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The EU ETS and firm profits: an ex-post analysis for Swedish energy firms

Abstract

In January 2005, the EU launched the first international emissions trading system (EU ETS), aimed at reducing carbon emissions in a cost-effective way by means of a market-based instrument. This paper uses the treatment/control, before/after design of the natural experiment approach to investigate the treatment effect of the EU ETS on the profitability of a sample of Swedish energy firms in 2005 and 2006. The author investigates whether over-allocated and under-allocated firms respond differently to the EU ETS. The estimation results in general suggest no significant impact in 2005 and a negative significant impact in 2006. The sub-sample analysis suggests that profitability of over-allocated and under-allocated firms were affected differently by the EU ETS in 2005, but not in 2006.

Keywords: EU ETS, difference-in-differences, fixed effect.
JEL Classifications: D22, Q50, Q58.

Introduction

In January 2005, the European Union launched the first international emissions trading system, the EU ETS, intended to act as a driving force to promote business interest in reducing CO_2 emissions. The EU ETS is seen as an important tool in enabling the EU to fulfill its commitment in the Kyoto Protocol of reducing greenhouse gas emissions. In its first phase 2005-2007, the system covers CO_2 emissions from a limited number of industrial sectors, primarily the energy sector and some other energy-intensive industries. The regulated units are installations carrying out prescribed activities[1], – e.g., combustion of fuels, production of steel, and production of pulp – above certain capacity thresholds. The energy sector is involved as the primary trading sector in the sense that the combustion process of producing electricity causes high CO_2 emissions. It has been debated whether the EU ETS will place a premium on electricity prices and decrease the competitiveness of other energy intensive sectors, particularly those that are confronted with serious international competition. It is widely accepted that firms within the energy sector could make windfall profits with the design of the EU ETS in its first phase, 2005-2007, by benefiting from the premium on electricity price and a free allocation of allowances (Sijm et al., 2006). In this paper, we focus on a sample of Swedish energy firms associated with electricity production and district heating and investigate whether the profitability of these firms are affected by the EU ETS.

Previous quantitative studies of the EU ETS have mainly used simulation models to carry out analyses at the national or industry level. Oberndorfer et al. (2006) summarize various simulation models focusing on competitiveness and employment in relation to the EU ETS and conclude that the impact of the EU ETS on competitiveness is modest. In a related study, Brännlund and Lundgren (2007) use Swedish firm-level data on outputs and inputs between 1991 and 2001 to estimate a factor demand model, and then simulate different policy scenarios. Their simulation results indicate that the effects of the EU ETS on the Swedish primary industry will depend on the level of the current carbon tax, the price of the permits, and the future price of electricity. Empirical studies of the EU ETS are emerging recently and center on the dynamics of carbon prices (Fell, 2010; Widerberg and Wråke, 2009; Keppler and Mansanet-Bataller, 2010). Econometric studies of the EU ETS at the firm level are few due to a lack of data. One exception is the study by Anger and Oberndorfer (2008) who assessed the impact of the relative allocation of allowances on competitiveness and employment in a sample of German firms in 2005. Their results provide evidence that the actual allocation within the EU ETS framework in the first phase did not have a significant impact on revenues and employment. This paper attempts to shed more light on the issue by using the natural experiment to analyze the firm level data from Sweden. As the available data are up to 2006, this study covers the first two years of the implementation of the EU ETS.

The focus of the paper is on energy firms, applying a difference-in-differences econometric method to investigate the treatment effect of the EU ETS on profitability. The treatment group was comprised of the firms that own the regulated installations and are associated with electricity production and district heating under the Swedish Standard Industrial Classification 2002 (SNI 2002). The control group was restricted to firms with the same industrial classification, so that they would share similar industrial characteristics with the treatment group. The installations covered by the EU ETS in the energy sector in Sweden are mostly combustion units, with a capacity above the EU ETS threshold. With the design, both treatment and control

[1] "Installation" here means a stationary technical unit, e.g., machines or equipment, by which one or more activities listed in Annex I of the EU ETS Directive is carried out. The activities listed in Annex I include energy activities and the production and processing of ferrous metals, mineral industries, and pulp and paper industries (Directive 2003/87/EC).

groups are to some extent involved in electricity production, making it difficult to identify the effects of the EU ETS caused by changes in the electricity price. Meanwhile, there are many factors contributing to the price formation for electricity. How and to what extent the CO_2 allowance price is translated into the electricity price may be better studied by some bottom-up modeling analyses. For instance, Keppler and Cruciani (2010) develop a general equilibrium model involving consumers and producers to study the interaction between the carbon constraint and the price-setting mechanism in the energy sector. They show that the EU ETS in the first phase generated additional rents in excess of € 19 billion per year for the European electricity producers. Specific to Nordic countries, Kara et al. (2010) extends a fundamental electricity market model with the introduction of the CO_2 allowance price. The fundamental model takes into account of input mix and balances the generation of electricity between thermal power, hydropower and other power sources so that the total variable generation costs are minimized. According to the model calculation, the annual average electricity price will raise by 0.74 €/MWh for every 1 €/tCO_2 in the Nordic area.

The main purpose of the paper is to study the effect of the EU ETS on firms' profitability due to, among other things, trade of allowances and potential investment in technology improvement in the context. To better understand the consequences of trade of allowances, we divide the firms in treatment into two sub-groups according to their short or long positions of allowances evaluated ex post. The idea is that, as a consequence of trade of allowances, the firms that have excess allowances (hereinafter referred as over-allocated firms) can gain from selling surplus of allowances, while the firms that are in net short of allowances (hereinafter referred as under-allocated firms) suffer from buying additional allowances (or investing in abatement technology) to cover their excess emissions. Apart from the cost-effectiveness, another objective of the EU ETS pursuant to the Porter hypothesis in economics is to provide an incentive for investment in efficiency improvement and in carbon free generation. Well-designed regulations, according to the Porter hypothesis, are aimed to visualize the ecological impact as well as potential technological and technical process innovations (Brännlund and Lundgren, 2009). Although the first phase of the EU ETS was generous in free allocation, it is expected that the EU ETS is a long-term policy and with increased stringency in the future. As such, the EU ETS in principle has an incentive for regulated firms to take precaution in advance. The estimation results, in general, suggest no significant impact of the introduction of the EU ETS on profitability of Swedish energy firms in 2005 and a negative significant impact in 2006. The sub-sample analysis indicates that over-allocated and under-allocated firms respond differently to the EU ETS in 2005, however, no such evidence is uncovered in 2006.

The rest of the paper is organized as follows. Section 1 introduces a general institutional background to both the EU ETS and Swedish climate policy. Section 2 presents the theoretical reasoning, data, econometric model, and estimation results. The final section concludes the paper.

1. Institutional background

1.1. The general background of the EU ETS. Ever since the 1980s, climate change has emerged as one of the most important environmental issues. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted as the basis for a global response to climate change. This was complemented in 1997 by the Kyoto Protocol, in which the EU as a whole made the commitment to reduce its greenhouse gas (GHG) emissions by 8 percent during the period 2008-2012 compared to the level in 1990. In 1998, the EU reached the so-called EU Burden-Sharing Agreement to differentiate this target among its member states. Since then, emissions trading has been brought forward in the interest of promoting the Burden-Sharing Agreement. Based on Directive 2003/87/EC, the EU ETS was officially put into practice in 2005, and it now plays a central role in the EU's commitment in the Kyoto Protocol. The Directive stipulates three phases in the EU ETS, namely, phase 1: 2005-2007, the Learning by doing period; phase 2: 2008-2012, the Kyoto Protocol period; and phase 3: the post 2012 period.

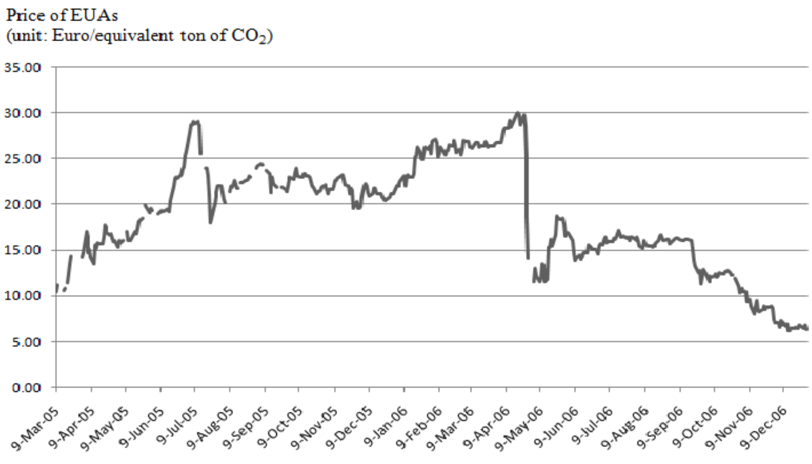
The EU ETS sets the initial emissions caps and then issues a certain amount of emission allowances (EUAs) based on certain criteria. EUAs are then allowed to be traded freely within the EU and even worldwide[1]. Different marginal abatement costs across individual firms generate the incentive for trade, and a carbon market is then created to enable firms to find the lowest cost of abatement. Generally speaking, cost-minimizing firms with higher marginal abatement costs than the price of allowances would like to buy allowances instead of reducing output or investing in abatement. Oppositely, cost-minimizing firms with lower marginal abatement cost would like to invest in abatement to save allowances for selling. Meanwhile, the initial allocation of allowances has a remarkable influence on the incentive for trade. According to the guideline of the EU ETS, a portion of the allowances were initially allocated for free. Particularly, more than

[1] EUAs play a role as a security in financial markets which can be accessed by other traders around the world through clearing members and brokers.

95% of allowances were grandfathered during the phase 1. A main objective of the free allocation was to ensure that the introduction of the EU ETS did not reduce the profitability of the eligible companies (Sijm et al., 2006). Also, within the EU ETS, the member states have considerable freedom to lay out the national allocation plan (NAP)[1] which ex-ante decides how many allowances to allocate in total for a trading period and how many to distribute to each installation. Basically, the amount allocated to each installation is determined on the basis of either historical or projected emissions of the installation. Once the NAP is decided, it cannot be changed within each phase. Moreover, banking and borrowing of allowances were not allowed from the phase 1 to the phase 2. Banking is generally allowed from the phase 2 to the phase 3, while borrowing is till refrained.

The EU ETS has grown bigger and stronger over the different phases. Phase 2 of the EU ETS encompasses the years for compliance with Kyoto commitment, and the total allocation in EU-25 has been suggested to be around 6% below the phase 1's allocation to help ensure that the EU as a whole delivers on the Kyoto commitment (EU Commission, 2005). Grandfathering is still the principle to allocate the allowances in phase 2, but up to 10% of allowances are permitted to be auctioned compared to 5% in phase 1. Great changes have been made in phase 3. To achieve an increased efficiency, the trading period is promoted to be 8 years, longer than the previous two phases. A single EU-wide cap is introduced and allowances will be allocated on the basis of harmonization rules, i.e., all firms across EU with the same or similar activities will be subject to the same rules. The NAPs therefore are abolished. Another feature of phase 3 is a substantial increase in the amount of auctioning. Full auctioning is the rule from 2013 onwards for electricity generators. 20% auctioning is for other sectors, which is to be increased linearly to 70% in 2020. The scope of the ETS will be extended to include CO_2 emissions from petrochemicals, ammonia and aluminum, and NO_2 emissions from some sectors. The aviation will also be included in the EU ETS from 2012.

During phase 1, there were some 11,500 installations from carbon-intensive sectors and about 46 percent of Europe's CO_2 emissions were covered by the EU ETS (Swedenergy, 2005). In the months after the EU ETS was first launched, the price of allowances rose from 10 €/tCO_2 to a peak price of almost 30 €/tCO_2 in the middle of 2005. Later, when the verified emissions data were released in the spring of 2006, the price fell sharply (Figure 1).



Source: European Energy Exchange.

Fig. 1. Intra-day auction prices of EUA

1.2. The EU ETS in Sweden. Since the oil crisis of the early 1970s, Sweden has gone through a structural change in regard to its energy supply. The biggest change has been the decrease in oil from 77% of the total energy supply in 1970 to 33% in 1997, which was made possible mainly due to the development of hydropower and the nuclear program (Ellerman et al., 2008). An observation has been that CO_2 emissions in the Swedish energy sector have declined by approximately 40% between 1970 and 1998, after which the government put more effort into environmental regulation to try to achieve an environmentally friendly economy. Sweden is now sometimes referred to as one of the countries that have shown that it is possible to break the link between economic growth and greenhouse gas emissions[2].

[1] For the decentralized structure of the EU ETS and its implications for economic efficiency, see Kruger et al. (2007).

[2] Over the last nine years, Swedish emissions have on average been 4.9 percent below 1990 levels, while the GDP over the same period has grown by around 3 percent per year. However, there has been criticism of how these emissions have been measured. UN statistics (UN, 2010), for instance, show on the contrary that Sweden has increased its GHG by 12.7% since 1990, including emissions from deforestation.

The current Swedish environmental policy is based on 16 environmental quality objectives (EQOs), of which the first is to reduce climate impact. The Swedish climate strategy consists of targets, instruments, regular follow-up and periodical assessment of the development towards established targets. The instruments used for achieving the climate strategies have been steadily developed since the late of 1980's and now contain carbon dioxide taxes, energy taxes, the EU ETS, the Electricity Certificate System, long term/voluntary agreements, and subsidies[1]. An energy tax was introduced in Sweden in the 1950s and has been an important source of public revenue (Johansson, 2006). The carbon dioxide tax joined the policy system as a supplement of the energy tax in 1991. It has been increased several times and is now relatively high compared to other countries[2].

Sweden joined the EU ETS when it was officially launched in 2005. The installations regulated in Sweden are primarily combustion units carrying out activities connected to electricity production and district heating. The introduction of the EU ETS in Sweden has so far led to some changes in other climate related instruments. For instance, the combined heat and power plants (CHP) covered by the EU ETS and that have high efficiency are exempted from the carbon tax, of which they paid 21% before the EU ETS was introduced. Additionally, some restrictions on CO_2 emissions and quantity of fossil fuel used subject to the Environmental Code[3] have been removed for plants covered by the EU ETS (Nordic Council of Ministers, 2006). Emissions from Swedish installations in the EU ETS were equivalent to around 33% of total emissions in Sweden over the period 2005-2007. The auction has not been included in Swedish NAPs due to the consideration of competitiveness of trading sectors. Around 80% of emissions under the EU ETS were from industrial installations and 20% from electricity and district heating installations. This differs substantially from the breakdown for EU ETS as a whole, where emissions from energy supply installations are greater (approximate 60%) than emissions from industrial installations (approximate 40%) (Ministry of the Environment, Sweden, 2009). The EU ETS is a relatively new instrument in Sweden. Table 1 shows the quantified effects of different policy instruments used in Sweden to control of CO_2 emissions.

Table 1. Policy instruments for Swedish climate strategy with quantified effects (Ministry of Environment, Sweden, 2009)

Instrument	GHGs	Status	Estimated reduction in million tons $CO_{2\text{-eq}}$ per year compared with 1990 (N.E. = not estimated)			
			2005	2010	2015	2020
Cross-sectoral instruments						
Local investment program (LIP)	All	Concluded (1998-2008)	Up to 1	Up to 1	Up to 1	Up to 1
Climate investment program (KLIMP)	All	Concluded (2003-2008)	Up to 0.5	Up to 0.8	Up to 1	Up to 1
Delegation for sustainable cities	All	Ongoing (2009-	N.E.	N.E.	N.E.	N.E.
Environmental code	All	Ongoing (1999-	N.E.	N.E.	N.E.	N.E.
Climate information campaign	All	Concluded (2002-2003)	N.E.	N.E.	N.E.	N.E.
Research and development	All	Ongoing (1990-	N.E.	N.E.	N.E.	N.E.
Production of electricity and district heating						
Energy tax	CO_2	Ongoing (1957-	13	16	17	16
Carbon tax	CO_2	Ongoing (1991-				
The electricity certificate system	CO_2	Ongoing (2003-				
The EU ETS	CO_2	Ongoing (2005-				
Industrial emissions from combustion and processes (including fluorinated GHGs)						
Energy tax	CO_2	Ongoing (1957-	-	-	-	-
Carbon tax	CO_2	Ongoing (1991-				
The electricity certificate system	CO_2	Ongoing (2003-				
The EU ETS	CO_2	Ongoing (2005-				
Proposals for reduced lowering of carbon tax for industries outside the EU ETS and for the introduction of energy tax on fossil fuels for heating in industry	CO_2	Planned (with start 2011-2015)	-	-	0.4	0.4

[1] For an overview on the Swedish climate policy, see the Ministry of the Environment, Sweden (2009).
[2] For an overview on carbon taxes over the world, see Sumner et al. (2011).
[3] Environmental Code is the basic environmental regulation in Sweden which entered into force on January 1, 1999 by amalgamating 15 previous environmental acts.

Table 1 (cont.). Policy instruments for Swedish climate strategy with quantified effects (Ministry of Environment, Sweden, 2009)

Instrument	GHGs	Status	Estimated reduction in million tons $CO_{2\text{-eq}}$ per year compared with 1990 (N.E. = not estimated)			
			2005	2010	2015	2020
Program for energy efficiency improvement	CO_2	Ongoing (2005-	N.E	N.E.	N.E.	N.E.
F-gas regulation including mobile air conditioners directive	HFCs	Ongoing	0	0.2	0.5	0.7

1.3. Swedish electricity market. The electricity market in Sweden has gone through some major changes since the end of 1990s. The reforms are in line with the evolvement of the Nordic power market. In 1996, the legislation for competition in electricity market became effective in Sweden. In the same year, Sweden joined the Norwegian market, in what became the first international power exchange Nord Pool. The integration with Finland and Denmark was taken gradually as border tariffs were removed from Finland in 1998 and Denmark in 2002. Over the last few years, the Nordic electricity market is becoming increasingly integrated with electricity market from the south of the Baltic, in particular Germany and Poland (Swedish Energy Agency, 2006). The resulting competition indicates that electricity supply can no longer be analyzed from a strictly Swedish perspective. An overview of electricity statistics in 2005[1] shows that 46.4% of electricity production in Sweden was from hydropower, and 45% from nuclear power. The electricity from thermal power only took up 1.5%. In Norway, 99% of electricity production was based on hydropower, while thermal and wind took up 0.6% and 0.4% respectively. In Finland, 39% of electricity was generated by combined heat and power (CHP) plants, 33% from nuclear power, and 20% from hydropower. In Denmark, 60.1% of electricity production was based on thermal power, gas and wind in total contributed to 38% of electricity production. Access to cheap hydropower in the Nordic power system has been decisive for the extent to which other and more expensive generation capacity has been used. The Nordic region's rising demand for electricity has, however, necessitated increased operation of coal-fired condensing power plants, above all in Denmark and Finland (Swedenergy, 2005). The hydropower production reached historically high levels in 2005, but electricity prices have not fallen compared with 2004. The Energy Markets Inspectorate of Sweden[2] attributed the high price to the effects of the EU ETS introduced in 2005, combined with relatively high prices for fuels (Energy Market Inspectorate, 2006).

A big proportion of electricity producers in Sweden are in state ownership. In total, the Swedish state owns approximately 43% of the power generation capacity, non Swedish owners around 43%, municipalities around 9% and others roughly 5%. Acquisitions and mergers have progressively reduced the number of major electricity producers. The five largest electricity producers generated around 88.9% of Sweden's total electricity output in 2005 and 89.2% in 2006 (Swedenergy, 2006). Although there is a strong concentration of power generation assets in a small number of large producers, Bask et al. (2011) have studied from a Nordic perspective that electricity suppliers had statistically significant but small market power, and the market power has been reduced as the Nord Pool area has expanded.

Apart from the market integration and the EU ETS, there are also other policy instruments affecting energy firms in Sweden. Among them, the most important economic instrument is electricity certificate system (ECS) launched in 2003. The aim of the ECS is to bring a greater proportion of electricity production from renewable sources into the country's energy system, increasing the production of electricity from renewable sources and from peat by 25 TWh by 2020 relative to production in 2002. For each MWh of renewable electricity, the producer receives a green certificate that can be traded between electricity producers and users. All electricity users, with the exception of manufacturing processes in energy-intensive industries, are obliged to purchase green certificates for a certain quota or percentage of their total consumption. The quota obligation in 2005 was 10.4%, which was successively increased to 17.9% in 2011. A joint Swedish-Norwegian electricity certificate market is planned to start in January 2012, with the agreement running until 2036 (Swedish Energy Agency, 2011). As the expansion of renewable electricity is in line with the reduction of emissions in energy sector, the ECS would also encourage the fuel switching and efficiency improvement in electricity production.

2. Empirical analysis

2.1. A theoretical background. The advantage of emissions trading is that it creates certainty with regard to the environmental outcome (cap), while minimizing the overall compliance cost through the

[1] The statistics are from public statistics in Statistics Sweden, Statistics Norway, Statistics Finland and Danish Energy Agency respectively.

[2] The Energy Market Inspectorate is an independent regulatory authority, supervising the Swedish electricity, natural gas and district heating market. It is subordinate to the Ministry of Enterprise, Energy and Communication, Sweden.

market mechanism (cost-effectiveness). In this study, we use firm profitability as the outcome variable of interest, and investigate the impact of the EU ETS on a sample of Swedish energy firms. The EU ETS may affect both variable and fixed costs of firms (Smale et al., 2006). Under the regulation, CO_2 emissions become a factor of production that has to be paid in the same way as labor and raw materials. In regard to the carbon price, the introduction of the EU ETS could also affect investment decisions of firms. Oberndorfer and Rennings (2007) elaborate on how three short-term factors, i.e., energy intensity, the opportunity to abate carbon emissions, and the ability to pass through the cost of CO_2 emissions, determine the impact of the EU ETS on firm competitiveness. In this paper, we also consider that trade of allowances could cause a cash flow to firms and influences profits directly[1]. Firms that sell allowances would receive revenues, while firms that buy allowances incur costs. The factors contributing to the impact of the EU ETS on firm profits are summarized in Figure 2, which is based on Figure 1 in Oberndorfer and Rennings (2007). Next, we elaborate on how the EU ETS might affect profits of energy firms in the Swedish context according to Figure 2.

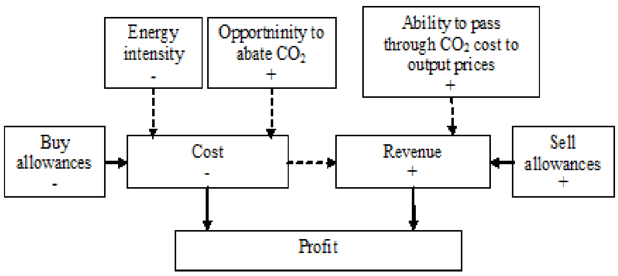


Fig. 2. The short-term factors contributing to the impact of the EU ETS on firm profits

First, the more energy intensive (measured as energy used per unit of production) the firm is, the higher the costs induced by the EU ETS. This is because energy intensive firms in general generate high CO_2 emissions. With the grandfathering, the cost pressure on energy intensive firms induced by the EU ETS would be considerably weakened. In the sample of Swedish energy firms, the cost pressure is further relieved as nuclear power and hydroelectricity dominates the electricity production. These two sources together contribute to 91% and 90% of total electricity production in 2005 and 2006, respectively. Also, even though wind power makes up only 1% of the total power production, it has grown rapidly in recent years, from a generated 203 GWh in 1997 to 1,432 GWh in 2007[2]. Thus, in this setting, the electricity produced from combustion process creating CO_2 emissions may only make up a small portion of total production in our sample of firms. This indicates that the regulated Swedish energy firms are not exposed to high cost pressure under the EU ETS.

Second, it has been claimed that the energy sector had more low-cost emission abatement opportunities than other sectors in Sweden (Widerberg and Wråke, 2009). Such low-cost abatement opportunities could come from the ability to switch fuels and the potential to improve energy efficiency, which are in line with ongoing instruments such as the Electricity Certificate System (ECS) and the national climate and energy target by 2020[3]. The potential for low-cost emission abatement could help the regulated Swedish energy firms to some extent to relieve cost pressure induced by the EU ETS. In this setting, the EU ETS would stimulate the firms to exploit their opportunities of abatement and encourage the innovations of improving production efficiency. The investment incentive is in conformity with the Porter hypothesis in economics, which states that the "well-designed" environmental policies could enhance productivity or bring out a new comparative advantage of some type, which can lead to improved competitiveness. There has been a huge literature on Porter hypothesis both theoretically and empirically. Brännlund and Lundgren (2009) is a good review with a broad coverage on the studies addressing Porter hypothesis. Whether or not energy firms covered by the EU ETS will invest in efficiency enhancement and carbon free generation, and to what extent if it does occur are subject to empirical studies. The investment incentive under the EU ETS might be confounded with that under the ECS as both policies encourage carbon free generation technology. However, it is noted that the quota obligation of the ECS is carried by electricity users. This implies that the ECS treat energy firms symmetrically. Nevertheless, regulated energy firms under the EU ETS are confronted with higher cost pressure compared to unregulated energy firms. For that reason, the regulated firms might have more incentive to invest in abatement and/or carbon free technology. Although the grandfathering and immature mechanisms in the first and second phase would reduce the expectations on the EU ETS, the long-term nature and more stringent regulations in the

[1] Note that the profit measure used in the study is the accounting profit from income statement, in which the shadow value of future benefits from investment in clean technology is not included.

[2] Total power production in 1997 and 2007 are 145,221 GWh and 144,708 GWh respectively.

[3] The Swedish climate and energy targets by 2020 are (1) a 40% reduction in GHG with 1990 as the reference; (2) at least 50% renewable energy; (3) 20% more efficient energy use; and (4) at least 10% renewable energy in transports. For more details, see Ministry of the Environment (2009).

future would render firms to take actions sooner rather than later. Put it differently, if we believe that the EU ETS is a "well-designed" policy in principle, we would count on incentive in investment and expect process improvements in regulated firms. A relevant study on the EU ETS in Sweden is Sandoff and Schaad (2009) based on a survey conducted in 2006. They conclude that internal reduction of CO_2 is seen as the most important measure to handle the CO_2 deficit under the EU ETS in Sweden. The most important action is to develop and implement new production process, including switching fuels and raw materials. Besides, more than half companies responded the survey view the EU ETS impact as one of the key issues when taking long-term decisions.

Third, it is widely accepted that the CO_2 price can be passed through to the electricity price (Sijm et al., 2006; Chen et al., 2008; Fell, 2010). The CO_2 allowance price indicates an opportunity cost to energy firms. It would increase the marginal cost for electricity production and thus increases electricity price. Due to the peculiar production structure of the energy sector, where different sources are ranked in a merit curve according to their variable costs, the extent to which different power generating technologies are affected differs widely (Keppler and Cruciani, 2010). Access to cheap hydropower in the Nordic power system has been decisive for the extent to which other and more expensive generation capacity has been used. In the mean time, the Nordic region's rising demand for electricity has necessitated increased operation of coal-fired condensing power plants, above all in Denmark and Finland. Fell (2010) uses a co-integrated vector autoregressive model to conduct an impulse analysis of electricity prices in the Nordic market and the CO_2 price induced by the EU ETS, and reports that the cost of CO_2 is almost entirely passed through. Kara et al. (2010) extends a fundamental electricity market model with the introduction of the CO_2 allowance price. On minimizing the total variable generation costs the model calculates that the annual average electricity price will raise by 0.74 €/MWh for every 1 €/ton CO_2 in the Nordic area. In view of the fact that the electricity price integrated with the CO_2 price applies to all electricity in the market regardless of the sources of generation, the Swedish energy firms, including those that are not subject to the EU ETS, will benefit from the premium in electricity price, especially those with a high proportion of nuclear, hydroelectric, and wind power.

Furthermore, we turn to the allocation of allowances. In Sweden, freely allocated allowances to energy installations in the first period of 2005-2007 constituted 80% of their historical average emissions during the period of 1998-2001, and most of these installations were subject to the activity of combustion. Even so, the energy sector in Sweden as a whole had a surplus of allowances during the years of our study: 262,000 tons in 2005, corresponding to 6.4% of the total allocation to energy sector and 208,000 tons in 2006 corresponding to 5% of the total allocation. One reasonable explanation for this surplus is that energy firms in Sweden have been improving their energy efficiency and switching to renewable sources of fuel. The surplus of allowances indicates that energy firms in Sweden, on average, could enjoy the benefits of selling off some of the free allocation of allowances.

Another interesting point is to distinguish the impacts of the EU ETS on over-allocated and under-allocated firms. These two types of firms might have similar features as in the same industry and regulated by the EU ETS, but they differ with respect to the consequences of trade of allowances. Under-allocated firms will have to buy additional allowances. On the contrary, over-allocated firms can increase their profits by selling the surplus of allowances. In the empirical part of this paper, we divide the firms in treatment into two sub-samples, under-allocated firms and over-allocated firms, according to their relative allocation of allowances to their actual emissions. This is done by following Anger and Oberndorfer (2008), who developed an allocation factor calculated as the quotient of allocated allowances divided by verified emissions. It follows that the regulated firms with an allocation factor less than one are those with more verified emissions than the freely allocated allowances, i.e., under-allocated firms.

2.2. Data. In this study, we use data on allocated allowances and verified emissions at the installation level, as well as economic data at the firm level. The data processing mainly follows Anger and Oberndorfer (2008).

The installation level emissions data are published annually by the Swedish Energy Agency. The data contain the annual amount of allocated allowances and verified emissions for each installation covered by the EU ETS in Sweden. To facilitate the analysis with available economic data, we extract the emissions data on 2005 and 2006. The installation level emissions data are integrated to the firm level. This left us a group of 216 firms[1] that own the regulated installations. These firms were sorted into six sectors based on their two digital SNI2002 code[2] (Table 2).

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[1] Eleven (11) firms were excluded from the analysis due to missing economic data.
[2] SNI 2002 is the Swedish standard industrial classification 2002 accurate to five digits.

On this basis, the treatment group in the study was comprised of firms within the sectors of electricity production (SNI 40110), electricity distribution (SNI 40131), and steam and hot water supply (SNI 40300), amounting to a total of 104 firms. The reasons for this selection are: (1) the vertical integration of the electricity market makes it hard to exactly separate electricity generation from distribution across firms based on the SNI 2002 codes. Some firms assigned to electricity distribution (SNI 40131) may be involved with electricity generation as well. (2) According to Statistics Sweden, steam and hot water supply (SNI 40300) mainly covers the manufacture and distribution of steam and hot water from combined heat and power plants (CHP), which makes it hard to separate pure electricity generation within this sub category. With this design, we can study the question of how the EU ETS affects firm profitability within the electricity and district heating sectors. In addition, the sample of firms in the treatment group was also divided into two subsamples according to their short or long positions of allowances. In the sample, over-allocated and under-allocated firms, respectively, amounted to 64 and 39 in 2005 and 61 and 42 in 2006[1]. About 11 firms that were over-allocated in 2005 became under-allocated in 2006, and about 8 firms changed in the opposite way.

Table 2. Sector distribution of all regulated firms (calculated from the sample used in the study)

Sector		No. of firms	Percentage
SEC1	Manufacture of pulp, paper and paper product (21)*	38	17.59
SEC2	Manufacture of chemicals and chemical products (24)	10	4.63
SEC3	Manufacture of other non-metallic products (26)	13	6.02
SEC4	Manufacture of basic metals (27)	11	5.09
SEC5	Electricity, gas and hot water supply (40)	111	51.39
	Production of electricity (40 110)	17	
	Distribution of electricity (40131)	18	
	Trade of electricity (40132)	6	
	Distribution and trade of gaseous fuels through mains (40220)	1	
	Steam and hot water supply (40300)	69	
SEC6	Others (13, 14, 15, 20, 23, 25, 29, 31, 34, 35, 45, 51, 70, 90, 93)	33	15.28
Total		216	100

Notes: *The numbers in the parenthesis are the corresponding two digital SNI 2002, which are used to classify the sectors.

The economic data used in the study were supplied by Statistics Sweden. It is a panel data set extracted from Statistics Sweden's business database. The data we have access to cover all registered Swedish firms from the year 1985 to 2006, providing basic accounting variables, e.g., profits and turnover. In this study, we used data from 2004 to 2006 to exploit the before/after structure of our research design. The reason of using the data only from 2004 to 2006 is discussed in the next section. As for the treatment/control structure, we firstly construct the control group by using all other energy firms with the same five digit SNI 2002 codes as the treatment group, i.e., SNI 40110, 40131, and 40300. This amounted to 865 firms. The descriptive statistics for the main variables in the study are presented in Table 3a to 3c for the respective groups. It is worth noting that based on descriptive statistics firms in the EU ETS are on average larger than firms in the control group. Also, there is big variance within each group. In the empirical part, we have thus also tried a propensity score matching method attempting to find a control group similar to the treatment group regarding firm size. More on the choice of comparison group will be discussed in detail below.

Table 3a. Summary of the general treatment group and control group

Variable	Year	Control group			Treatment group as a whole		
		Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.
Net profit (Unit: thousand SEK)	2004	789	22 799.34	300 204.30	103	125 516.30	889 659.40
	2005	865	29 077.15	327 809.40	104	129 775.30	600 305.00

[1] There was one firm in 2005 and one in 2006 that lacked emissions data and could not be sorted as either an over-allocated or under-allocated firm.

Table 3a (cont.). Summary of the general treatment group and control group

Variable	Year	Control group			Treatment group as a whole		
		Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.
Turnover (Unit: thousand SEK)	2006	865	18 620.34	426 975.10	104	179 550.60	1 382 461.00
	2004	789	73 484.45	457 047.00	103	643 036.40	2 674 295.00
	2005	865	76 365.81	497 442.10	104	679 419.10	2 753 180.00
	2006	865	80 904.19	514 814.30	104	771 524.30	3 345 275.00

Table 3b. Summary of sub treatment groups (2005)

Variable	Year	Under-allocated firms in 2005			Over-allocated firms in 2005		
		Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.
Net profit (Unit: thousand SEK)	2004	38	51 296.79	187 045.70	64	171 476.80	1 120 365.00
	2005	39	60 024.62	268 670.50	64	174 225.80	735 095.40
	2006	39	56 025.82	246 797.20	64	257 564.50	1 752 656.00
Turnover (Unit: thousand SEK)	2004	38	442 956.90	1 095 522.00	64	771 545.00	3 290 482.00
	2005	39	456 078.70	1 101 672.00	64	825 796.00	3 406 042.00
	2006	39	488 784.60	1 127 056.00	64	955 531.80	4 175 786.00

Table 3c. Summary of sub treatment groups (2006)

Variable	Year	Under-allocated firms in 2005			Over-allocated firms in 2005		
		Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.
Net profit (Unit: thousand SEK)	2004	42	50 019.26	179 330.80	60	179 973.40	1 157 050.00
	2005	42	154 480.70(1)	659 514.90	61	114 486.50	566 177.70
	2006	42	54 723.67	239 141.80	61	268 001.00	1 795 150.00
Turnover (Unit: thousand SEK)	2004	42	553 641.40	1 233 921.00	60	714 246.20	3 360 174.00
	2005	42	561 112.10	1 236 162.00	61	770 169.50	3 456 097.00
	2006	42	601 572.30	1 275 711.00	61	899 609.30	4 249 048.00

Notes: This large number comes from one firm that had excess allowances in 2005 but was in short of allowances in 2006 and had dramatic changes in profits in the studed years.

3.3. The econometric model. On the ground that the policy intervention is to some extent exogenous to the firms and the available data are in a longitudinal format, we take the EU ETS as a natural experiment and apply difference-in-differences to investigate the treatment effect on the treated. We make use of dummy variables to distinguish firms according to the before/after, treatment/control structure of the natural experiment. Assume that we are in a two-period context that straddles the policy change: the first period (t = 1) refers to the pre-EU ETS year and the second period (t = 2) refers to the EU ETS year. Let d_{2t} denote a dummy variable for the second (post-policy change) time period, i.e., $d_{2t} = 1$ if $t = 2$ and 0 otherwise. To distinguish the firms in the treatment group from those in the control, we introduce a binary policy indicator ETS_{it}, which is unity if firm i owns regulated installations in period t. Put it differently, ETS_{it} is equal to 1 if firm i is regulated by the EU ETS in period t. It then follows that ETS_{it} is 0 for all the firms in the pre-EU ETS year. Before introducing the model, it is worth noting that the firms in the treatment and control groups are widely different in size as indicated above, which makes first-hand comparison of profits inappropriate. To address this problem, we divide the net profits by turnover in the same year to obtain a ratio[1], which helps with the validity of comparison and mitigates the potential problem of heteroskedasticity in relation to firm size. We start with the simplest form[2]

$$\tilde{\pi}_{i,t} = \frac{\pi_{i,t}}{TO_{i,t}} = \alpha + \beta_0 d_{2t} + \beta_1 ETS_{it} + a_i + u_{it}, \quad t = 1,2, \quad (1)$$

in which we write out the error term into two parts, with a_i as the unobserved time invariant component or equivalently representing heterogeneity of firms and u_{it} as the idiosyncratic component, while $\pi_{i,t}$ and $TO_{i,t}$ represent the individual firms' profits and turnover in period t, respectively. The strategy here is to difference out the unobserved fixed effect with respect to the two time period, which gives

$$\tilde{\pi}_{i,t=2} - \tilde{\pi}_{i,t=1} = \beta_0 + \beta_1 (ETS_{i,t=2} - ETS_{i,t=1}) + \\ +(u_{i,t=2} - u_{i,t=1}) \quad (2)$$

or

[1] The ratio is roughly called the profit margin in financial analysis.

[2] The model is consistent with the equation (13.26) in Wooldridge (2003). Some other models put α and a_i together as a single term to indicate the fixed effect. Here, we kept them separate to address the fact that a_i is the unobserved error term.

$$\Delta\tilde{\pi}_i = \beta_0 + \beta_1 ETS_i + \Delta u_i, \quad (3)$$

where $ETS_i = 1$ represents the firms in treatment. By assuming that the mean of Δu_i is zero and the variance of Δu_i is constant in (1), we can then estimate the β_1 in a standard OLS framework and obtain an unbiased estimator simply as

$$\hat{\beta}_1 = \overline{\Delta\tilde{\pi}_{treat}} - \overline{\Delta\tilde{\pi}_{control}} \quad (4)$$

which is also called the difference-in-differences estimator (Wooldridge, 2003).

In the study, we are interested in the questions that whether the EU ETS has impact on the profitability of energy firms and whether over-allocated firms respond to the EU ETS differently in comparison with under-allocated firms. The first question can be investigated by testing $\beta_1 = 0$ *against* $\beta_1 \neq 0$ in equation (1). As for the second question, we introduce dummy variables for the two types of firms and estimate the following equation:

$$\Delta\tilde{\pi}_i = \gamma_0 + \gamma_1 underallocated_i +$$
$$+\gamma_2 overallocated_i + \Delta u_i,$$

where the variable of $underallocated_i$ takes the value 1 for under-allocated firms in the studied EU ETS year and 0 for other firms (including over-allocated firms and non-EU ETS firms), the variable of $overallocated_i$ is defined in the same manner. What we are interested is then to test the hypothesis of $\gamma_1 = \gamma_2$ *against* $\gamma_1 \neq \gamma_2$.

Meyer (1995) stated clearly in his seminal paper of natural experiments that one of the main threats to the validity of inference from the difference-in-differences research design is that changes besides the treatment are not likely to always influence all groups in the same way. For instance, the fuel prices would have greater influence on the more energy intensive firms; weather conditions such as precipitation would influence energy supply firms much more than the steel makers. By this token, the research design of the difference-in-differences is most plausible when the control group is very similar to the treatment. As such, we take all other firms with the same industrial classification as the treatment group to construct the control group since they share the common industrial characteristics. With such a design, our focus is on the impact of the EU ETS from the consequences of trade of allowances and induced investment. The impact of the EU ETS from the premium in electricity prices are not identified as both the treatment and control groups benefit from the increased electricity price. Hence, the coefficient related to the introduction of the EU ETS in the model mainly contains the impact from the trade of allowances and technology improvement.

Also, as well known, the validity of the difference-in-differences estimator is based on the assumption that the trends of the outcome variable in the studied period would be the same in both treatment and control groups in the absence of the treatment. It is known in the literature that it is hard to check the assumptions underlying the difference-in-differences estimation as they are made about unobservable quantities. In particular, the common trend assumption is never testable. Considering that the energy sector in Sweden has gone through major changes between 1996 and 2002 in line with the integration of Nordic power market, we take the year 2004 as the pre-EU ETS year in the study. To get an idea of the plausibility of the common trend assumption, we perform a "placebo" difference-in-differences. We use a "fake" treatment group, that is, the treatment group firms in a pre-treatment period. We compare the average relative profits between two pre-treatment periods, 2003 and 2004, between the "fake" treatment group and control group. The estimates from the "placebo" difference-in-differences are not statistically significantly different from zero at 5% level. The results of "placebo" difference-in-differences are reported in Table 4a.

2.4. The empirical results. The estimation results are presented in Tables 4a and Table 4b below. The reported standard errors are White's standard errors, corrected for heteroskedasticity of unknown form (Wooldridge, 2002). The results show that, taking the treatment group as a whole, the EU ETS estimate in 2005 is 1.763 indicating a positive impact of the EU ETS on regulated firms compared to unregulated firms in energy sector. However, the estimate is not statistically significant. The estimate in 2006 is -1.147 statistically significant at 5% level, implying a negative impact of the EU ETS on the regulated energy firms. Regarding the sub-sample analyses, the estimates for over-allocated and under-allocated firms in 2005 are 1.791 and 1.716 respectively. The estimates are very similar in magnitude, although neither of them is statistically significant. Our interest is to see if the two types of firms are affected similarly by the EU ETS. To that end, we perform a Wald test[1] for the hypothesis test that $\gamma_1 = \gamma_2$ *against* $\gamma_1 \neq \gamma_2$. The p-value of the test is 0.0491, which suggests that the difference is statistically significant at 5% level. That is, over-allocated firms have a slightly higher profit margin compared to the under-allocated firms in 2005. The estimates in 2006 are -1.132 for over-

[1] The test was done in Stata by the Wald test on the basis of the variance-covariance matrix of estimates. Although the estimates and standard errors are similar for γ_1 and γ_2 (Table 4b), the covariance between γ_1 and γ_2 prompts us to reject the null hypothesis that $\gamma_1 = \gamma_2$ in 2005.

allocated firms and -1.170 for under-allocated firms. Both estimates are statistically significant at 5% level. On the face of them, it seems that under-allocated firms suffered more compared to the over-allocated firms. However, the *p*-value for the Wald test is 0.2417, which does not suggest the evidence for the different impact on the two types of firms in 2006. As seen in section 2.2 the descriptive statistics (Table 3a and 3b) show that firms affected by the EU ETS are on average much larger than firms in the present control group, the results could be affected by selection bias. As such, a simple propensity score matching method has also been applied. It follows by two steps. In the first step, a probit estimation is used to predict the probability to be in the treatment group using the number of employees, profits after financial items and turnover as the independent variables. The control group is then constructed by selecting firms that have the predicted probability fallen into the same range of treatment group. It is noted that all qualitative results from the estimations using all firms in the present control group are similar with the ones using the firms restricted by the propensity score method. The results including all firms in the present control group are the ones presented in this paper[1].

Table 4a. Estimates on the policy indicator (ETS)

	"Placebo" diff-in-diffs			2005			2006		
Variable	Estimate	Std.	*t*	Estimate	Std.	*t*	Estimate	Std.	*t*
ETS	-0.266	0.3654	-0.73	1.763	1.4906	1.18	-1.147	0.5192	-2.21
Contant	0.303	0.3642	0.83	-1.731	1.4904	-1.16	1.129	0.5189	2.18
Obs.	761			798			797		
R-squared[1]	0.0001			0.0003			0.0009		

Notes: [1] It is noted that the *R*-squared in the estimation are rather small. However, the purpose of the analyses is not to fit a model to explain the dependent variable but to focus on the estimates of the coefficient parameter which shed light on the effect of the interesting factor.

Table 4b. Estimates for the separate analysis

	2005			2006		
Variable	Estimate	Std.	*t*	Estimate	Std.	*t*
Over-allocated	1.791	1.4918	1.20	-1.132	0.5196	-2.18
Under-allocated	1.716	1.4915	1.15	-1.170	0.5200	-2.2 5
Contant	-1.731	1.4914	-1.16	1.129	0.5193	2.17
Obs.	797			796		
R-squared	0.0003			0.0009		

As stated in the theory section, the treatment effect is mainly from the impact of trade of allowances and technology improvement. From Figure 1 above, we see that the price of allowance in 2005 was initially around 10 €/tCO_2 but rose to a highest level close to 30 €/tCO_2 in July and thereafter fluctuated around 22 €/tCO_2 for the remainder of the time. In 2006, the price initially went up, but when the first data on verified emissions were released in the spring of 2006, it fell sharply since the data showed that most of the countries exhibited a "long" position. Since then, the price has decreased dramatically, almost touching 5 €/tCO_2 toward the end of 2006. This indicates that the impact from buying and selling allowances was much stronger in 2005 than it was in 2006. With respect to technology improvement, the most direct way to abatement is to invest in machinery. As shown in Table 5, the investment in machinery on average grew at a higher rate in 2006 in the treatment group than in the control group. The variable of investment in machinery in our dataset is too general to determine how much is related to the EU ETS[2], but it does give us a rough idea that investment in abatement and energy efficiency were occurring. It is also in conformity with the Porter hypothesis and the principle of taking precautions, since the regulation of the EU ETS is known to be more restrictive in the future. However, it is worth noting that we studied the first two years of implementation, which might be too short a period to show the causal effect of the EU ETS on investment in abatement. Still, taking it for granted that the investment is occurring, a possible explanation for our findings of the insignificant impact in 2005 is that the benefits from selling the surplus of allowances were cancelled out by the induced investment costs. As seen above, energy firms in Sweden have a surplus of allowances amounting to 262 000 tons in 2005, corresponding to 6.4% of total allocation in the sector. On average, energy firms under the EU ETS

[1] The results using firms restricted by propensity score method are available from the author upon request.

[2] The variable of investment in machinery in the data is a general account which covers machinery, equipment and tools.

can earn some profits from selling the surplus. This combined with the possible investment costs induced by the EU ETS contributes to the insignificant impact in 2005. In 2006, the surplus of allowances amounts to 208 000, corresponding to 5% of total allocation to energy sector in the same year. With less surplus and lower price, the benefits from selling the surplus are shrinking in the energy sector. As regarding the investment induced by the EU ETS, it is reasonable to expect higher investment in 2006 compared to 2005, as the uncertainty on the policy is reduced along the implementation. Besides, the price of allowances has dropped dramatically in 2006 due to the signal of over-allocation in the first phase. It is expected that the allocation in the second phase is to be more stringent to fulfill the Kyoto commitment. As such, the rational firms would take actions sooner rather than later to mute the impact from the expected-to-be more stringent policy in the future. The negative impact in 2006 can thus be explained by the shrinking benefits and the increasing induced investment costs.

The explanation for the results that under-allocated and over-allocated firms were affected differently in 2005 but not in 2006 could be that the price of allowances was relatively high in 2005, imposing a strong impact from trade of allowances on profits. As we also see when the price went down in 2006, no statistically significant effects were found any more. The slightly higher estimate for the over-allocated firms in 2005 supports our idea that over-allocated firms could gain from selling their surplus of allowances, while under-allocated firms suffer from having to buy additional allowances. However, the difference between the two types of firms is small, which is to be expected since the trade of allowances is not the main activity in energy firms generating profits.

Table 5. Summary of gross investment in machinery

Variable	Year	Control group			Treatment group as a whole		
		Obs	Mean	Std. dev.	Obs	Mean	Std. dev.
Gross invest. In machinery (Unit: thousand SEK)	2004	789	9 307.44	66 667.87	103	81 290.43	199 882.70
	2005	865	11 009.36	88 303.71	104	100 397.20	266 516.40
	2006	865	15 916.57	132 611.60	104	164 146.70	678 498.10
Growth rate[1] of gross invest. in machinery	2004	339	0.15	1.67	100	0.15	1.37
	2005	349	0.12	1.73	99	0.11	1.32
	2006	392	-0.01	1.77	98	0.38	0.98

Notes: [1] The growth rate is calculated as the log difference of gross investment in machinery. There are a few firms in the control group, with an investment in machinery equal to 0, that were excluded when calculating the growth rate by the log difference.

Conclusion

In this paper, we use a sample of Swedish energy firms to conduct an empirical analysis of the impact of the EU ETS on the profitability of firms. The research design in the study makes it difficult to investigate the impact from changes in the electricity price in relation to the EU ETS. The purpose is rather to shed light on the effect of the EU ETS on firm profitability due to the trade of allowances and technology improvement. A difference-in-differences strategy is applied on an unobserved fixed effect two-period panel data model to investigate the treatment effect. To our knowledge, this paper is the first of its kind in the quantitative studies of the EU ETS.

The estimation results do not show any significant impact of the EU ETS on firm profitability in 2005, but suggest a negative significant impact in 2006. The results can, perhaps, be interpreted by following changes in the price of allowances and potential investments in abatement. The price of allowances was relatively high in 2005, but quite low in 2006. From Table 5, we also see an increase in investment in machinery during these years, which may be related to the introduction of the EU ETS. It could be that the free allocation and relatively high price of allowances in 2005 cancel out the induced investment costs occurring in firms, resulting in an insignificant impact of the EU ETS. However, when the price of allowances went down in 2006, the benefits from the free allocation were reduced, and the empirical analysis shows a negative impact of the EU ETS on firm profitability. Also, the sub-sample analysis shows that the EU ETS had a different impact on under-allocated and over-allocated firms in 2005, but not in 2006. A possible explanation for this is that the relative high price of allowances in 2005 had a strong impact on firms from buying and selling the allowances, and the low price in 2006 weakened the impact of trading allowances.

Analogous to Anger and Oberndorfer (2008), a point related to the methodology needs to be emphasized here. It is by all means very early to conduct an ex-post analysis for the EU ETS. To date, the firm-level economic data available to us is only up to 2006. For a long-term policy, an ex-post analysis of the early years can bring forward appealing insights, but the robustness of the estimated reform effects could be questioned. In this way, the main purpose of the study was to set up a model as a basis for future study. Furthermore, the analysis can be applied to other measurements of interest as well. The reason for choosing profitability is that profits should respond quickly to the reform. Other measurements, such as investment, may respond with a time lag, but could also be the focus of future studies.

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