Estimations of only the second EU ETS period

Since the first phase of the EU ETS was in fact a trial phase, and since Norway did not become fully integrated in to the system until 2008, I found it reasonable to test the effect of just the second phase. It is well documented (e.g. Ellerman and Buchner 2008) that the allocation of allowances in the trial phase was a bit to generous, so it is interesting to see if the effect found on profitability was only a result of over-allocation the first three years. Since banking of allowances were not allowed in the first phase, firms would not be able to transfer the permit value (and thus perhaps profitability) from the first phase to the second phase, which makes it even more relevant to test the only the effect from 2008-2012.

Furthermore, since the cap on emission was tightened in the second phase (cf. section 2.1.2), it could be that the negative effects found on emissions are mostly results of the second phase. In that case, when "ignoring" the first phase in the regression, we could a see stronger effect of the EU ETS on both absolute emissions and emission intensity.

When comparing this robustness test, where the EU ETS dummy is only equal to 1 when a firm is regulated in the second period, to the main estimation results the resemblance is striking. The coefficient value of the EU ETS dummy has increased in all estimations, but it is still positive and insignificant when examining profitability. Hence, it does not look like the positive effect found in the main estimation was just a result of the first phase. The EU ETS dummy is also still negative when looking at emissions, but there it has become more significant as well. In FE it is actually significant at the 10% level with absolute emissions as dependent variable, and significant at the 11% level when examining emission intensity. Apart from that, the estimation results are very similar to the main estimation. Therefore, it may look like the emission reduction efforts were greater in the second period, but the difference from this estimation and the main estimation is quite small.

Estimations without firms that were previously regulated by CO_2 tax

As mentioned in chapter 2, some Norwegian firms in the EU ETS were previously regulated by the CO_2 tax (fishmeal and pulp/paper industry). This is also the case with 13 firms in the data sample, meaning that they were subject to CO_2 emission regulation before the introduction of EU ETS. Since those 13 firms therefore could have initiated abatement efforts due to carbon regulation long before 2005/2008, it seemed reasonable to perform a robustness test excluding those firms that were previously regulated by the tax.

The results of this third robustness test show little diversion from the main estimates when it comes to profitability. Some variables become more significant, but the EU ETS dummy is still positive and insignificant. When looking at both absolute emissions and emission intensity in FE however, the EU ETS dummy becomes more insignificant and has lower value. The coefficients are still negative in FE, but positive in RE. However, RE estimates cannot be trusted in that model, since the Hausman test clearly prefers FE. The loss of significance might be due to the decreased treatment group, since there here are only 22 firms in the treatment group compared to 35 in the original sample, but it might also be that the 13 firms left out were the major contributors to emission reduction.

Estimations using only industries containing EU ETS regulated firms

The last robustness test has been described previously in chapter 4.1 (the reasoning for performing this test is also discussed there), and is an estimation using only firms within the two-digit NACE codes that contain EU ETS regulated firms. The results of this test show that there are few differences between these estimates and the main estimates: some changes in statistical significance, but no changes in the big picture.

All in all, these four robustness tests have for most parts confirmed the results from the main estimations. Based on these findings, it is therefore reason to believe that the estimates discussed in section 5.1 and 5.2 are trustworthy.

6. Conclusion

The purpose of this thesis was to assess whether the inclusion in EU ETS has had a significant impact on Norwegian land-based firms or not. By using a panel of 111 firms, both regulated and non-regulated by the ETS, from 2001-2012, I tried to isolate the regulative effect on profitability and CO_2 emissions using mainly fixed effects (FE) and random effects (RE) as econometric estimators. In addition to the main models, four robustness tests were performed in order to validate the results.

The first main finding was that it does not look like the EU ETS has had a significant impact on firms' profitability. This finding is in line with previous research on the EU (see section 2.2). However, the ETS-dummy has a positive coefficient sign in almost all estimations, including the robustness tests. Although one should be careful interpreting results that are not statistically significant, it might indicate that more firms have been affected positively than negatively. I also found little significant differences among industrial sectors, but the results may suggest that firms in "chemicals and pharmaceuticals" and "power and waste" industries have benefited from more the ETS than the remaining sectors. So, to address the title of this thesis, on the aggregate level and based on these findings the polluters have not paid in the EU ETS. But then again, the results are too uncertain to draw the opposite conclusion as well.

The second main finding was that there have most likely been emission reductions due to the ETS, but the scale and significance of these emission reductions are quite uncertain. Regarding absolute emissions, the FE model reported a suspiciously high reduction due the ETS, while the RE model reported a reduction of roughly 1%. This was also the case with emission intensity; the FE estimate was very high and the RE estimate really low. Although the Hausman test clearly prefers FE in both cases, and the ETS-dummy is almost significant at the 10% level there (while the RE estimates are highly insignificant), these estimates are fairly unrealistic. Thus, it is difficult to conclude if the emission reductions due to EU ETS has been significant or not, but it could seem like the effect has been larger on absolute emissions than on emission intensity. Also, when investigating sectorial differences I found that ETS regulated firms in the "metals and minerals" industry reduced their emissions the least of all the indsutries, both in terms of absolute emissions and emission intensity.

Some disclaimers regarding the results must however be mentioned. First of all, the data might suffer from attrition bias due to mismatch problems and missing data, since it is difficult to say whether the omission of these observations was systematic or not. Second, the control group is far from perfect. Since firms are regulated for a reason (they have particular characteristics regarding pollution) it is impossible to have a control group which inherits the exact same characteristics, since the control group would then also be regulated. It is often challenging to establish the counterfactual, and it is difficult to say how much it deviates from what would actually have happened without the ETS. Third, there might be too little variation on the firm level among the variables, since energy prices are firm invariant. The robustness tests were however performed to address some of these problems, and since they do not alter the main conclusions, the bias might not be that large. Still, the results should be taken with a grain of salt.

Since this study is, to my knowledge, the first empirical firm-level analysis of the EU ETS in Norway, extensions and improvements are many. For example, one improvement would be to get energy prices (and perhaps other additional variables) on firm-level as well, which is something I would have tried to get if I had more time. Other variables could also be used as proxy for output instead of revenue (e.g. energy use or other input use), especially in the emission intensity estimation. Further, it would have been interesting to assess the effect of permit prices and allocation of permits on emissions and profitability as well, and then using only ETS regulated firms. It would also have been useful to include 2013, since allocation rules have been changed and more firms are regulated in the third trading period.

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Appendix A: Additional figures

Table A.1: Allocated allowances and verified emissions from sampled firms in the food industry

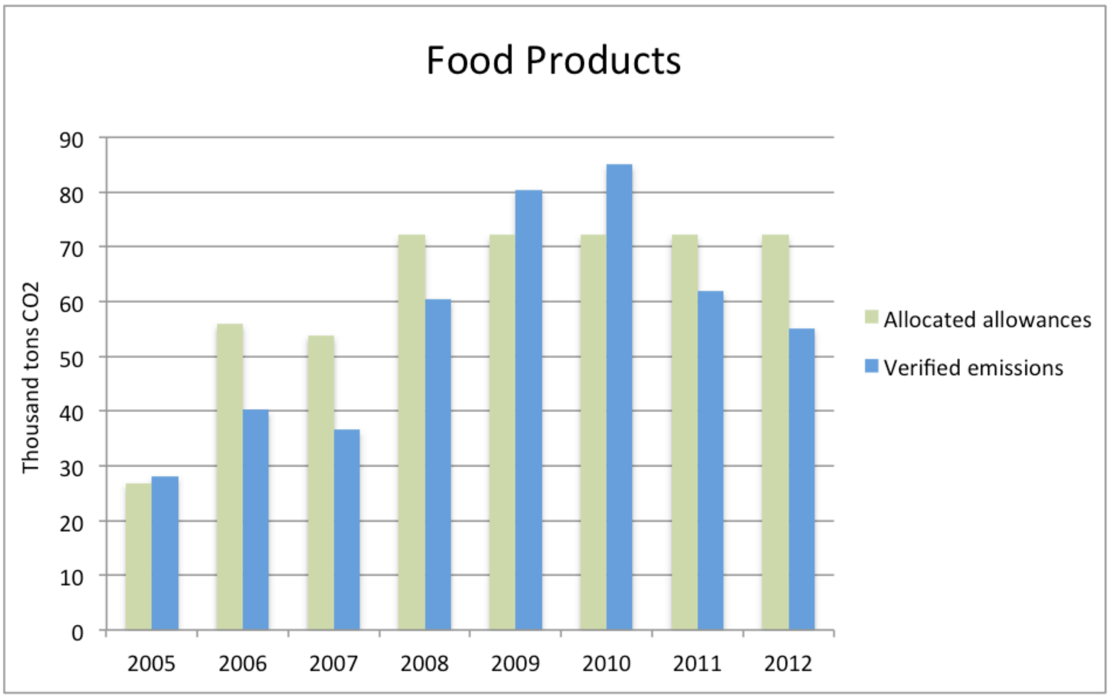


Table A.2: Allocated allowances and verified emissions from sampled firms in the pulp and paper industry

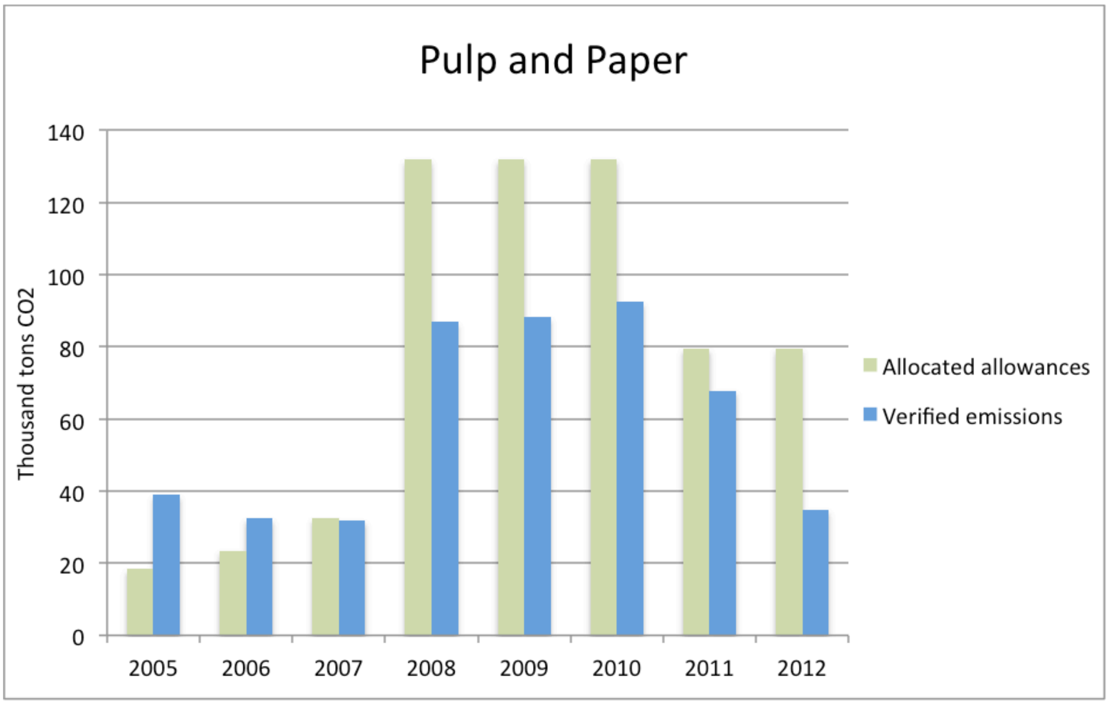


Table A.3: Allocated allowances and verified emissions from sampled firms in the chemicals and pharmaceuticals industry

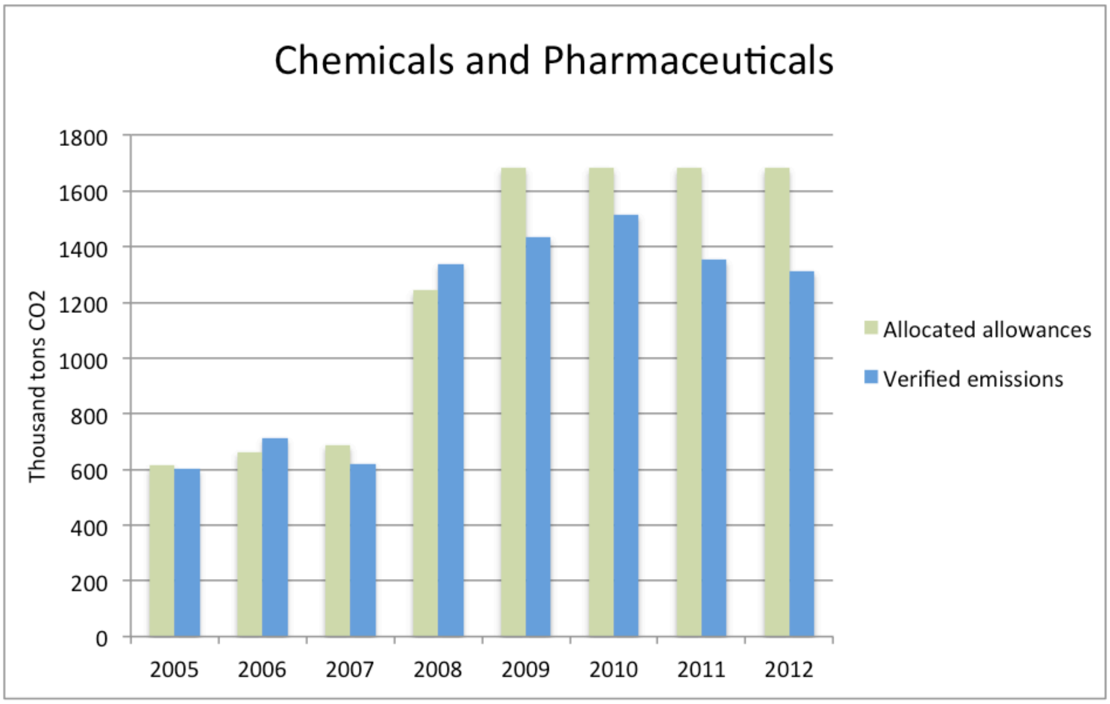


Table A.4: Allocated allowances and verified emissions from sampled firms in the metals and minerals industry

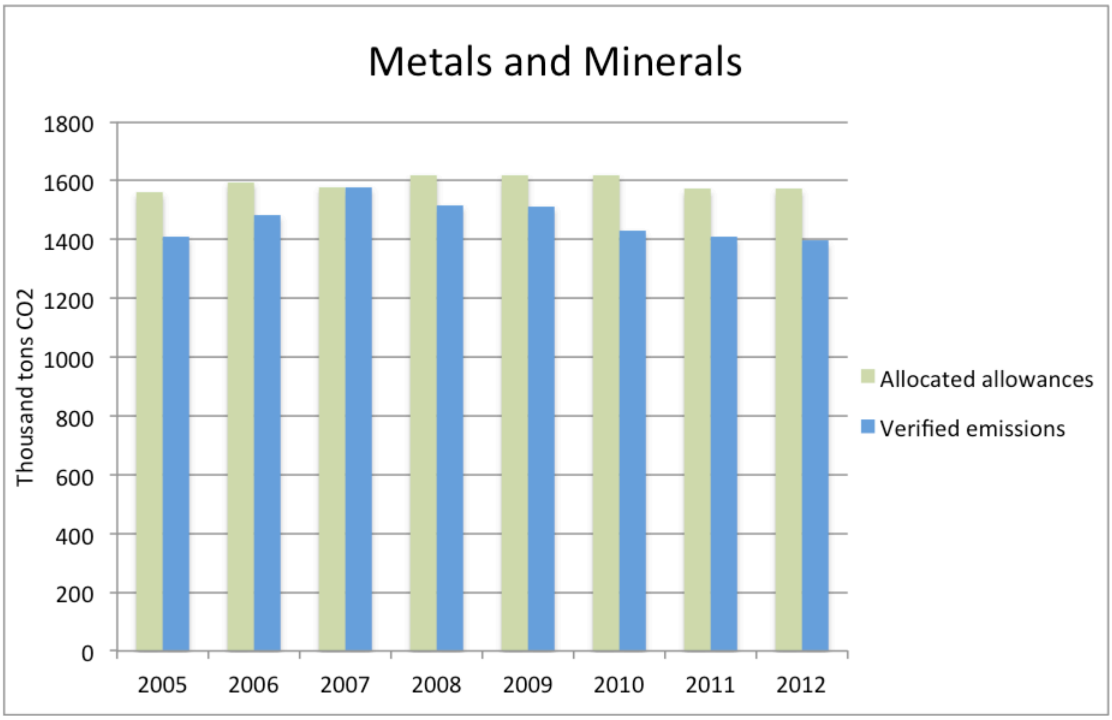
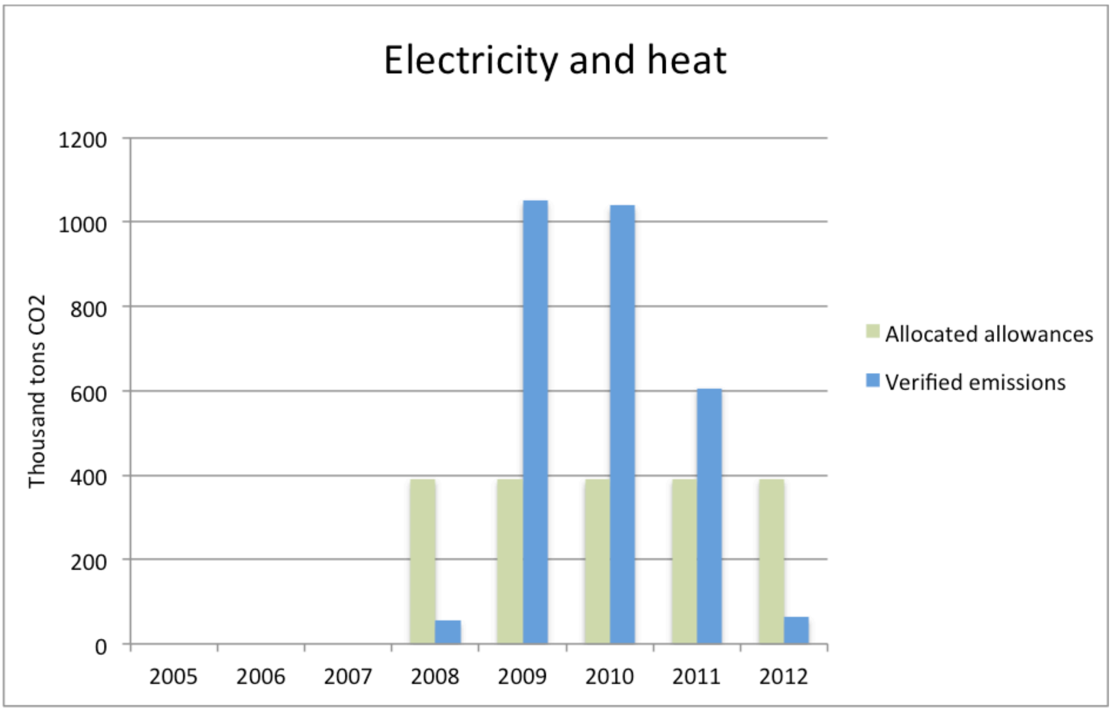


Table A.5: Allocated allowances and verified emissions from sampled firms in the power industry



Appendix B: Additional econometric analyses

Table B.1: Correlations between variables

	pm	roa	lnemis	lnemis~t	lnreve~e	lnempl	lnoilp	lnelpr~e	lnci	lnempl~t
pm	1.0000									
roa	0.5744	1.0000								
lnemis	0.0187	-0.0366	1.0000							
lnemisint	-0.0534	-0.0971	0.8748	1.0000						
lnrevenue	0.1387	0.1065	0.4272	-0.0642	1.0000					
lnempl	0.0268	0.0254	0.2494	-0.1803	0.8505	1.0000				
lnoilp	-0.0122	0.0263	0.0043	0.0080	-0.0059	-0.0541	1.0000			
lnelprice	0.0921	0.1106	-0.2640	-0.1500	-0.2631	-0.1787	0.0244	1.0000		
lnci	0.0433	-0.0429	0.5345	0.4198	0.3175	0.0224	0.1652	-0.1663	1.0000	
lnemplint	-0.2172	-0.1587	-0.3860	-0.1844	-0.4508	0.0860	-0.0807	0.1951	-0.5635	1.0000

Table B.2: Pooled OLS regression with pm as dependent variable

```
Linear regression                               Number of obs =     1065
                                                F( 22,   108) =     2.28
                                                Prob > F      =   0.0027
                                                R-squared     =   0.0798
                                                Root MSE      =   16.872

                                    (Std. Err. adjusted for 109 clusters in id)
```

pm	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ets	3.737301	3.271396	1.14	0.256	-2.747173	10.22177
lnempl	.7588344	.7100515	1.07	0.288	-.6486108	2.16628
lnci	.320474	1.267203	0.25	0.801	-2.191342	2.83229
lnoilp	-9.429181	4.511544	-2.09	0.039	-18.37184	-.4865187
lnelprice	4.684765	3.235431	1.45	0.151	-1.728422	11.09795
lnemisint	-.7908278	.3926744	-2.01	0.047	-1.569177	-.0124791
ind1	-3.640233	8.309415	-0.44	0.662	-20.11094	12.83047
ind2	-12.17792	6.280867	-1.94	0.055	-24.62769	.2718502
ind3	-16.25739	7.168823	-2.27	0.025	-30.46724	-2.047539
ind4	-13.75243	7.257619	-1.89	0.061	-28.1383	.6334263
ind5	-11.96377	6.279186	-1.91	0.059	-24.41021	.4826668
ind6	-20.97478	7.064636	-2.97	0.004	-34.97811	-6.971444
year						
2002	-2.576015	1.261277	-2.04	0.044	-5.076085	-.0759455
2003	-1.300311	1.324946	-0.98	0.329	-3.926585	1.325963
2004	2.533748	1.245966	2.03	0.044	.0640261	5.00347
2005	2.93419	1.546111	1.90	0.060	-.1304709	5.99885
2006	3.608154	2.30617	1.56	0.121	-.9630742	8.179383
2007	3.357098	2.516239	1.33	0.185	-1.630525	8.344721
2008	4.460072	3.003081	1.49	0.140	-1.492555	10.4127
2009	-2.528612	2.024589	-1.25	0.214	-6.541698	1.484475
2010	-.2289847	3.251392	-0.07	0.944	-6.673808	6.215839
2011	3.036201	2.464649	1.23	0.221	-1.849161	7.921563
2012	0	(omitted)				
_cons	47.05314	32.11989	1.46	0.146	-16.61405	110.7203

Table B.3: Pooled OLS regression with roa as dependent variable

```
Linear regression                               Number of obs =     1067
                                                F( 22,   108) =     2.12
                                                Prob > F      =   0.0059
                                                R-squared     =   0.0875
                                                Root MSE      =   13.576

                                (Std. Err. adjusted for 109 clusters in id)
```

roa	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ets	1.595348	2.00563	0.80	0.428	-2.380158	5.570854
lnempl	.5703682	.7629474	0.75	0.456	-.941926	2.082662
lnci	-.7741055	.602653	-1.28	0.202	-1.968668	.4204573
lnoilp	-2.160914	3.135132	-0.69	0.492	-8.37529	4.053461
lnelprice	3.051786	3.60179	0.85	0.399	-4.087586	10.19116
lnemisint	-.494737	.3376041	-1.47	0.146	-1.163927	.1744529
ind1	4.069037	7.633855	0.53	0.595	-11.06259	19.20066
ind2	-1.046443	3.037524	-0.34	0.731	-7.067342	4.974455
ind3	-9.41236	4.219095	-2.23	0.028	-17.77534	-1.049382
ind4	-3.817725	3.268971	-1.17	0.245	-10.29739	2.661943
ind5	-4.560108	3.076625	-1.48	0.141	-10.65851	1.538297
ind6	-12.63385	3.721018	-3.40	0.001	-20.00955	-5.258142
year						
2002	-1.355415	1.666848	-0.81	0.418	-4.659397	1.948567
2003	-.6309545	1.489207	-0.42	0.673	-3.582821	2.320911
2004	3.192201	1.510449	2.11	0.037	.1982281	6.186173
2005	2.091273	1.878069	1.11	0.268	-1.631386	5.813932
2006	2.337471	1.921725	1.22	0.227	-1.471721	6.146663
2007	3.11749	1.59387	1.96	0.053	-.0418379	6.276817
2008	3.06619	1.89416	1.62	0.108	-.6883639	6.820743
2009	-1.497168	1.550287	-0.97	0.336	-4.570106	1.57577
2010	1.779995	1.437998	1.24	0.218	-1.070366	4.630356
2011	1.012393	1.386972	0.73	0.467	-1.736826	3.761612
2012	0	(omitted)				
_cons	16.6263	23.8688	0.70	0.488	-30.68581	63.93841

Table B.4: Pooled OLS regression with lnemis as dependent variable

Linear regression	
Number of obs =	**1063**
F(22, 108) =	**13.05**
Prob > F =	**0.0000**
R-squared =	**0.4969**
Root MSE =	**2.0758**

(Std. Err. adjusted for **109** clusters in id)

lnemis	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ets	**1.579425**	**.3583954**	**4.41**	**0.000**	**.8690226**	**2.289826**
lnrevenue	**.5576117**	**.2385041**	**2.34**	**0.021**	**.0848552**	**1.030368**
lnci	**.7722468**	**.2060676**	**3.75**	**0.000**	**.3637851**	**1.180708**
lnempl	**-.0239119**	**.2676237**	**-0.09**	**0.929**	**-.5543885**	**.5065648**
lnoilp	**-1.041868**	**.5846197**	**-1.78**	**0.078**	**-2.200686**	**.1169496**
lnelprice	**-.6081586**	**.7789608**	**-0.78**	**0.437**	**-2.152194**	**.9358768**
ind1	**.4352588**	**.8398624**	**0.52**	**0.605**	**-1.229494**	**2.100012**
ind2	**-.5017499**	**.8038246**	**-0.62**	**0.534**	**-2.09507**	**1.09157**
ind3	**.2457555**	**1.008148**	**0.24**	**0.808**	**-1.752568**	**2.24408**
ind4	**-.1903461**	**.8891401**	**-0.21**	**0.831**	**-1.952776**	**1.572084**
ind5	**1.150359**	**.8152731**	**1.41**	**0.161**	**-.4656533**	**2.766372**
ind6	**-1.921859**	**1.102814**	**-1.74**	**0.084**	**-4.107829**	**.2641102**
year						
2002	**.1217109**	**.241353**	**0.50**	**0.615**	**-.3566927**	**.6001145**
2003	**.3317188**	**.2778626**	**1.19**	**0.235**	**-.2190532**	**.8824907**
2004	**.3080674**	**.2103774**	**1.46**	**0.146**	**-.1089371**	**.725072**
2005	**.2739247**	**.1946207**	**1.41**	**0.162**	**-.1118472**	**.6596966**
2006	**.1668958**	**.1820144**	**0.92**	**0.361**	**-.1938884**	**.52768**
2007	**-.2869582**	**.2049462**	**-1.40**	**0.164**	**-.693197**	**.1192807**
2008	**-.1320152**	**.1991357**	**-0.66**	**0.509**	**-.5267367**	**.2627062**
2009	**-.3067607**	**.2259579**	**-1.36**	**0.177**	**-.7546486**	**.1411271**
2010	**-.0161768**	**.2113435**	**-0.08**	**0.939**	**-.4350963**	**.4027427**
2011	**.1552986**	**.1452166**	**1.07**	**0.287**	**-.1325459**	**.443143**
2012	**0**	(omitted)				
_cons	**3.419876**	**4.3492**	**0.79**	**0.433**	**-5.200994**	**12.04075**

Table B.5: Pooled OLS regression with lnemisint as dependent variable

```
Linear regression                               Number of obs =      1067
                                                F( 21,    108) =    11.42
                                                Prob > F       =   0.0000
                                                R-squared      =   0.3812
                                                Root MSE       =   2.0889

                                  (Std. Err. adjusted for 109 clusters in id)
```

lnemisint	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ets	1.49839	.3546077	4.23	0.000	.7954963	2.201284
lnempl	-.447854	.1149349	-3.90	0.000	-.675675	-.2200331
lnci	.6370241	.1933323	3.29	0.001	.2538058	1.020242
lnoilp	-.9423789	.5938818	-1.59	0.115	-2.119556	.2347979
lnelprice	-.2990043	.7827605	-0.38	0.703	-1.850571	1.252563
ind1	.6021987	.7992904	0.75	0.453	-.9821336	2.186531
ind2	-.5437657	.7545603	-0.72	0.473	-2.039435	.9519038
ind3	.4467429	.9795808	0.46	0.649	-1.494956	2.388442
ind4	-.0415949	.8666885	-0.05	0.962	-1.759522	1.676332
ind5	1.290572	.7776977	1.66	0.100	-.2509595	2.832104
ind6	-1.79481	1.085352	-1.65	0.101	-3.946166	.3565468
year						
2002	.0995543	.2415497	0.41	0.681	-.379239	.5783476
2003	.3079379	.2769678	1.11	0.269	-.2410604	.8569362
2004	.2579173	.2101305	1.23	0.222	-.1585978	.6744323
2005	.2589682	.1932548	1.34	0.183	-.1240964	.6420328
2006	.102415	.1865763	0.55	0.584	-.2674115	.4722415
2007	-.32601	.2115658	-1.54	0.126	-.7453702	.0933502
2008	-.2169267	.2065791	-1.05	0.296	-.6264023	.1925489
2009	-.3076766	.2321485	-1.33	0.188	-.7678351	.152482
2010	-.0803848	.2187405	-0.37	0.714	-.5139665	.3531969
2011	.0963969	.1576691	0.61	0.542	-.2161305	.4089244
2012	0	(omitted)				
_cons	-.719679	4.179669	-0.17	0.864	-9.004508	7.56515

Table B.6: Testing for linear functional form with pm as dependent variable

pm	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ets	.1136212	1.793312	0.06	0.950	-3.441033	3.668276
lnempl	-6.220009	4.919894	-1.26	0.209	-15.97209	3.532074
lnci	-2.194927	1.651229	-1.33	0.187	-5.46795	1.078096
lnemisint	-.7332822	.5229418	-1.40	0.164	-1.769844	.3032792
lnoilp	.157609	1.889525	0.08	0.934	-3.587757	3.902975
lnelprice	-4.965138	2.726224	-1.82	0.071	-10.36899	.4387114
ind2	0	(omitted)				
ind3	0	(omitted)				
ind4	0	(omitted)				
ind5	0	(omitted)				
ind6	0	(omitted)				
ind7	0	(omitted)				
y2	.0139436	.027111	0.51	0.608	-.0397952	.0676824
y3	-.0001016	.0003413	-0.30	0.766	-.000778	.0005748
y4	-5.86e-06	.0000269	-0.22	0.828	-.0000592	.0000474
_cons	61.03013	39.95807	1.53	0.130	-18.1737	140.234
sigma_u	20.283268					
sigma_e	12.70116					
rho	.71833265	(fraction of variance due to u_i)				

Table B.7: Testing for linear functional form with roa as dependent variable

roa	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ets	-.4606133	2.016242	-0.23	0.820	-4.457155	3.535928
lnempl	-.3295584	1.337561	-0.25	0.806	-2.980836	2.321719
lnci	-.1753528	1.203556	-0.15	0.884	-2.56101	2.210305
lnemisint	-.514693	.6052929	-0.85	0.397	-1.714489	.6851025
lnoilp	-.0032231	1.911081	-0.00	0.999	-3.791317	3.78487
lnelprice	.1570752	2.972227	0.05	0.958	-5.734394	6.048544
ind1	0	(omitted)				
ind2	0	(omitted)				
ind3	0	(omitted)				
ind4	0	(omitted)				
ind5	0	(omitted)				
ind6	0	(omitted)				
y2	.3286419	.2314867	1.42	0.159	-.1302049	.7874888
y3	-.023551	.023973	-0.98	0.328	-.0710696	.0239677
y4	.0004273	.0006774	0.63	0.529	-.0009155	.0017702
_cons	-2.4249	19.14711	-0.13	0.899	-40.37779	35.528
sigma_u	9.6267907					
sigma_e	11.248383					
rho	.42278551	(fraction of variance due to u_i)				

Table B.8: Testing for linear functional form with lnemis as dependent variable

lnemis	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ets	.0034535	.1257869	0.03	0.978	-.245878	.252785
lnrevenue	-.0267994	.1924603	-0.14	0.890	-.4082891	.3546903
lnci	-.0020042	.0988045	-0.02	0.984	-.1978518	.1938434
lnempl	.012032	.1809522	0.07	0.947	-.3466466	.3707107
lnoilp	-.0034695	.2879795	-0.01	0.990	-.5742949	.5673559
lnelprice	-.0728669	.1968932	-0.37	0.712	-.4631435	.3174096
ind1	0	(omitted)				
ind2	0	(omitted)				
ind3	0	(omitted)				
ind4	0	(omitted)				
ind5	0	(omitted)				
ind6	0	(omitted)				
y2	.5119941	.5828325	0.88	0.382	-.6432811	1.667269
y3	-.0568177	.083973	-0.68	0.500	-.2232667	.1096313
y4	.0018603	.0033295	0.56	0.578	-.0047394	.00846
_cons	-2.653236	7.770025	-0.34	0.733	-18.05477	12.7483
sigma_u	2.5173229					
sigma_e	1.0922617					
rho	.84156127	(fraction of variance due to u_i)				

Table B.9: Testing for linear functional form with lnemisint as dependent variable

lnemisint	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ets	-.0006832	.1354841	-0.01	0.996	-.2692362	.2678698
lnempl	.0008627	.1787694	0.00	0.996	-.3534893	.3552146
lnci	.0000411	.1107433	0.00	1.000	-.2194714	.2195536
lnoilp	-.0147967	.2926192	-0.05	0.960	-.5948188	.5652253
lnelprice	-.0631767	.219991	-0.29	0.775	-.499237	.3728836
ind1	0	(omitted)				
ind2	0	(omitted)				
ind3	0	(omitted)				
ind4	0	(omitted)				
ind5	0	(omitted)				
ind6	0	(omitted)				
y2	30.66922	22.97279	1.34	0.185	-14.86683	76.20527
y3	8.950168	6.631518	1.35	0.180	-4.194652	22.09499
y4	.731067	.5371771	1.36	0.176	-.3337111	1.795845
_cons	-109.463	81.19537	-1.35	0.180	-270.4063	51.48026
sigma_u	2.489268					
sigma_e	1.0996006					
rho	.83672824	(fraction of variance due to u_i)				

Table B.10: FE and RE regression with absolute emissions as dependent variable, and without *revenue* as independent variable. Here compared to the main model with *revenue (“norevenue”* is the model without).

Variable	fe_lnemis	fe_norevenue	re_lnemis	re_norevenue
ets	**-.25284666**	**-.29481957***	**-.01277721**	**-.0796049**
lnrevenue	**.67722955***		**.60208677***	
lnemplint	**.39611763****	**-.11832529**	**.26023368***	**-.20581468***
lnci	**.11104991**	**.10337483**	**.33230277*****	**.33839292*****
lnoilp	**(omitted)**	**(omitted)**	**-.04697995**	**-.13547232**
lnelprice	**-.04751783**	**-.09954818**	**-.10977888**	**-.18656667**
ind1	**(omitted)**	**(omitted)**	**-1.1854949**	**-.45494483**
ind2	**(omitted)**	**(omitted)**	**-1.6998631****	**-1.3204202****
ind3	**(omitted)**	**(omitted)**	**-.70810661**	**-.12828489**
ind4	**(omitted)**	**(omitted)**	**-.88982324**	**-.22291795**
ind5	**(omitted)**	**(omitted)**	**.35737095**	**1.0646537**
ind6	**(omitted)**	**(omitted)**	**-4.0671055*****	**-3.636531*****
year				
2002	**.17527974**	**.16644897**	**.15627764**	**.14449695**
2003	**.41022042****	**.41214961****	**.38868597***	**.39034116***
2004	**.34538663***	**.32980462**	**.31710218***	**.31435615***
2005	**.42167235****	**.4019305***	**.35293503*****	**.36942166*****
2006	**.36645168***	**.33849377**	**.2676261***	**.28404652***
2007	**.09894855**	**.04951418**	**-.00558145**	**-.01266411**
2008	**.08708888**	**.08758289**	**-.02976501**	**.0298554**
2009	**.26693578**	**.20400047**	**.12332948**	**.09855612**
2010	**.30555542**	**.25730044**	**.17234999**	**.17364921**
2011	**.35582278**	**.31776772**	**.22204588****	**.24940148*****
2012	**.13727024**	**.06923478**	**(omitted)**	**(omitted)**
_cons	**1.9472353**	**6.9595504*****	**1.6919502**	**5.97105***

legend: * p<.1; ** p<.05; *** p<.01

Table B.11: FE and RE regressions, with interaction variables (ets*industry dummies), with profit margin and ROA as dependent variables.

Variable	feinter_pm	reinter_pm	feinter_roa	reinter_roa
ets	**4.2859232***	**31.441026***	**4.5928901**	**5.1927109**
lnempl	**-6.9202805**	**-2.4210926**	**-.78212659**	**.13499017**
lnci	**-2.4259815**	**-2.3639656**	**-1.0537127**	**-1.1298142**
lnoilp	**(omitted)**	**-4.8964436**	**(omitted)**	**-1.4444329**
lnelprice	**-5.4553886**	**-3.7125695**	**-3.1130027**	**-.68001207**
lnemisint	**-.86823518**	**-.9916984***	**-.77828892**	**-.75660812****
ind1	**(omitted)**	**7.5267887**	**(omitted)**	**5.8226952**
ind2	**(omitted)**	**-4.4088642**	**(omitted)**	**-.70805581**
ind3	**(omitted)**	**-6.5715006**	**(omitted)**	**-5.2798587**
ind4	**(omitted)**	**-9.0893511**	**(omitted)**	**-3.9348361**
ind5	**(omitted)**	**-.86733412**	**(omitted)**	**-2.8627955**
ind6	**(omitted)**	**-15.371625****	**(omitted)**	**-12.368347*****
ets_ind2	**(omitted)**	**-26.621761**	**(omitted)**	**-.3413646**
ets_ind3	**-5.5028466**	**-31.814534***	**-6.3216018**	**-6.7908631**
ets_ind4	**1.0286173**	**-25.465653**	**1.7944774**	**.61640888**
ets_ind5	**-5.6398353**	**-32.480252***	**-3.1565214**	**-4.3348008**
year				
2002	**-1.2336096**	**-1.5478963**	**-1.1601347**	**-1.2316279**
2003	**.41185305**	**.0842828**	**.6158596**	**.23867932**
2004	**1.3264418**	**2.1471601***	**3.1826346***	**3.3692474****
2005	**-.69625247**	**1.4132778**	**.63774714**	**1.4754031**
2006	**.04266285**	**2.5915175**	**1.3166167**	**2.1329439**
2007	**-.276865**	**2.1562584**	**2.1913306**	**2.9768665***
2008	**.73943183**	**3.6286927**	**2.3071297**	**3.100453**
2009	**-3.1526105**	**-1.595737**	**-1.1962049**	**-.9724035**
2010	**.09746525**	**1.9382839**	**2.2524836**	**2.4986701***
2011	**1.1889386**	**3.9962846**	**.53503917**	**1.3233314**
2012	**-3.218705**	**(omitted)**	**-.96054579**	**(omitted)**
_cons	**69.23797**	**69.315964**	**25.524033**	**25.352151**

legend: * p<.1; ** p<.05; *** p<.01

Table B.12: FE and RE regressions, with interaction variables (ets*industry dummies), with absolute emissions and emission intensity as dependent variables.

Variable	feinter_emis	reinter_emis	feinter_emi~t	reinter_emi~t
ets	-.32368384*	.02520479	-.35592742*	-.17111422
lnemplint	.39046014**	.25419105*	.64482463***	.57070321***
lnrevenue	.66509607***	.59661704***		
lnci	.10797338	.33470094***	.11013624	.31708492***
lnoilp	(omitted)	-.0624109	(omitted)	.01010307
lnelprice	-.01689643	-.0884343	.00470903	-.02890984
ind1	(omitted)	-1.1587571	(omitted)	-1.7624349**
ind2	(omitted)	-1.6841454**	(omitted)	-2.0490119**
ind3	(omitted)	-.51897545	(omitted)	-1.023347
ind4	(omitted)	-.89264727	(omitted)	-1.4405292
ind5	(omitted)	.33885126	(omitted)	-.23345664
ind6	(omitted)	-4.0393398***	(omitted)	-4.4622799***
ets_ind2	(omitted)	.01392486	(omitted)	.18110559
ets_ind3	-.21015379	-.38925357	-.13639379	-.1540064
ets_ind4	.16144849	.11494034	.23833226*	.34662041
ets_ind5	.33093812***	.21412283	.35650102***	.42723116
year				
2002	.16781803	.14725098	.17306652	.15653067
2003	.4082598**	.38563739*	.40792515**	.38588404*
2004	.34575951*	.31850739*	.35286169*	.31998336*
2005	.41016755**	.34146548***	.42160183**	.3328917***
2006	.35454208	.25643616*	.36994592*	.24687028
2007	.08617994	-.01671841	.11219688	-.00836677
2008	.08274605	-.02954656	.08440558	-.066939
2009	.25949893	.1176664	.29228325	.1385143
2010	.29771303	.16904775	.32814293	.17394984
2011	.35030403	.22343638**	.3673545	.20129107**
2012	.13116228	(omitted)	.16612545	(omitted)
_cons	1.9944477	1.7025643	-.45022561	-1.0316891

legend: * p<.1; ** p<.05; *** p<.01

Appendix C: Robustness tests

Table C.1: Robustness test I: using lagged independent variables, here with PM and ROA as dependent variables.

Variable	ferob1_pm	rerob1_pm	ferob1_roa	rerob1_roa
ets				
L1.	.59054957	1.9682776*	.73892588	.64388558
lnempl				
L1.	-2.4870518*	-.15537594	-2.6352839*	-.27989033
lnci				
L1.	-3.0303763*	-1.8926403*	-2.2858021**	-1.5229226**
lnoilp				
L1.	(omitted)	-1.8009867	(omitted)	3.0463657*
lnelprice				
L1.	-12.869461***	-8.4697383**	-11.064218***	-5.039161**
lnemisint				
L1.	.02557323	-.26024862	-.10089187	-.28778411*
ind1	(omitted)	-9.4085492*	(omitted)	3.8439277
ind2	(omitted)	-18.111782**	(omitted)	-1.7363198
ind3	(omitted)	-25.945643***	(omitted)	-11.269787**
ind4	(omitted)	-26.138243**	(omitted)	-6.493466**
ind5	(omitted)	-20.660161**	(omitted)	-6.5967438**
ind6	(omitted)	-27.45609***	(omitted)	-12.727865***
year				
2003	2.547506**	2.0444934**	3.6743403***	3.3650616***
2004	4.3293955***	3.8817281***	5.9516054***	5.5625455***
2005	1.805996*	2.1454998**	2.1732124*	1.9588387*
2006	.93609363	1.7921424*	2.8098414*	2.3391338*
2007	4.0063218***	4.5946343**	5.0686738***	3.8383628**
2008	1.9155338*	2.6180766*	4.289416**	3.274223**
2009	-.60136207	-.35620585	1.6751097*	-.68637861
2010	1.6945243	.91312838	5.1138083**	3.5882049**
2011	5.1365266**	4.2916651**	4.9567232***	2.490453**
2012	.27747416	(omitted)	2.6868934*	(omitted)
_cons	73.377969**	69.994599**	66.870194***	21.090689*

legend: * p<.5; ** p<.1; *** p<.01

Table C.2: Robustness test I: using lagged independent variables, here with absolute emissions and emission intensity as dependent variables.

Variable	ferob1_emis	rerob1_emis	ferob1_emis~t	rerob1_emis~t
ets				
L1.	**-.22769314***	**-.01082888**	**-.21418689***	**-.00595718**
lnrevenue				
L1.	**.57511312*****	**.53766467*****		
lnci				
L1.	**.20324897****	**.41486169*****	**.08765429***	**.26329714*****
lnemplint				
L1.	**.49974571*****	**.40754741*****	**.16048128***	**.15686702***
lnoilp				
L1.	**(omitted)**	**-.3793763***	**(omitted)**	**-.18885415**
lnelprice				
L1.	**-.05559858**	**-.159342**	**-.12943721**	**-.14573113**
ind1	**(omitted)**	**-1.2353537***	**(omitted)**	**-1.3940212****
ind2	**(omitted)**	**-1.7654717****	**(omitted)**	**-1.9713981*****
ind3	**(omitted)**	**-1.054126***	**(omitted)**	**-1.213025***
ind4	**(omitted)**	**-1.0555599***	**(omitted)**	**-1.3059308****
ind5	**(omitted)**	**.21117475**	**(omitted)**	**-.09048704**
ind6	**(omitted)**	**-4.2856796*****	**(omitted)**	**-4.226981*****
year				
2003	**.24270081****	**.21349567****	**.2779249*****	**.25402617****
2004	**.16142838***	**.12085057***	**.14627079***	**.10899445**
2005	**.21412104***	**.23982616***	**.20893093***	**.21968441***
2006	**.17843578***	**.22983504***	**.12382745**	**.12580205***
2007	**-.07790121**	**.00634446**	**-.06143818**	**-.05204074**
2008	**-.07020952**	**-.03391398**	**-.16324488***	**-.18310316***
2009	**.03028418**	**.13770728***	**.15385315***	**.15780645***
2010	**.12593977**	**.10218905***	**.15966962***	**.09676722***
2011	**.17736305**	**.19967389****	**.20791689***	**.162248***
2012	**-.09134376**	**(omitted)**	**.01158773**	**(omitted)**
_cons	**3.6513864***	**5.3530962****	**-3.5285043****	**-2.4597818***

legend: * p<.5; ** p<.1; *** p<.01

Table C.3: Robustness test II: considering only the second EU ETS period as regulated. Here with PM and ROA as dependent variables.

Variable	ferob2_pm	rerob2_pm	ferob2_roa	rerob2_roa
ets2	2.8864129	4.0891777	2.7431646	3.1714722
lnempl	-6.8957898	-2.2988314	-.74710918	.14217319
lnci	-2.2363141	-1.5921601	-.90868271	-.90734571
lnoilp	(omitted)	-6.3184346*	(omitted)	-2.0965108
lnelprice	-5.2959922	-3.6308511	-3.1379248	-.78445199
lnemisint	-.83937812	-.97514269*	-.75037692	-.71816957**
ind1	(omitted)	-2.059742	(omitted)	5.1922452
ind2	(omitted)	-13.456077	(omitted)	-.88717293
ind3	(omitted)	-17.330609**	(omitted)	-7.6973081*
ind4	(omitted)	-18.339424*	(omitted)	-3.9872016
ind5	(omitted)	-11.458004	(omitted)	-3.9178222
ind6	(omitted)	-23.813897***	(omitted)	-12.601316***
year				
2002	-1.224495	-1.6622291	-1.1061992	-1.2237703
2003	.38240076	-.05731736	.61955585	.18804215
2004	1.3024885	2.2555632**	3.1737848*	3.4075006**
2005	-.47521451	2.2207079*	1.1229908	2.1208823
2006	.24469074	3.4825601*	1.8032837	2.8570683
2007	-.03826994	3.0630494	2.7066597	3.6988914**
2008	.16837123	3.6962461	2.1020814	3.1124783*
2009	-3.772214	-2.1257529	-1.4288169	-1.2388118
2010	-.5103699	1.6414821	2.0317028	2.3540546
2011	.5759602	3.929236	.30143069	1.2771415
2012	-3.7872229	(omitted)	-1.1543145	(omitted)
_cons	67.665975	81.026321*	24.697247	28.611153

legend: * p<.1; ** p<.05; *** p<.01

Table C.4: Robustness test II: considering only the second period of EU ETS as regulated. Here with absolute emissions and emission intensity as dependent variables.

Variable	ferob2_emis	rerob2_emis	ferob2_emis~t	rerob2_emis~t
ets2	-.29192155*	-.15362145	-.28082435	-.13797004
lnrevenue	.74793431***	.63425072***		
lnemplint	.27205243*	.11817643	.43484923***	.37285529***
lnci	.08679317	.28901594***	.07980781	.25941779**
lnoilp	(omitted)	.02827726	(omitted)	.09959924
lnelprice	-.085335	-.12744832	-.06786204	-.07817446
ind1	(omitted)	-1.1703742	(omitted)	-1.6360883**
ind2	(omitted)	-1.7475442**	(omitted)	-2.0213921***
ind3	(omitted)	-.70516505	(omitted)	-1.0868346
ind4	(omitted)	-.98400576	(omitted)	-1.3933109*
ind5	(omitted)	.331982	(omitted)	-.11422749
ind6	(omitted)	-4.0371836***	(omitted)	-4.3472813***
year				
2002	.18012218	.16570196	.18322629	.17443214
2003	.41306327**	.4012025*	.41151535**	.4010193*
2004	.3284298	.30189612*	.33129845	.29973508*
2005	.35407987*	.31750291**	.36147076*	.30738484**
2006	.29268381	.22150871	.30202527	.21041455
2007	-.00524321	-.08114991	.00914514	-.08064465
2008	.07334856	-.04625353	.07133206	-.08547964
2009	.28212284	.15701567	.30581415	.17749407
2010	.30886397	.18287595	.32988553	.18624897
2011	.36364602	.22461048**	.37479746	.20416818**
2012	.144256	(omitted)	.17041186	(omitted)
_cons	.32309888	.12482963	-1.679567	-2.6014891

legend: * p<.1; ** p<.05; *** p<.01

Table C.5: Robustness test III: without firms that were previously regulated by the carbon tax. Here with PM and ROA as dependent variables.

Variable	ferob3_pm	rerob3_pm	ferob3_roa	rerob3_roa
ets	.42216153	2.121106	1.5993016	1.729622
lnempl	-7.2191753	-2.2065394	-.63656349	.449731
lnci	-3.1154853	-1.8948865	-1.3411581	-1.1203937*
lnoilp	(omitted)	-3.9481058	(omitted)	.39218832
lnelprice	-6.6216371	-4.8464858	-5.8849147*	-3.1190225
lnemisint	-.79029576	-.90442126*	-.67610998	-.64098854**
ind1	(omitted)	-2.855291	(omitted)	4.3201095
ind2	(omitted)	-14.242061	(omitted)	-2.1244313
ind3	(omitted)	-15.100735	(omitted)	1.175503
ind4	(omitted)	-19.271927*	(omitted)	-5.4165128*
ind5	(omitted)	-12.455326	(omitted)	-5.364444*
ind6	(omitted)	-24.756978**	(omitted)	-13.407109***
year				
2002	-.72974507	-1.0337952	-.27323391	-.32193581
2003	1.1589404	.72623932	1.7350313	1.2659932
2004	2.2226502	2.8131305**	4.5672372**	4.4196953***
2005	.28749644	1.7307724	1.9970903	1.9061218
2006	1.9906508	3.5966067	4.1806562*	3.6029408*
2007	.75503459	2.2943026	3.2827061	3.0552814*
2008	2.0622995	3.832876	3.9644497*	3.2854471
2009	-2.5069264	-1.7636809	-.49934009	-1.0948882
2010	.79371786	1.5956687	3.0543278	2.1577794
2011	2.505418	4.00947	2.1566996	1.3981554
2012	-1.8274197	(omitted)	.61422607	(omitted)
_cons	79.241523	73.680699	34.5499**	22.225463

legend: * p<.1; ** p<.05; *** p<.01

Table C.6: Robustness test III: without firms that were previously regulated by the carbon tax. Here with absolute emissions and emission intensity as dependent variables.

Variable	ferob3_emis	rerob3_emis	ferob3_emis~t	rerob3_emis~t
ets	-.12830422	.12273125	-.11241403	.12411551
lnrevenue	.6308119***	.62692124***		
lnemplint	.37504143**	.32624147**	.65642484***	.62614536***
lnci	.10823345	.36549631***	.11777001	.33444684**
lnoilp	(omitted)	.12836352	(omitted)	.19470881
lnelprice	.10223578	.00214896	.12015752	.05621511
ind1	(omitted)	-1.1573456	(omitted)	-1.6761483**
ind2	(omitted)	-2.3929256***	(omitted)	-2.8255336***
ind3	(omitted)	-.73897951	(omitted)	-1.215591
ind4	(omitted)	-.85178078	(omitted)	-1.3016201*
ind5	(omitted)	.39593982	(omitted)	-.0825293
ind6	(omitted)	-3.993514***	(omitted)	-4.3680108***
year				
2002	.19686512	.20069646	.20242091	.20959262
2003	.42560825**	.42647135*	.42102137*	.42230171*
2004	.3974254*	.35913039*	.40098556*	.35703913*
2005	.44777901**	.32626036**	.45274206**	.31685888**
2006	.36566361	.20472029	.37672249	.19861333
2007	.11526586	-.0549494	.13209207	-.04986009
2008	.11294769	-.08586173	.10292305	-.12257408
2009	.27887047	.11305906	.30814167	.13825994
2010	.2786072	.100895	.30856588	.11600755
2011	.38675648	.17036281**	.40071379	.15907681*
2012	.22776726	(omitted)	.25121307	(omitted)
_cons	1.7992526	.28914719	-.95088996	-2.1238013

legend: * p<.1; ** p<.05; *** p<.01

Table C.7: Robustness test IV: using only industries containing EU ETS regulated firms. Here with PM and ROA as dependent variables.

Variable	ferob4_pm	rerob4_pm	ferob4_roa	rerob4_roa
ets	.7021352	1.7838228	2.5256006	2.4757531
lnempl	-10.613565	-3.3108737	-2.5799711	-.30022464
lnci	-3.2403571	-3.4853789	-1.3607103	-1.719088*
lnoilp	(omitted)	-6.8136971	(omitted)	-2.9152073
lnelprice	-8.2372157*	-5.5827726	-7.0457068**	-3.3518076
lnemisint	-1.8258765*	-1.569995**	-.98871435*	-.79136169**
ind2	(omitted)	-36.926169**	(omitted)	-4.0120418
ind3	(omitted)	-42.655833**	(omitted)	-12.762225*
ind4	(omitted)	-42.405657**	(omitted)	-8.0490254
ind5	(omitted)	-34.513416**	(omitted)	-8.0829065
year				
2002	-1.2421477	-1.7464651	-.76383639	-1.0132339
2003	-.58824654	-.86944845	-.6056339	-.82279338
2004	.62662046	1.9122621	2.2804511	2.9479156*
2005	-2.8282918	.3827146	-2.0000825	-.13327662
2006	-1.8416196	2.0892923	-1.8313635	.23469384
2007	-1.5987337	2.2198602	.71531887	2.5751061
2008	.63300859	5.0728861	1.5602863	3.5464022
2009	-4.4567114*	-1.9179295	-2.7701015	-1.9260928
2010	-.37490168	2.5388891	1.7469392	2.8687333*
2011	1.3518706	5.6010995*	.12337685	2.1086739
2012	-4.836569	(omitted)	-2.2485331	(omitted)
_cons	100.0282	129.25995**	48.412234***	52.666476**

legend: * p<.1; ** p<.05; *** p<.01

Table C.8: Robustness test IV: using only industries containing EU ETS regulated firms. Here with absolute emissions and ROA as dependent variables.

Variable	ferob4_emis	rerob4_emis	ferob4_emis~t	rerob4_emis~t
ets	-.30977368	-.15674539	-.3030923	-.13589909
lnrevenue	.57804389***	.50771735***		
lnemplint	.32156678**	.19775326	.64116837***	.57364421***
lnci	-.00008685*	-.00008648**	-.00011151**	-.0001181**
lnoilp	(omitted)	.30101674	(omitted)	.43633231
lnelprice	-.48897673	-.50395775	-.47767251	-.46078536
ind2	(omitted)	-2.7031835***	(omitted)	-2.8799559**
ind3	(omitted)	-2.2473844**	(omitted)	-2.4837895**
ind4	(omitted)	-1.8746797*	(omitted)	-2.1728374*
ind5	(omitted)	-.77234614	(omitted)	-1.1223549
year				
2002	.12656604	.14705495	.13385182	.16095784
2003	.31289729***	.32351344***	.32581782***	.34374855***
2004	.23966731	.19203*	.25540601	.19551786*
2005	.27513696	.11352894	.31195801	.10773959
2006	.23604452	.02907819	.27961694	.0183694
2007	.03794544	-.14229793	.09711102	-.13047686
2008	.09099117	-.17148298	.12866821	-.21591677
2009	.25494975	.09971001	.33176363	.1453053
2010	.40912643	.20726472*	.4842948*	.22842758*
2011	.49112065	.2320067**	.55607383*	.21725377**
2012	.26173513	(omitted)	.34079219	(omitted)
_cons	5.2481446***	5.2225716	2.1426983	1.1141479

legend: * p<.1; ** p<.05; *** p<.01

Norges miljø- og
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universitet

Postboks 5003
NO-1432 Ås
67 23 00 00
www.nmbu.no