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The Financial and Environmental Performance of Firms Exposed to the EU Emissions Trading Scheme

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Declaration of Original Authorship

I confirm that this thesis is my own work and the use of all materials from other sources has been fully and properly acknowledged. The thesis was proofread by Ms. Barbara Docherty. The authorship is not compromised and the substance of work remains fully my own.

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Abstract

This thesis is an empirical-based study of the European Union's Emissions Trading Scheme (EU ETS) and its implications in terms of corporate environmental and financial performance. The novelty of this study includes the extended scope of the data coverage, as most previous studies have examined only the power sector. The use of verified emissions data of ETS-regulated firms as the environmental compliance measure and as the potential differentiating criteria that concern the valuation of EU ETS-exposed firms in the stock market is also an original aspect of this study.

The study begins in Chapter 2 by introducing the background information on the emission trading system (ETS), which focuses on (i) the adoption of ETS as an environmental management instrument and (ii) the adoption of ETS by the European Union as one of its central climate policies. Chapter 3 surveys four databases that provide carbon emissions data in order to determine the most suitable source of the data to be used in the later empirical chapters. The first empirical chapter, which is also Chapter 4 of this thesis, investigates the determinants of the emissions compliance performance of the EU ETS-exposed firms through constructing the best possible performance ratio from verified emissions data and self-configuring models for a panel regression analysis. Chapter 5 examines the impacts on the EU ETS-exposed firms in terms of their equity valuation with customised portfolios and multi-factor market models. The research design takes into account the emissions allowance (EUA) price as an additional factor, as it has the most direct association with the EU ETS to control for the exposure. The final empirical Chapter 6 takes the investigation one step further, by specifically testing the degree of ETS exposure facing different sectors with sector-based portfolios and an extended multi-factor market model.

The findings from the emissions performance ratio analysis show that the business model of firms significantly influences emissions compliance, as the capital intensity has a positive association with the increasing emissions-to-emissions cap ratio. Furthermore, different sectors show different degrees of sensitivity towards the determining factors. The production factor influences the performance ratio of the Utilities sector, but not the Energy or Materials sectors. The results show that the capital intensity has a more profound influence on the utilities sector than on the materials sector. With regard to the financial performance impact, ETS-exposed firms as aggregate portfolios experienced a substantial underperformance during the 2001–2004 period, but not in the operating period of 2005–2011. The results of the sector-based portfolios show again the differentiating effect of the EU ETS on sectors, as one sector is priced indifferently against its benchmark, three sectors see a constant underperformance, and three sectors have altered outcomes.

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1 Introduction to the thesis

1.1 Background of carbon emissions management

Greenhouse gas (GHG) emissions and global climate change have become common terms in recent years. The excessive stock of GHGs in the atmosphere, human activities-related in particular, is considered to be strongly associated with the increase in average temperature, which leads to global climate change (IPCC, 2001b: 4-5). GHG emissions most commonly refer to carbon dioxide (CO_2) emissions, and have raised increasing concerns world-wide. As cited in the Stern Review, the Intergovernmental Panel on Climate Change (IPCC) concluded in their 2001 report that new and stronger evidence has been found that most of the warming observed over the past 50 years can be attributable to human activities (IPCC, 1990; IPCC, 1995; Stern, 2006: 7). Various publications (Smith *et al*., 2001; IPCC, 2007; Stern, 2008a) have expressed their concerns that the implications and risks of climate change on the environmental, economic and social dimensions globally can be unprecedented, and suggested that action against the potential harmful impacts of climate change is required.

The potentially damaging consequences of climate change and its implications for our living environment and economy are undesirable. These consequences range from irreversible environmental events, such as the loss of species, land and, in the long term, the disruption of global oceanic circulation (IPCC, 2001a: 83), to damages to the global economy. The costs associated with the climate change issues could add up to 1% to 10% of global GDP, depending on the scenario configuration (Stern, 2006: 161; IPCC, 2007: 64–65). While it is unlikely that all regions will suffer from the same degree of climate change impact, it can intensify the problem of inequality among the richer and poorer countries, as presumably the richer countries will possess more resources and advanced technology to tackle climate change-related issues., A response from societies, nations, as well as non-governmental and private organisations will be necessary, in order to mitigate these potential impacts. One of the major actors is the IPCC, established by the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) in 1988, whose primary mission is assess and react to climate change-related issues. It reviews and assesses the latest scientific, technical and socio-economic information produced world-wide is relevant to climate change. The work of the IPCC is an aggregation of the voluntary contributions of numerous scientists (IPCC, 2013a). The most important outputs of the IPCC's work are the assessment reports, which aim to inform the world of the latest state of climate change-related knowledge potential issues. Four assessment reports have been published, in 1990, 1995, 2001, and 2007, respectively, while the fifth assessment report was released in phases from September 2013 to October 2014 (IPCC, 2013b).

Another important response at international level is the United Nations Framework Convention on Climate Change (UNFCCC), which was adopted and opened for signature in 1992, in Rio de Janeiro, with the intention to prevent the catastrophic consequences of global climate change (UNFCCC, 2014). The members[1] of UNFCCC meet annually in the Conference of Parties (COP) to assess and update the progress of dealing with climate change-related issues. One of the most important agreements that has underpinned the need for mandatory action on GHG emissions reduction was made during the third Conference of Parties (COP3), in Kyoto, in 1997 and named the Kyoto Protocol. The Protocol requires 37 industrialised countries and EU members commit to a legally binding target of reducing their emissions by 5% below the 1990 level,[2] either solely or jointly during the period 2008–2012[3] (UNFCCC, 1998).

With the progress of these international initiatives regarding climate change, the path of adopting appropriate instruments for an effective GHG reduction became clearer. The adoption of the Kyoto Protocol in 1997 saw a substantial step in the direction of preparing market-orientated methods for GHG emissions management. Unlike the command-and-control method, such as directly imposing a rigid and universal standard of emission limits indiscriminately on all emission sources, market-based methods offer the opportunity for the producers who are liable for these emissions to determine how much 'the right' to emit

1 The Convention divides countries into three main groups: Annex I Parties contain the industrialised countries which were OECD members in 1992 plus the economies in transitions countries, such as the Russian Federation, the Baltic States; Annex II Parties consist of Annex I countries who are OECD members and are responsible for funding that enables developing countries to undertake emission reduction activities. Non-Annex I Parties are mostly developing countries (UNFCCC, 2013)

2 Details are specified in Annex B of the Kyoto Protocol (UNFCCC, 1998).

3 The first commitment period. In the COP18 in Doha, in 2012, several major amendments to the Kyoto Protocol were made. Parties committed to a new reduction target of 18% below the 1990 level during the eight-year period from 2013 to 2020; the compositions of Parties in the second commitment period has been different from that in the first (UNFCCC, 2012).

is worth to them. Three market-based mechanisms – the International Emissions Trading, Clean Development Mechanisms, and Joint Implementation – were introduced in the Kyoto Protocol. These mechanisms can be utilised by countries with an emission reduction commitment to achieve their targets in a more flexible manner.

Emissions Trading, one of the flexible mechanisms of particular interest in this thesis, works by first creating a market for emissions rights, which could be considered as a newly defined commodity. The market can be created in several ways, with the following two being the most common: the cap-and-trade system and the baseline-and-credit system. These two systems differ substantially in their design characteristics (Brohé *et al*., 2009: 42), which involve primarily the process of defining the 'commodity'. A cap-and-trade system is created by defining a new set of property rights and imposes an absolute cap within the system. The cap determines the amount of allowances available and the allowances are distributed to the participating parties in the scheme based on designated allocation methods. The baseline-and-credit system works through generating emissions reduction credits from projects that reduce emissions below a designated baseline. The reduction credits can be used to achieve the agreed emissions reduction commitment as well as being traded among different parties with reduction targets, as the credits can write off the emissions produced. The Clean Develop Mechanism and Joint Implementation are examples of the baseline-credit system.

The third assessment report prepared by Working Group III of the IPCC (Bashmakov and Jepma, 2001) presents a full examination of the policies and measures that could be applied to GHGs emissions mitigation at national and international level, which serves as a practical guide for evaluating difference policy instruments. The report points out that market-based instruments became well received among governments for their potential to achieve environmental effectiveness in a relatively cost-efficient manner. It should be noted that the IPCC report stresses that it is unlikely that one policy alone can fully address GHG emissions as well as other climate change-related problems for most nations, which appears to be a consensus view among several other studies (Rayner and Prins, 2007; Stern, 2008b; Brohé *et al*., 2009: 36–39).

1.2 Research interests: The EU ETS and its implications

This section provides essential background information on the subject of this thesis, the EU ETS and its environmental and financial implications. It starts by introducing why EU ETS has been chosen as the subject of interest, which is followed by the introduction of the research question proposal along with the key studies that have inspired the research question and analyses planned. The section ends with a short introduction to the data required.

1.2.1 Why EU ETS?

This section explains the reasons behind the main research interest of this thesis, the EU ETS, which is to date the largest cap-and-trade system for GHGs world-wide, and its implications. EU ETS is considered a topic of particular relevance for a number of specific reasons, which primarily include its scale and multisectoral and spatial coverage, as well as the current lack of empirical evidence on the subject of EU ETS-related impacts on the financial markets. The scale of EU ETS is significant in its multisectoral and multinational coverage. According to European Commission, EU ETS covers approximately 45% of total GHGs in the European Union, and for the first two trading periods after its introduction, EU ETS covered more than half of the CO_2 emissions within the Community.

Convery (2009) identifies the emerging trends in the literature on emissions trading in Europe by surveying the existing research work, and finds that the majority of EU ETS literature has so far focused on policy perspectives. The context and history, allowance allocation, as well as other EU ETS-associated policy implications, such as the alternatives to the current allocation method, have been of particular interest for researchers. However, the category of Markets, Trading, and Finance has seen a relatively low number of publications. A large number of studies inthe Market, Trading, and Finance category has attempted to identify and explain allowance price determinants, such as the studies by Alberola *et al*. (2009a; 2009b) and Creti *et al*. (2012), as well as the trading activities or strategies in the carbon market itself, for instance the study by Crossland *et al*. (2013). Studies with empirical analyses of the stock market implications of EU ETS are rarely seen. A similar review of the EU ETS literature can also be found in Zhang and Wei (2010). Oberndorfer (2009) and Veith *et al*. (2009) are the first studies that provide empirical evidence of a potential link between the EU carbon market and the stock market, though with sample firms being limited to the power sector. The lack of publications on the subject of a carbon market–stock market link thus offers a significant opportunity to add more depth to the research area of emissions trading and the EU ETS, as well as to fill in gaps in the empirical literature.

EU ETS is one of the the key instruments implemented by the European Union to comply with its emissions reduction target. It also represents the determination and intention of the European Union to take the leading position in shaping global climate policies. EU ETS has the aim of effectively reducing CO_2 and other GHG emissions to the targeted level in a cost-efficient manner (EC, 2013c). While the environmental goal is the priority in order to fulfil the EU reduction commitment and ultimately to avoid the serious consequences of GHG-related climate issues, the additional benefit of minimising the mitigation costs makes EU ETS appealing to the compliant sectors. The scale and coverage of EU ETS is one of its unique features; it is to date the largest regulated GHG emissions trading system in the world, covering more than 11,000 installations, across 31[4] participating member states and covers the major emitters of various sectors. A more in-depth examination on the scale of EU ETS and the dominant position of EUA trading is presented in the next section to underpin the decision of focusing on the EU ETS.

1.2.2 The European vs. the global carbon market

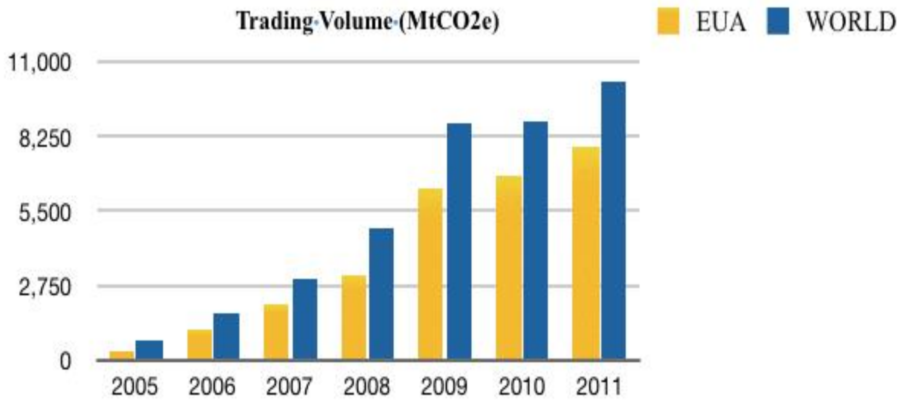
Table 1.1 and Figure 1.1 show the position of the European carbon market relative to the global carbon market. The market created by the EU ETS began to dominate global carbon trading despite the trading activities during the initial launch period being rather conservative. The numbers reveal that the European Union Allowance(s) (EUA), the unit of emissions allowance defined by the EU ETS, accounts for a large proportion of global carbon trading activities. The EUA represents one tonne of CO_{2e} emissions, which is designed to be the equivalent of the Assigned Amount Unit (AAU) defined under the Kyoto Protocol to provide a better link to the carbon market globally. The EUA market and overall carbon market saw a twofold growth in trading value in 2008,

4 28 EU countries plus Iceland, Liechtenstein, and Norway from the European Economic Area (EEA) as of 2014, the third phase of the EU trading system.

Table 1.1 Trading activity of EUA and world carbon market

	Volume ($MtCO_{2e}$)			Value (USD million)		
	EUA	World	EUA % of World	EUA	World	EUA % of World
2005	321	710	45.21%	7,908	10,864	72.79%
2006	1,104	1,745	63.27%	24,436	31,235	78.23%
2007	2,060	2,984	69.03%	49,065	63,007	77.87%
2008	3,093	4,836	63.96%	100,526	135,066	74.43%
2009	6,326	8,700	72.71%	118,474	143,735	82.43%
2010	6,789	8,772	77.39%	133,598	159,191	83.92%
2011	7,853	10,281	76.38%	147,848	176,020	84.00%

This table presents the share of EUA in relation to global carbon market trading activities. The first column indicates the year of the trading recorded. Source: Carbon Finance Unit at the World Bank annual carbon market report (WorldBank, 2007, 2009, 2011, 2012).



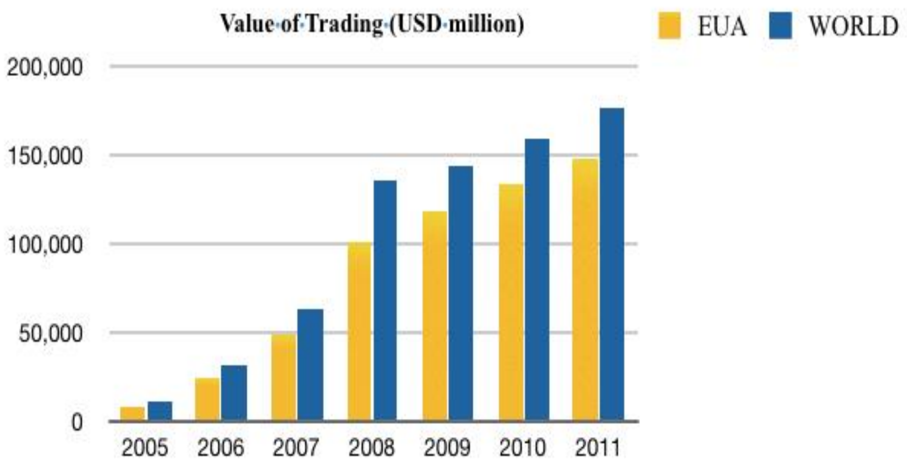


Figure 1.1. Trends in trading volume and value of carbon emissions allowances
Source: Carbon Finance Unit at The World Bank (World Bank, 2006, 2007, 2008, 2009, 2010, 2011, 2012)

the first year of the new trading period of EU ETS, although the markets for the project-based credits experienced a decline. This observation once more indicates the crucial status of EUA trading in driving the global carbon market. The financial crisis, which eventually led to a large-scale recession, also hit the carbon market particularly during the year 2008–2009. Both EUA and the international carbon market saw a considerable amount of trading volume increase while the value of the market did not increase in a corresponding ratio. The global recession hit the carbon market from the demand side, as deteriorating economic conditions led to low production output, low energy consumption and thus low emission allowances demand. Firms with the allowance surplus aimed to cash in their allowances, which drove up trading activities. However, the value of allowances was suppressed due to oversupply, and hence the total value of trading did not see a proportional growth.

In short, the unique status and dominant position of the EU ETS provides great research opportunities. The development of the market created under EU ETS and the output of real market data makes an empirical-based investigation feasible. The main research interest of this thesis and the emphasis on empirical investigation will be described in the following section.

1.2.3 What are the specific issues of interest in this thesis?

This section describes the main interest of this thesis, along with key references that shape the research questions and motivate the analyses. As this chapter focuses on introducing the main research interest, a more detailed review of the relevant empirical literature is provided in the respective empirical chapter. The research interest of this thesis originates from two aspects of the EU ETS after an extensive review of the relevant literature and reports. First, have EU ETS-exposed firms experienced any significant impact on their share prices? Second, does the implementation of EU ETS substantially influence the emissions behaviour of firms? Three independent yet inter-related sets of analyses are designed to investigate these questions with real market data and verified EU ETS data:

1) An examination of the implications of EU ETS on the stock market value of the regulated firms is planned, which is the main interest of this thesis. The analysis

examines the underlying assumption that emissions trading might provide a cost saving opportunity in emissions reduction abatement from a financial market perspective. This analysis is primarily inspired by Oberndorfer (2009), Veith *et al.* (2009), and Mo *et al.* (2012), who investigate the stock price performances of large electricity firms which are subject to EU ETS compliance.

2) A follow-up investigation to identify the further factors that might alter the EU ETS impact on firms' share prices is conducted. This analysis receives partial inspiration from Knight (2011), with a sector-orientated variation. The primary assumption builds upon sectoral differentiation driving investors' considerations with regard to the carbon market–financial market linkage, instead of temporal and spatial factors. This analysis also draws inspiration from conceptual studies, such as Hourcade *et al*. (2007) and Lund (2007), as well as from empirical studies (Bushnell *et al.*, 2013; Chapple *et al*., 2013).

3) An analysis that identifies and empirically tests the factors associated with firm-level carbon emissions efficiency for firms regulated by the EU ETS is performed. This analysis is motivated by the literature that investigates the interactions between carbon emissions and their determinants. The key reference is the study by Cole *et al*. (2012), who have empirically tested determinants of firm-level CO_2 emissions per unit of production using an extensive dataset of Japanese manufacturing firms. Prior to their firm-level study, they also conducted an empirical-based study investigating the industry-level emissions determinants with UK data (Cole *et al.*, 2005). This analysis also complements the previous two sets of analyses by enhancing the linkage between all empirical analyses and practicability of the thesis.

In order to conduct these analyses, which are expected to provide insights into the research interests of this thesis, a comprehensive dataset, which can provide appropriate data points for a robust analysis, is required. To begin with, firms with compliance obligation in the EU ETS, i.e. the EU ETS-exposed firms, need to be identified for all investigations as well as the emissions of each company, as the subject of investigation in all three proposed research questions requires such information. Second, the status of the firm, particularly whether the company is publicly traded, is specifically required for the second and third questions, as the share price of the firm is the subject of investigation. After an extensive survey of various sources of data, which is documented in Chapter 3, the Carbon Market Data's EU ETS Company Database provides company-level data with sufficient geographical and temporal coverage as well as the assured level of verification. Most importantly, the emissions data from its EU ETS Database is within the regulated context, which provides a solid base for the empirical analyses to be conducted. More detailed discussions of the data required with regard to each research question, including explanatory variables for different model specifications, are presented in the respective empirical chapters (Chapter 4, 5, and 6).

1.3 Research questions and the empirical findings

This thesis intends to empirically examine the effects of emissions trading on ETS-exposed firms in terms of their emissions behaviour as well as on stock price performances. The analyses and findings benefit from econometrics techniques and accountable real market data that is sourced from the transaction log administered by the European Commission. The finding adds value to various aspects of the current EU ETS literature, which is briefly presented in this section.

Empirical Chapter 1

Chapter 4 examines the effect of the planning and implementation of the EU ETS on the stock market performance of the regulated firms. Companies used to emit CO_2 and other GHGs at no cost, whereby the costs are essentially externalised within the society. The situation has changed since 2005; the right to emit is now restricted and additional emission allowances must be obtained at extra cost where an entity emits over its designated cap, which forces the firm to internalise these costs. The EU ETS may thus have a negative effect on the stock market performance of regulated firms, as it forces them to pay, directly or indirectly, for their carbon emissions. (Baumert *et al.,* 2003; Burtraw *et al.,* 2001; Chapple *et al.,* 2013).

The main question asked in Chapter 4 is as follows: will the firms which are or will be subject to a mandatory emission restriction introduced by the EU ETS experience any significant impact in terms of their stock price performance? The planning and implementation of the EU ETS may have a negative effect on the stock price performance of the relevant firms, from the ETS regulation requiring the firms to internalise the cost of their emissions. Compliance with the emissions restriction, as a consequence, is expected to cost the participating firms considerably more than the business as usual scenario before the ETS was proposed and implemented (Laurikka and Koljonen, 2006; Pope and Owen, 2009; Linn, 2010). Through the introduction of an ETS, firms are also considered to be increasingly subject to potential environmental liabilities and cost impacts in the medium to long term (Bushnell *et al*., 2013; Bode, 2006; Hughes, 2000).

Most of the empirical studies that have examined the EU ETS-related effects on the stock market focused on small sub-samples of all the listed firms participating in the EU ETS. In particular, four studies shed light on the impact of the EU's emission trading schemes on the share prices of affected companies using actual market data. Oberndorfer (2009) conducted the first econometric analysis that investigated the relationship between the emission allowance prices and the stock returns of twelve major European electricity providers. Veith *et al*. (2009) investigated the capital market response to emission allowance price changes with the dataset of 22 major electricity companies in Europe and the APT-style market model. A more recent study with empirical analyses covering the first five years (2005–2009) of the EU ETS, by Mo *et al*. (2012), measures the impact of EU ETS on electricity firms in terms of their shareholder value. They use a modified multi-factor market model to estimate the sensitivity (beta) of stock returns of 12 electricity firms to the allowance price variation. Their findings reveal that the allowance price effect on stock returns changes from Phase 1 to Phase 2. The EUA prices appreciation tends to be accompanied by the corporate value appreciation in Phase 1, while the opposite is observed in Phase 2.

The results of the first part of the analysis show that EU ETS-exposed firms demonstrate the expected underperformance at the highest statistical significance level but only in the sample period 2001–2004 (pre-EU ETS period), during which the ETS Directive was proposed and being negotiated but not yet launched. This is of particular interest, as none of the previous studies has empirically examined the share price performance of the ETS-regulated firms during the pre-ETS period. Once the EU ETS began in 2005, the regulated firms did not experience any subsequent negative effects on their stock prices. These results are in line with previous studies, which observe no adverse impacts on share prices of regulated firms within the EU ETS context (Oberndorfer, 2009; Veith *et al*., 2009), as the performance impact appears to arrive ex ante in terms of reduced investor expectations

(Chapple *et al.*, 2013; Hughes, 2000). This chapter therefore does not find a significant negative contemporaneous impact of the EU ETS on stock market performance, but only a significant negative ex ante impact of the EU ETS on the stock market performance of emission intensive firms. Hence, it is questionable if firms and eventually their shareholders are internalising sufficient costs to contribute in a meaningful way to the proposed climate change mitigation. The irony of the forward-looking nature of the financial market is that while the firms may have internalised sufficient cost during the period before the EU ETS (2001–2004), they have clearly not done so during the EU ETS itself. Since a meaningful climate change mitigation requires consistent efforts, it seems fair to argue that firms are currently not internalising sufficient cost (EC, 2009b; Hepburn and Stern, 2008).

Empirical Chapter 2

Chapter 5 investigates two questions. First, the differentiation of the EU ETS effects on share prices at sector level is empirically examined by estimating the stock return performance of the sector-based portfolios using standard and extended market models. Second, the effect of the emissions status, which is determined by the net allowance holding position, on the share prices of ETS-regulated firms is further examined at two levels. This analysis intends to find out whether the emissions status of firms is relevant in the valuation process of stock market investors, and whether the firms and sectors are valued differently due to their net allowance holding position.

The sector differentiation regarding the ETS exposure was conceptually elaborated by Hourcade *et al*. (2007), who suggested that the carbon emissions-related characteristics of a sector, which determined the sector’s exposure to the EU ETS, depended on (i) its energy intensity, (ii) its ability to pass costs through to consumers and (iii) its carbon abatement opportunities. While they did not analyse each industry separately on these characteristics, they made simple predictions that the health care and consumer discretionary sectors were less energy intensive than the energy, utilities, and materials sectors and hence less affected by the EU ETS. Among the three more affected sectors, they considered the utilities’ sector to be in a better position due to its better opportunity to pass costs through to consumers given its relatively low international competition compared with the materials sector. Lund (2007) further argued that the EU ETS’ cost impact on the materials sector would be 3–4 times higher than its impact on the energy sector and hence the materials-related industries should be affected most by the EU ETS. However, neither of these two papers (Hourcade *et al*., 2007; Lund, 2007) investigated the relationship between the carbon characteristics of these participating sectors and stock market returns.

The only analysis of EU ETS-related effects on the stock market returns of different industries has been published by Bushnell *et al*. (2013). They focus on a specific event, the 25 April 2006 carbon price crash, and investigate the responses of various industries. They find, somewhat counterintuitively, that carbon or electricity intensive industries are hurt most in their share price performance due to the carbon price crash. They explain their finding by the predominantly grandfathered emissions in the "trial" phase of the EU ETS, and the fact that the asset value of the emission allowances held in large quantities by the carbon and electricity intensive firms crashed on April 25, 2006. In other words, they believe that investors are more concerned with the potential revenue reduction than the cost reduction of carbon or electricity intensive industries. This finding is contrary to the climate change mitigating intention of the EU ETS policy makers, as the findings revealed that from the investors' perspective, ETS does not appear sufficiently stringent to have internalised enough emissions-related costs to the emission sources. Hence, it seems very worthwhile to study if this effect also holds beyond the specific event for the full first phase and extended trading periods.

The results reveal that six out of seven sectors significantly underperformed the market benchmark during the pre-ETS period of 2001–2004. The Energy sector has been valued indifferently by the stock market since the launch of the EU ETS in 2005. During the estimation period that covers both trading periods (2005–2010), the Utilities, Health Care, and Consumer Staples sectors experienced an underperformance while Materials, Industrials, and Consumer Discretionary saw an outperformance against the market benchmark. This finding suggests that the sector differentiation of the EU ETS effect on share prices of the regulated firms is significant. The further analysis that examines the performance of portfolios consisting of firms with different emission status in the main sectors appears fairly similar to the results of the sector portfolio performance estimation, regardless of the portfolio's emission status.

The main conclusions drawn from the empirical findings in this chapter concern two aspects. The first aspect confirms that the stock price performance of ETS-regulated firms can be differentiated at sector level to a certain degree as different levels of abnormal portfolio returns are observed. It appears that performance can also be differentiated by sectoral emission status as the under-emitting sector sees a reward in the share value while the over-emitting sector consistently experiences a value penalty. The second aspect concerns the fact that stock return performances differentiated by emission status cannot be seen at firm level within the sectors. The results are interpreted as showing that stock market investors consider the emission status and the net allowance holding positions of the sector relevant and value stocks consistently with the positive value relevance proposal of Johnston *et al.* (2008).

Empirical Chapter 3

The main research question in Chapter 6 is: what factors systematically explain the emissions behaviour of firms which are regulated by the EU ETS? Two streams of literature motivate and help to build the main framework of the empirical design, which specifically investigates the determinants of the firm-level CO_2 emissions performance of EU ETS-regulated firms. Inspiration is initially drawn from studies that focus on empirically examining the determinants of emissions, for this stream of the literature studies a similar subject, either GHG or carbon emissions. Although the specific subject of interest in this chapter is firm-level emissions, studies that investigate emissions at the aggregate level, such as industry or country levels, are also reviewed, for two reasons. First, the aggregate-level emissions provide a foundation for the estimation model to drill down to the firm-level emissions as the aggregate-level data ultimately are inclusive of disaggregate-level data. For instance, the overall industrial-level emissions consist of individual plant/firm-level emissions (Cole *et al.*, 2005). Second, studies that concentrate on firm-level emissions are relatively limited, presumably due to data availability (Cole *et al.*, 2012). The second stream of literature investigates more generally which factors are related to corporate environmental performance. The rationale behind referencing this stream of literature is inspired by Delmas and Blass (2010), who suggest a framework that uses the emission level an indicator for corporate environmental performance. Thus, the factors that influence corporate environmental performance, especially the emissions-related aspects, could also affect the carbon emissions.

Cole *et al.* (2005, 2012) suggest that firm-level carbon emissions are related to a series of firm characteristics, among which capital intensity and production level are of particular interest in this chapter. This chapter is the first attempt to provide empirical evidence on the determinants of firm-level emissions behaviour within the EU's emissions restriction setting on a multinational and sectoral scale, and the results are a valuable addition to the current literature in environmental management, in particular within the GHG emissions management area. This will be be helpful in identifying the factors associated with the carbon emissions of firms in order to more effectively manage emissions and achieve the reduction target.

The analysis benefits from a panel dataset that comprises the largest EU ETS-regulated European listed firms, in terms of their shares of allowances allocated and verified emissions. The sample dataset covers in total a six-year operating period of the EU ETS and seven sectors, making the dataset the first one to include emission trading scheme data of industries outside the utilities sector. A new emission performance measure, the emission-to-cap ratio, is constructed to indicate the compliance level of respective firms regulated by the EU ETS. This is done by scaling the verified emissions of each firm by its emission cap, and serves as the dependent variable. A ratio larger than 1 indicates that the firm is emitting over its cap and needs additional emissions allowances to maintain the compliance level. The relationship between the ratio and the potential determinants is expected to reveal whether a certain factor can be significantly attributed to the increase/decrease in emissions.

The estimation results of regressions with the baseline model show that among which the capital intensity effect and production output effect are prominent and consistent with the results in Cole *et al.* (2005, 2012) that both factors drive up the emissions of firms. The business model of a firm appears dominant in determining its emission compliance performance. The sector-specific analysis further reveals that the energy sector appears more sensitive to legislative action while the firm characteristics do not seem influential in explaining the emissions variation within the sector at any statistically accepted significance level. Estimation results with the materials sector and utilities sector-specific interaction terms-added models follow a similar pattern, as production, capital intensity, and sector differentiation effects again remain supported at overall level, while the test of sector-specific effect has no significant coefficients. With an extended analysis that focuses on the utilities sector, it is revealed there is a shift of explanatory power from the utilities sector dummy caused by certain utilities' sector-specific interaction terms. The extended regression indicates that the production effect within the utilities sector takes away the statistical significance of the utilities' sector dummy, while the capital intensity effect within utilities demonstrates less dominance in taking over the explanatory power of the sector dummy. The main policy implications from the analysis in this chapter include the necessity for sector-specific environmental targets and incentives to achieve the target, as different sectors inevitably experience different levels of sensitivity to certain environmental issues, such as carbon emissions.

This thesis contributes to an understanding of the mandatory emissions trading scheme and its implications for two main aspects, the corporate financial performance side and environmental performance side. The first empirical chapter examines the implications of the emissions trading scheme from the financial market perspectives. Although this thesis is not the first paper that investigates this particular relationship, it has enhanced this area of literature by largely expanding the scope of the dataset, with respect to both the number of firms and the coverage of multiple sectors. It further benefits from the verified data collected from the trading scheme, which allows an in-depth analysis concerning how stock market investors value different emissions compliance status. The research design is targeted specifically at revealing whether the EU's emission trading scheme has had any significant effect on the valuation of the firms regulated. The design takes into account the most direct factor associated with the trading scheme, the emissions compliance status, which has not yet seen in the previous studies that have investigated a similar subject within the EU ETS context.

The varying degree of exposure to emissions restriction facing different sectors is taken into account in the final empirical chapter. This expands the scope of the current empirical studies, which almost exclusively examine companies in the utility/power sector. The analysis in Chapter 5 provides the first piece of empirical evidence that confirms that differences in the level of exposure to the same environmental regulation can be detected at the sector level. While previous studies conceptually demonstrated that different sectors are likely to have varied degrees of exposure to the EU ETS, Chapter 5 empirically tests the degree to which these sectors are exposed and quantifies the ETS-related effect on sectors in terms of equity valuation, which appears to be the first attempt so far to have done so.

Lastly, Chapter 6 utilises emissions data from the EU ETS to examine the compliance behaviour drivers of the regulated firms, the first attempt to date to the author's knowledge. A new emissions performance measure is made possible with the data produced and collected from a mandatory scheme as the data reported is subject to a mandatory verification and reporting process, which ensures the accuracy and reliability of the measure. The design of the sector-firm characteristic interaction terms identifies whether a certain factor has a stronger effect on the firms in any specific sector in terms of their emissions, which is also a novel attempt as a multi-sector dataset is available.

The remainder of this thesis is structured as follows. Chapter 2 provides the background information on the emissions trading mechanism and the EU ETS in particular. Chapter 3 documents the data used in this thesis, including the requirements and the selection process of the dataset. The basic features and information contained in the dataset are also described and followed by an exploration of the emission allowance price trend during the first and second trading period of EU ETS. Chapter 4 examines the first research question proposed – does EU ETS have any significant effect on the share prices of the regulated firms? The analysis utilises the real market data and the verified emissions data of ETS-regulated firms, as well as econometrics techniques involving regression applications with the standard and extended Carhart-style model (Carhart, 1997). Chapter 5 further explores the effects of EU ETS on share prices by focusing on sector-level differentiation. Chapter 6 investigates the last research question proposed – which factors systematically explain firms' emissions levels in relation to their respective emissions cap? – and intends to shed light on firm emissions behaviour within a mandatory emission cap context in Europe while also complementing the previous two empirical chapters by adding more practicability to the research composed in this thesis. Chapter 7 concludes the thesis.

2 The Background to Emissions Trading

2.1 Introduction

This chapter aims to provide a building block of the thesis by giving a comprehensive review of the essential theoretical and technical aspects which are relevant to its central research interest, the European Union's emissions trading scheme (EU ETS) and its implications. The chapter begins in Section 2.2 by introducing the concern of greenhouse gas (GHG) emissions, which EU ETS aims to manage. This is intended to reinforce the motivation of this research project by emphasising the need for subsequent action after recognising the issue of concern and its potential impact. The examination of the efforts and responses which are meant to assess and mitigate the problem, made aggregately by nations and organisations internationally, is presented in Section 2.3. These inputs, such as The Intergovernmental Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC) in essence chart the emergence of the market-based instruments which have been used to manage emissions problem in recent years. Section 2.4 discusses the emergence of current climate change policies, which demonstrates an evident movement towards market-based mechanisms. The current state of the global carbon market, the product of such market-based mechanisms, is then presented in Section 2.5 to provide a picture of the scale of the application and development of emissions trading in practice. This also serves a second purpose, which is to view the European carbon market in a global context and evaluate its significance as the main research topic of this thesis.

A more detailed review and examination of the fundamental knowledge and operational aspects of the EU ETS comprises the second half of Chapter 2. The EU ETS review starts with the origin and drivers of EU ETS creation in Section 2.6, which introduces the political foundations and other driving factors that led to the creation of EU community-wide ETS. The regulatory framework of the trading scheme is described in Section 2.7 following the introduction of the EU ETS. Section 2.8 describes the technical aspects of the EU ETS, including its implementation and operation, in particular the essential mechanisms that enable the smooth operation of the cap-and-trade system. An overview of the European carbon market – in particular, the price development of the 'commodity' of the carbon, the EU allowances _ can been seen in Section 2.9. Section 2.10 reviews several studies and reports that have evaluated the performance of the trading scheme in terms of its operation, before the final Section 2.10 briefly concludes.

2.2 The need for carbon emissions management

This section briefly introduces the root from which the research questions in this thesis stems: carbon emissions and climate change. The section intends to reinforce the motivation of the research project by emphasising the need for subsequent action after recognising the issue of concern and its potential impacts. Human activities-related GHG emissions, most commonly referred to as carbon dioxide (CO_2) emissions, have raised world-wide concerns in recent years. A series of assessment reports compiled and published by the IPCC have indicated that excess amount of GHG inventory in the atmosphere is substantially associated with global climate change (GCC). For instance, the Stern Review comments that ‘The IPCC concluded in 2001 that there is new and stronger evidence that most of the warming observed over at least the past 50 years is attributable to human activities’ (Stern, 2006: 7; IPCC, 1990, 1995).

Various publications have also stressed that the implications and risks of climate change on the environmental, economic, and social dimensions can be global and significant, and suggested that action against the potential harmful impacts of climate change is required. For instance, the IPCC’s third assessment report mentions that the increasing risks of certain irreversible events, such as loss of species, forests, and altered oceanic circulation regimes, are likely to occur due to the cumulative interaction of human activities-related factors. The report wrote that: ‘Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases’ (IPCC, 2007: 8). ‘Costs and benefits of climate change for industry, settlement and society will vary widely by location and scale. ... Where extreme weather events become more intense and/or more frequent, the economic and social costs of those events will increase.’ (IPCC, 2007: 12). The 1995 IPCC assessment also concluded that most parts of the world are highly likely to experience net negative climate change impacts (IPCC, 2001a, 1995).

The impact of climate change on the economic phase is another cause for concern. Although it is considered a highly complex and also controversial process to make numerical estimates of impact at the aggregate level, most of which remain at a medium-to-low confidence level and speculative, nevertheless, these figures can provide an insight into various aspects of the potential impact on our vulnerability to climate change, including signs, orders of magnitude, and patterns (Smith *et al*., 2001: 941). The quantified economic loss in the Stern Review estimated a 5–10% loss in global GDP with 5-6 degrees Celsius warming, with poor countries suffering costs in excess of 10%, been considerably higher than in many previous studies (Stern, 2006: 161). The estimate from the 2007 IPCC assessment report showed on average a global loss of 1–5% GDP for 4 degrees Celsius warming. All regions would experience net negative impacts either by the decline in net benefits or by the increase in net costs for an increase in temperature greater than 2–3 degrees Celsius. (IPCC, 2007: 64-65)

The potentially damaging consequences with regard to climate change impacts on our living environment and the economy are undesirable, and a consensus on the need to undertake action internationally and collectively as the first step to mitigate the climate change has gradually emerged. The next step is to examine the efforts and responses made by societies, including governments and non-governmental organisations (NGOs), in order to adapt to and mitigate climate change.

2.3 Relevant inputs on climate change mitigations

A brief introduction to climate change mitigation-related inputs is presented in the following section to give an overview of the trends of climate change concerns and a clearer understanding of how these inputs can shape the emergence of current climate change policies which target carbon emissions reduction. Table 2.1 provides summarised information on the objectives of each input, and a more detailed discussion of the features and contributions of each input follows.

Table 2.1 Relevant inputs on addressing the climate change and GHG emissions

YEAR	INPUT	OBJECTIVES
1972	United Nations Environment Program (UNEP), established by United Nations General Assembly	UNEP provides leadership and encourages partnership for environment concerns by inspiring, informing, and enabling people and nations to maintain a quality of life without compromising that of future generations.
1988	The Intergovernmental Panel on Climate Change (IPCC), established by UNEP and the World Meteorological Organization (WMO)	IPCC is an intergovernmental body that provides opinions and assessments of scientific evidence concerning the current state of climate change knowledge and its potential environmental as well as socio-economic impacts.
1992	United Nations Framework Convention on Climate Change (UNFCCC), set up and open for signature	UNFCCC enables international cooperation on what can be done to limit global average temperature rise and climate change, and meanwhile to cope with any associated impacts.
1997	Kyoto Protocol adopted during the third annual Conference of Parties (COP) by the UNFCCC	It was agreed during the negotiation of the Protocol to set a legally binding emissions reduction target for main industrialised (Annex I*) countries and allowing the use of flexible mechanisms by Annex I countries to meet their reduction commitments.
2000	European Climate Change Programme (ECCP) launched by the European Commission	ECCP was established to respond to the needs of EU community-wide action on limiting CO_2 emissions and aims to identify and establish all the elements required of EU strategies for the imposition of the Kyoto Protocol.
2000	Climate and Carbon Finance by The World Bank	The World Bank Group's climate finance aims to provide funds to support low-emissions and resilient developments, especially in developing countries.

YEAR	INPUT	OBJECTIVES
2001	GHG Protocol by the World Resources Institute and the World Business Council for Sustainable Development	The GHG Protocol is a multi-stakeholder partnership of business, NGOs, and others and its mission is to develop internationally accepted GHG accounting and reporting standards for governments and business leaders to understand, quantify and manage GHG emissions
2003	Directive 2003/87/EC formally issued	The ETS Directive established the scheme for GHG emissions allowances trading within the European community.
2005	Launch of EU ETS	The EU community-wide trading scheme intends to assist the member states and the European Union as a whole to achieve emissions reductions in a more flexible manner.
2012	Doha Amendment to the Kyoto Protocol (COP18)	A second commitment period of 8 years starting from January 2013, and a smooth continuation of the Protocol, were agreed.

This table presents the relevant inputs that have shaped the current communal concerns on climate change and subsequent climate change policy proposals and implementation. Information on each input is gathered from publicly available sources and compiled by the author. The first column indicates the year in which the specific input was initiated, the second column lists each input, and the third column briefly describe the objectives of each input. The sources of information include: UNEP (UNEP, 2013a), IPCC (IPCC, 2013a), UNFCCC (UNFCCC, 2013c), Kyoto Protocol (UNFCCC, 1998), ECCP (EC, 2013b), GHG Protocol (WRI&WBCSD, 2004), Climate finance The World Bank (TheWorldBank, 2013a, 2013b)

United Nations Environment Programme (UNEP) was established in 1972, and has since become the voice for the environment within the United Nations system. UNEP's work covers the assessment of global, regional, and national environmental conditions and trends, the development of international and national environmental instruments, and the enhancement of the wise management of the environment by institutions (UNEP, 2013a). The issues of concern to UNEP include climate change, disasters and conflicts, ecosystem management, environmental governance, and harmful substances as well as resource efficiency. UNEP addresses specific aspects surrounding climate change, including the adaption, mitigation, reducing emissions from deforestation and forest degradation (REDD+) as well as building new finance models to promote the green economy. Enabling individuals, organisations, and countries to address these issues in order to combat climate change is strengthened by the collaboration of UNEP with numerous partners, including the IPCC and UNFCCC, which are described in the following paragraphs (UNEP, 2013b).

The IPCC was established by UNEP and the World Meteorological Organization (WMO) in 1988 to be the leading international body that assesses global climate change. Its main function is to review and assess the latest scientific, technical, and socio-economic information produced world-wide which is relevant to the comprehension of climate change and the work of the IPCC is an aggregation of the voluntary contributions of numerous scientists (IPCC, 2013a). There are three Working Groups, a Task Force and a Task Group contributing to the work, and each has different assigned subjects. The assessment of the physical science aspects of the climate system and climate change is done by Working Group I, Working Group II assesses the vulnerability of socio-economic and natural systems to climate change, consequences of climate change, and options for adapting to it, and Working Group III contributes to the assessment of options for climate change mitigation through reducing GHG emissions and promoting activities that remove GHGs from the atmosphere (IPCC, 2013c). The major outputs of the IPCC are the assessment reports, which aim to inform the world of the latest state of knowledge on climate change; four assessment reports have been published in 1990, 1995, 2001, and 2007, respectively, while the fifth assessment report was released in phases from September 2013 to October 2014 (IPCC, 2013b).

The United Nations Framework Convention on Climate Change (UNFCCC)[5] was adopted and opened for signature in 1992, in Rio de Janeiro. It is the major international treaty that deals the climate change specifically, and plays a crucial role in shaping climate change policies. Its primary intention has been to prevent catastrophic consequences of global climate change since its adoption and its main objective has remained to seek means of maintaining the concentration of GHGs in the atmosphere at a stablised level. 194 nations (Parties), including most of the industrialised countries, have signed the UNFCCC to date. The members of UNFCCC meet annually in the Conference of Parties (COP) to assess and update progress in dealing with climate change mitigation issues. The Kyoto Protocol is an international agreement that is linked to the UNFCCC, and it commits its signatory Parties by setting internally legally-binding emission reduction targets. It was adopted in Kyoto, in 1997, where the third COPs (COP3) of UNFCCC took place. The most important emission reduction agreement in the Article 3.1 of the Protocol reads: 'The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provision of this Article, with a view to reducing their overall emissions of such gases by at least five per cent below 1990 levels in the commitment period 2008 to 2012' (UNFCCC, 1998: 3). The reporting and verification procedures, flexible market-based mechanisms, and a compliance system formed the 'beating heart' of the Kyoto Protocol, while the legally binding commitment began to internalise the formerly considered 'unpriced externality' – the GHG emissions. The Protocol has urged governments to prepare legislation and policies that can help them meet their commitments, motivated businesses to make climate-friendly investment decisions, and lead to the creation of a carbon market (UNFCCC, 2013c). The details of the implementation rules for the flexible mechanisms, including international emissions trading, clean development mechanisms, and joint implementation were discussed and adopted in subsequent COPs (UNFCCC, 2013d).

The European Climate Change Programme (ECCP) was launched in June 2000 as the response of the European Commission to identifying and developing the necessary

5 UNFCCC (2014), Background on the UNFCCC: the international response to climate change. [Online]. Available: http://unfccc.int/essential_background/items/6031.php [Last Accessed Jan 2013].

elements to implement the Kyoto Protocol (EC, 2013b). The ECCP is a multi-stakeholder consultative process that brings together all relevant players, and builds on current emissions-related activities at EU level. The Programme is separated into two distinct periods of time for different essential tasks. The first ECCP ran from 2000 to 2004, and examined an extensive range of instruments with potential for reducing GHG emissions; the work was shared among 11 working groups and each group was responsible for identifying options and potentials for emissions reduction on the basis of cost-effectiveness. The EU Emissions Trading System (ETS) is one of the most important and innovative initiatives that resulted from the first ECCP (EC, 2013d). The second ECCP was launched in October 2005, in Brussels, with the initial objective of facilitating and supporting the actual implementation of the priorities identified in the first ECCP, such as the ETS. The second ECCP has further explored cost-effective options for GHG emissions reduction in synergy with the EU's Lisbon strategy for increasing economic growth and job opportunities (EC, 2013f). ECCP has been a crucial initiative that has led to a number of new policies and approaches for combating climate change since the European Union recognised that reacting to prevent the severe consequences of climate change should be among its top priorities. The ETS is considered to have become the key tool for GHG emissions reduction from industry most cost-effectively, and more effort has been devoted to the reformation of the system in order to make it more effective in terms of cutting emissions and saving overall abatement costs (EC, 2013c).

Significant efforts devoted by the private sector is also an essential element of the response from society to realise climate change mitigation. The World Bank initiated the world's first prototype carbon fund in 2000 with the intention of supporting the objectives of the Kyoto Protocol and facilitating GHG emissions reductions. Currently, the Carbon Finance Unit of the World Bank has created 15 carbon initiatives and facilities, which provide its fund participants with emissions reduction credits for their obligations under Kyoto Protocol while funding emissions reduction projects in developing countries and countries with economies in transition. These carbon funds and facilities have raised $3.4 billion to support over 150 projects in 65 developing countries, which has contributed to the reduction equivalent of over 181 million tons of CO_2 emissions since 2000 (TheWorld Bank, 2013b). The World Bank has demonstrated that market-based instruments can play a part in enabling cost-effective emission reductions while conveying the mitigation finance to developing countries, and has taken the lead role in shaping new-generation carbon instruments (TheWorld Bank, 2013a).

2.4 Market-based instruments in the environmental policy context

This section intends to provide a concise discussion on the emergence of current climate change policies, which demonstrates an evident preference for market-based mechanisms. The discussion starts with the classic economic theories of the treatment of an externality, which refers to the differences between the valuation of a certain item by society and that by the individual or company (Stern, 2006, 2008a; Brohe *et al*., 2009: 22). The discussion continues by showing how market-based mechanisms are placed in the modern environmental management context for mitigating global climate change through the acceptance of the flexible mechanisms in the Kyoto Protocol and the IPCC's assessment reports on mitigation methods (Bashmakov and Jepma, 2001).

Pollution problems are not a new issue. In fact, it has been long debated what is the most appropriate approach to manage pollution effectively. The widely cited Pigou[6] (1920) and the Coase (1960) theorem[7] of treatment for pollution, respectively, could be regarded as the two major foundation stones for environmental economics and economics instruments of externality control in the modern context. The classic Pigouvian proposal prescribes the use of taxation on externalities, while Coase (1960) opposes this approach for dealing with the problem of a harmful effect, if this effect comes internally from part of the production process (Brohé *et al*., 2009: 25; Baumol and Oates, 1971).

With an imaginary example of a farmer and a cattle raiser, Coase aimed the explain that the liability of damage caused by any physical action possesses the nature of an inadequately defined property right, and if this right is made clearly defined, the loss of value due to executing it can be accounted for by calculating the additional costs associated with this action. Given perfect competition and zero transaction costs, the loss

6 Pigou, *The Economics of Welfare* (1920) suggests imposing a unit-based tax on pollution output as a better approach than direct legal regulations.

7 Coase, in *The Problem of Social Costs* (1960) presents externalities (harmful effects) as poorly defined property rights under regulatory system. By making these property rights more well defined, transparent, and transferable, the system can be improved and these rights should flow to their highest value of use (Brohe *et al*., 2009: 26)

of value is supposed to be less than the value created through this action, otherwise, there is no need for such a right to be exercised (Coase, 1960). Using any harmful effect – for instance, carbon emissions during the production process– the installation liable for this amount of emissions should be left with options to account for this additional cost associated with the emissions produced in such a manner that the cost does not exceed its gain. Since the late 1960s, works that show that emissions trading can be used in practice to manage pollution in a low-cost manner have emerged and shaped policy instruments for current environmental/pollution management. Dales (1968: 93) was among one of the very first to propose a market for pollution to deal with environmental problems. It was followed by Baumol and Oates (1971), who proposed a set of rather arbitrary standards of environmental quality and imposed a set of prices on waste emissions sufficient to achieve these standards. They considered that such a 'resource-use prices' system carried important optimality features and practical advantages. In the mid 1980s, Tietenberg (1985) discussed the rather successful role that emission trading had played in environmental policy reform in the US Clean Air Act context.

While it is possible to directly impose regulations that restrict pollution sources indiscriminately, concerns over the negative economic consequences arise. Direct regulation, which often refers to a command-and-control (CAC) method, is overall a less complex method in terms of administration than market-based instruments, as universal standards are determined for all units. CAC would involve less unpredictable market mechanisms, such as behaviour of the market participants, hence the outcome could seem more controllable. However, it is argued that CAC offers little flexibility for compliance and can be costly despite the low transaction costs of execution; naturally, this method tends to encounter strong opposition and is a politically unpopular option (Brohe *et al.,* 2009: 28–31).

With the increasing concern about GHG emissions and the progress of several international initiatives regarding climate change, such as the UNFCCC and IPCC mentioned in Section 2.3, the path of adopting appropriate instruments for effective GHG reductions becomes clearer. The third assessment report prepared by the Working Group III of IPCC (Bashmakov and Jepma, 2001) presents a full examination on the policies and measures that could be applied to GHG emissions mitigation at the national and international level, which could serve as a practical guide for evaluating difference policy instruments. The report notes that market-based instruments have been well received by governments for their potential to achieve environmental effectiveness at an efficient overall cost. The IPCC report stresses that it is unlikely that a single policy instrument can fully address GHGs emissions as well as climate change problem for most nations, and other policy instruments should also be integrated at different levels, which is confirmed by several other studies (Rayner and Prins, 2007; Stern, 2008a; Brohé *et al*., 2009).

2.4.1 Tax (prices control) or emissions trading (quantity control)?

It is often of great concern, particularly for industry, that stringent environmental policies can be costly and hinder economic growth. Solutions to environmental problems, such as reducing GHG emissions, are thus required to be not only environmentally effective but also cost-efficient. While market-based mechanisms are currently preferred as the major tool to manage the emissions problem for their potential to be cost-effective (EC, 2013b; The World Bank, 2013a; Bashmakov and Jepma, 2001; Stavins, 2003), the decision of which method to apply still needs to be made. Brohe *et al*. (2009: 29) refer to the Stern Review (2006), and state that the context in which policies are applied is crucial.

Market-based instruments can be a price control, as they form the taxes or quantity control for the tradable permit system. Summarising from an extensive review by Stavins (2003) that provides valuable observations on practical experience of market-based instruments, it should be noted that the efficiency of the instruments applied depends on the relative position of the marginal cost and benefits patterns related to the problem (in this case, emissions) that needs to be dealt with. This links to another cause of the complexity of choosing between price and quantity control, as pointed out by McKibbin and Wilcoxen (2002): uncertainty. While price control produces uncertainty of environmental outcomes, quantity control brings uncertainty over the total costs of abatement. This uncertainty, which might hinder the decision making, can be rectified by examining the marginal abatement costs and benefits of the GHG emissions.

Voß (2007) conceptualises of emissions trading as an instrument for controlling climate change as an innovative process in governance. The journey of emissions trading starts from its early theoretical articulation in the 1960s and 1970s, and goes through a ‘proof of principle' period and an experimental prototype, such as the Acid Rain program in the USA. Development of other regional schemes mushroomed in the 1990s and eventually emissions trading became centre stage with the increasing concern about global climate change in recent years.

Hepburn (2006) examines the advantages of various instruments with regard to their respective efficiency under uncertainty. Weitzman (1974) suggests an illustrative modelling induction, that given one type of control, there is always a corresponding way to set the other control to reach the same result. From a purely theoretical perspective, if a quantity control is imposed and a certain amount of tradable permits are allocated and traded, the eventual permit price should equal the optimal price control – for instance, the taxation rate. Hepburn applies Weitzman's framework to a climate change context and concludes that the choice of instruments depends on the position of the marginal abatement cost and the damage function. For example, given that the marginal abatement cost is steep and the damage function relatively flat, the benefit of abating the damage associated with climate change is rather flat, so a price instrument would be the preferred option.

A similar illustration can be seen in Chapter 2 of Brohé *et al*. (2009: 34–36), introducing the concept of the discount rate, which indicates how future costs are translated into the present context. A low discount rate (on the overall costs related to climate change), as applied in the Stern Review, indicates that the damage cost has been considered a steep function, and the outcomes could be catastrophic in the case of failing to achieve the emission reduction targets, so that the marginal benefit of mitigating climate change problem is consequently high. The welfare of current and future generation should be considered on the same basis. Under these circumstances, trading is the preferred solution. This is open to considerable critiques – for instance, by Nordhaus (2007), who suggests the adoption of a high discount rate would be more realistic and the damage costs in the future would be less significant in today's terms.

Despite the fact that both price and quantity control proponents make sound arguments, it nevertheless seems unrealistic to simply pick price or quantity control as 'there is no silver bullet solution to climate policy' (Brohe *et al*., 2009: 39). Similar opinions were also expressed in the IPCC report, which pointed out that 'GHG emissions will not be addressed with a single policy instrument, but with a portfolio of instruments' (Bashmakov and Jepma, 2001: 402).

2.4.1(a) Benefits that can be generated by emissions trading

The benefit of emissions trading in economic terms can be illustrated by drawing the marginal abatement curves of two individual firms. A detailed analysis can be seen in Ellerman and Decaux (1998) as well as in Brohé *et al.* (2009: 27). If two or more parties are committed to achieve a certain amount of emissions reduction, given the marginal abatement costs are different for each party, which is generally the case, the overall abatement costs will be lower with the emissions trading mechanism than without trading as the reduction can be made more by the party with lower abatement cost (Figure 2.1).[8]

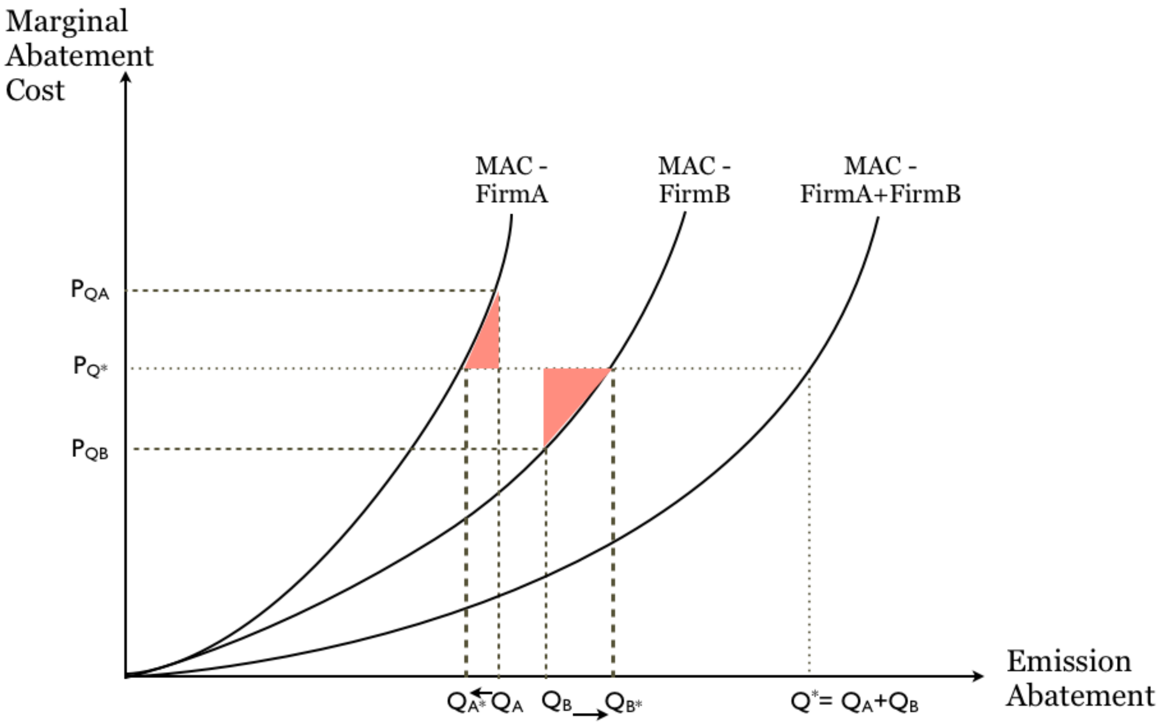


Figure 2.1 Benefits generated by emissions trading

P_{QA} and P_{QB} represent the marginal abatement cost (MAC) of Firm A and Firm B, respectively, without emissions trading, under the scenario that a reduction of emissions in the total amount of Q*, which equals $Q_A + Q_B$, is required. It is more expensive for Firm A to achieve the abatement (Q_A) all by itself, as it will be paying the higher marginal

8 Figure 2.1is mainly adopted from Ellerman and Decaux (1998) and Brohé *et al.* (2009:27).

abatement cost (P_{QA}). With the introduction of emissions trading, Firm B can create more emission permits by increasing its abatement (from Q_B to Q_{B*}) at the lower marginal abatement cost (P_{QB}) while Firm A can lower its total abatement costs (to reduce abatement from Q_A to Q_{A*}) by purchasing additional emission permits from Firm B. The benefit created by the introduction of emissions trading is shown by the coloured segments in the figure, which is essentially realised through the reduced abatement costs as the abatement is made mostly by the relatively ‘efficient’ emitter.

2.4.1(b) A numerical example of cost saving under emissions trading

The simple numerical example provided in Labatt and White (2007) can illustrate more clearly how economic benefits can be achieved in an emissions trading system. The example starts by assuming that both Installation A and Installation B have produced 5,000 tonnes of emissions higher than their respective emission cap set by the trading scheme and therefore, they need either to reduce their actual amount of emissions or to purchase additional ‘permits’ to emit to cover the excessive emissions. For Installation A, the cost of reducing one tonne of emissions is €5 while for Installation B, the cost is €15 per tonne. We further assume that the current trading price for one unit of emissions permit is €10. It can be clearly seen that for Installation A, it costs less to reduce the emissions by itself (€5*5,000) than to purchase the emission permits (€10*5,000). On the other hand, for Installation B, to purchase permits from the market costs it less (€10*5,000) than to reduce its actual emissions (€15*5,000). If Installation A reduces its emissions by 10,000 tonnes and sells the 5,000 tonnes of permits on the market, it can have a gain of €25,000 after complying with the cap. For Installation B, to purchase 5000 tonnes of permits on the market can result in €25,000 saving on abatement costs.

2.4.2 The Kyoto Protocol[9] and its flexible mechanisms

The adoption of the Kyoto Protocol saw a substantial step forward in more quickly preparing market-based instruments for GHG emissions management. The Protocol commits most industrialised nations to an emissions reduction target, which is legally

9 Details and information obtained from http://unfccc.int/kyoto_protocol as well as UNFCCC (1998).

binding internationally and with an overall reduction target of 5% against the 1990 emissions level. The detailed emission reduction targets of Annex B countries can be found in Appendix 2-A. The emission targets are expected to be achieved through mainly national measures, while nations with reduction commitments are allowed to use the flexible mechanisms specified in the Kyoto Protocol to achieve their reduction in a more cost-saving manner. A brief introduction to the three flexible mechanisms included in the Kyoto Protocol is presented in the following section.

Three flexible mechanisms, International Emissions Trading, Clean Development Mechanisms, and Joint Implementation, were introduced in the Kyoto Protocol, while the details regarding their application are defined in the following COP of UNFCCC, and in the seventh COP in particular, during which the Marrakech Accord was agreed in 2001.

- *International Emissions Trading*

  Emissions Trading works by first creating a market for the new commodity, emissions rights. Annex B countries that sign up to the Protocol can no longer emit unlimited GHGs as they commit to definite emissions targets, which are expressed as levels of emissions allowed. These allowed emissions are recorded in a unitary form and defined as 'Assigned Amount Units' (AAUs) (Brohe *et al.*, 2009: 71; Labatt and White, 2007: 10). AAUs are tradable among countries, which allows countries with an allowed amount of unused emissions to sell the rights to countries with excessive emissions. In addition to AAUs, other units could also be traded under the international ETS defined in the Protocol. These units can be created by the emissions reduction projects described in the following paragraphs.

- *Clean Development Mechanism*

The Clean Development Mechanism (CDM), defined in Article 12 of the Protocol (UNFCCC, 1998), allows a country with an emissions reduction or emissions limitation commitment under the Kyoto Protocol (Annex B Parties) to implement an emission-reduction project in developing countries. Such projects can earn tradable certified emissions reductions (CERs) credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets. This is the first global, environmental investment and credit scheme of its kind, providing a standardised emissions offset instrument, CERs.

A CDM project might involve, for example, a rural electrification project using solar panels or the installation of more energy-efficient boilers. The mechanism is expected to stimulate sustainable development and emissions reductions, while giving industrialised countries a degree of flexibility to choose how they will meet their emissions reduction or limitation targets (UNFCCC, 2013a; UNFCCC-CDM, 2014).

A CDM project must provide emissions reductions that are additional (UNFCCC, 2004) to what would otherwise have occurred. The projects must qualify through a rigorous and public registration and issuance process. Approval is given by the Designated National Authorities. Public funding for CDM project activities must not result in the diversion of official development assistance (ODA). The mechanism is overseen by the CDM Executive Board, answerable ultimately to the countries that have ratified the Kyoto Protocol. Operational since the beginning of 2006, the mechanism has already registered more than 1,650 projects and has been anticipated to produce CERs amounting to more than 2.9 billion tonnes of CO_2 equivalent in the first commitment period of the Kyoto Protocol, 2008–2012 (UNFCCC, 2013a).

- *Joint Implementation*

  Joint Implementation (JI), defined in Article 6 of the Kyoto Protocol (UNFCCC, 1998), allows a country with an emissions reduction or limitation commitment under the Kyoto Protocol (Annex B Party) to earn emissions reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one tonne of CO_2, which can be counted towards meeting its Kyoto target. JI offers Parties a flexible and cost-efficient means of fulfilling a part of their Kyoto commitments, while the host Party benefits from foreign investment and technology transfer (UNFCCC, 2013b).

  A JI project must provide a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to what would otherwise have occurred. Projects must have approval of the host Party and participants have to be authorised to participate by a Party involved in the project. Projects starting as from the year 2000 may be eligible as JI projects if they meet the relevant requirements, but ERUs may only be issued for a crediting period starting after the beginning of 2008 (UNFCCC-JI, 2014; UNFCCC, 2006). If a host Party meets all of the eligibility requirements to transfer and/or acquire ERUs, it may verify emissions reductions or enhancements of removals from a JI project as being additional to any that would have otherwise occurred. On such verification, the host Party may issue the appropriate quantity of ERUs. This procedure is commonly referred to as the ‘Track 1’ procedure. If a host Party does not meet all, but only a limited set of eligibility requirements, verification of emissions reductions or enhancements of removals as being additional has to be done through the verification procedure under the Joint Implementation Supervisory Committee (JISC). Under this so-called ‘Track 2’ procedure, an independent entity accredited by the JISC has to determine whether the relevant requirements have been met before the host Party can issue and transfer ERUs. A host Party which meets all the eligibility requirements may at any time choose to use the verification procedure under the JISC (Track 2 procedure) (UNFCCC, 2013b).

To briefly conclude, the emissions trading gains its position as the key climate policy instrument in current years by its potential for being cost-effective when implemented properly (EC, 2013b; Stavins, 2003) as well as for its political acceptance over taxes (Bashmakov and Jepma, 2001). It has clearly become a preferred choice among scheme in different nations (The World Bank, 2010, 2012). The following section introduces emissions trading in practice, beginning by explaining two common types of ETSs and how they operate. An overview of the current state of the global carbon market in terms of trading activities is presented in Section 2.5.

2.5 Emissions trading in practice

Emissions trading works by creating a market for emissions allowances. The market can be created in several ways, with the cap-and-trade system and the baseline-and-credit system being the most common. These systems differ mainly in their design characteristics (Brohe *et al.*, 2009: 42). A cap-and-trade system is created by determining a new set of property rights and imposes an absolute cap within the system. The cap decides the number of allowances available and the how allowances shall be distributed to the regulated parties (or parties voluntarily participating) in the scheme based on a designated allocation method. The regulated parties need to submit a corresponding amount of allowances that equal to their emissions, which completes the compliance procedure (Brohe *et al.*, 2009: 43–44). Unlike cap-and-trade, the baseline-credit system works through generating emissions reduction credits from projects that reduce emissions against a baseline value. The reduction credits can be used to achieve the agreed emissions reduction commitment as well as being traded among different parties with reduction targets. The CDM and JI are examples of the baseline-credit system (Brohe *et al*., 2009: 53). Table 2.2 presents the five types of emissions allowance units that are most commonly traded.

Table 2.2 Summary of different types of most commonly tradable units

Type	Unit and source	Framework	Validity
Assigned Amount Units (AAUs)	AAU is the emissions allowance allocated to Parties that sign up to the Kyoto Protocol. It is equal to 1 metric tonne of CO_{2e}	Kyoto Protocol	Global
Certified Emissions Reduction (CER)	CER is a credit issued under CDM which equals 1 metric tonne of CO_{2e}	Kyoto Protocol	Global
Emissions Reduction Unit (ERU)	ERU is a credit issued under JI which equals 1 metric tonne of CO_{2e}	Kyoto Protocol	Global
Removal Unit (RMU)	RMU is generated in UNFCCC Annex1 Parties by Land use, Land use change and Forestry activities that absorb carbon	Kyoto Protocol	Global
European Union Allowance (EUA)	EUA is designed to be identical with the equivalent of the AAU, which represents 1 metric tonne of CO_{2e} emissions and is issued within EU ETS	EU ETS	European Union

This table presents the five types of tradable carbon emissions units which are the most widely known. The first column lists the type of carbon emissions allowance or credit, the second column provides the unit measure and the sources of respective unit, the third column shows the framework in which the unit is defined, and the fourth column shows the context in which the unit can be validated and traded; the European carbon market and the international carbon market is linked through the EU Linking Directive (EC, 2004). Sources: Brohe *et al.* (2009:72); Labatt and White (2007: 10); UNFCCC, (2013a).

The current global carbon market can be categorised in two main segments, the allowance market and the project-based credits market, depending on what types of units are traded. Tables 2.3–2.6 present the position of EUA market relative to the global carbon market. The EUA market created under EU ETS begins to dominate global carbon trading despite the trading activities during the initial launch period of EU ETS being conservative. The numbers show the EUA trading account for a large proportion of global carbon trading activities. In addition, trends of EUA and global carbon market share great similarities, which can be characterised by rapid growth, influences from changing of trading phases, and impacts from economic recession. The EUA market was boosted between 2005 and 2006, as the uncertainties over the demand–supply chain and market mechanisms were gradually clarified. EUA and international carbon markets both saw a growing trend through 2005–2007, which coincided with the first trading period of EU ETS, and EUA trading activities were described as the engine, even the laboratory, of the global carbon market. Due to the demand for the derivatives with the Phase 2 allowances as the underlying assets, trading activity was still growing during the change in trading periods, despite the fact that the transactions and price of Phase 1 assets were close to zero (Ellerman *et al.*, 2010: 138–139).

The EUA market and the overall carbon market saw a twofold rise in trading value in 2008, the first year of the new trading period of EU ETS, although the markets for project-based credits experienced a decline. This observation again indicates the crucial status of EUA trading in driving the global carbon market. The financial crisis, which eventually led to a large-scale recession, also hit the carbon market particularly during the year 2008–2009. Both the EUA and the international carbon market saw a considerable amount of trading volume while the value of the market did not increase in a corresponding ratio. The global recession hit the carbon market in its demand fundamentals, as depressed economic conditions led to low production output, low energy consumption, and thus low demand for emissions allowances (The World Bank, 2010). Firms with surplus allowances aimed to cash them in, which drove up trading activities (The World Bank, 2009). However, the value of allowances was suppressed due to oversupply, hence the total value of trading did not see a proportional growth.

Table 2.3 EUA and world carbon market trading volume overview

	Trading Volume ($MtCO_{2e}$)						
	EU ETS	**Other**	**Allowance Markets**	**Spot & secondary offset market**	**Project-based credits**	**Global Market**	**EUA% of the Global Market**
2005	321	7	328	–	382	710	45.21%
2006	1,104	30	1,134	–	611	1,745	63.27%
2007	2,060	48	2,109	–	874	2,984	69.03%
2008	3,093	185	3,278	1,072	486	4,836	63.96%
2009	6,326	1,036	7,362	1,055	283	8,700	72.71%
2010	6,789	373	7,162	1,275	334	8,772	77.39%
2011	7,853	228	8,081	1,822	378	10,281	76.38%

This table presents the annual trading volume of separate segments of the global carbon market. The first content column shows the trading volume of EU ETS, the second column shows the trading volume of other allowances markets together, the third column shows the sub-total of all allowances markets, the fourth column shows the sub-total of the offset markets that consist of secondary Kyoto mechanisms' credits, the fifth column shows the sub-total of project-based transactions that consist of primary CDM and JI, the sixth column shows the total trading column of the global carbon market, and the seventh column indicates the percentage of the trading volume of EU ETS accounts for in relation to the global market. The numbers are extracted directly from the annual carbon market reports published by The World Bank; the total numbers may not add up precisely due to rounding, as well as to different presentations of carbon market segments in different years. Each annual report contains trading information on the previous two years, for instance, the 2010 report shows the trading volume and value for 2009 and 2008, and the 2009 report shows the trading details for 2008 and 2007. For the overlapping reported figures, the latest ones are used. Some figures which are shown with – are not available due to different reporting styles, suspension of the old trading systems and the addition of new systems. Source: The World Bank Carbon Finance Unit annual carbon market report (The World Bank, 2007, 2009, 2011, 2013a).

Table 2.4 EUA and world carbon market trading value overview

	Trading Value (USD million)						
	EU ETS	**Other**	**Allowance Markets**	**Kyoto offsets**	**Project-based credits**	**Global Market**	**EUA% of the Global**
2005	7,908	63	7,971	–	2,894	10,864	72.79%
2006	24,436	263	24,699	–	6,536	31,235	78.23%
2007	49,065	296	50,394	–	13,641	63,007	77.87%
2008	100,526	966	101,492	26,277	7,297	135,066	74.43%
2009	118,474	4,349	122,822	17,543	3,370	143,735	82.43%
2010	133,598	1,336	134,935	20,637	3,620	159,191	83.92%
2011	147,848	1,033	148,881	23,250	3,889	176,020	84.00%

This table presents the annual trading value (in USD million) of separate segments of the global carbon market. The first content column shows the trading value of EU ETS each year, the second column shows the trading value of other allowances markets, the third column shows the sub-total of all allowance markets, the fourth column shows the sub-total of the offset markets that consist of secondary Kyoto mechanisms' credits, the fifth column shows the sub-total of project-based transactions that consist of primary CDM and JI, the sixth column shows the total trading column of the global carbon market, and the seventh column indicates the percentage of the trading volume of EU ETS accounts for in relation to the global market. The numbers are extracted directly from the annual carbon market reports published by The World Bank; the total numbers may not add up precisely due to rounding, as well as to different presentations of carbon market segments in different years. Each annual report contains trading information for the previous two years, for instance, the 2010 report shows the trading volume and value for 2009 and 2008, and the 2009 report shows the trading details for 2008 and 2007. For the overlapping reported figures, the latest ones are used. Some figures which are shown with – are not available due to different reporting styles, suspension of the old trading systems and the addition of new systems. Source: The World Bank Carbon Finance Unit annual carbon market report (The World Bank, 2007, 2009, 2011, 2013a)

Table 2.5 World carbon market (excluding EU Allowances) trading volume breakdown

	Trading Volume ($MtCO_{2e}$)									
	Other Allowance market	New South Wales	Chicago Climate Exchange	Regional Greenhouse Gas Initiative	Assigned Allowance Units	Project-based credits	Clean Development Mechanisms		Joint Implementation	Others /Voluntary Market
							Primary	Secondary		
2005	**7**	6	1	_	–	**382**	341	10	11	20
2006	**30**	20	10	_	–	**611**	537	25	16	33
2007	**48**	25	23	_	–	**874**	551	240	41	42
2008	**185**	31	69	62	23	**486**	404	–	25	57
2009	**1,036**	34	41	805	155	**283**	211	–	26	46
2010	**373**	–	–	210	62	**1,609**	224	1,260	47	69
2011	**228**	–	–	120	47	**2,200**	264	1,734	104	87

This table presents the detailed breakdown of other allowances markets (excluding EU ETS) and project-based transactions in terms of trading volumes each year. The header column indicates the year of trading recorded. The first content column shows the sub-total trading volume of all other allowances markets (excluding EU ETS), the second column shows the trading volumes of the New South Wales GHG Abatement Scheme, the third column shows the Chicago Climate Exchange trading volume, the fourth column is the trading volume of the Regional Greenhouse Gas Initiatives of North America, the fifth column shows the trading volume of the AAUs under the UNFCCC Kyoto flexible mechanism framework, the sixth column shows the sub-total trading volumes of project-based transactions, the seventh and eighth columns show primary and secondary CDM transactions (CERs), respectively, the ninth column shows the JI transactions (primary and secondary ERUs) and the tenth column shows all other transactions. The numbers are extracted directly from the annual carbon market reports published by The World Bank; the total numbers may not add up precisely due to rounding, as well as due to different presentations of carbon market segments in different years. Each annual report contains trading information for the previous two years, for instance, the 2010 report shows the trading volume and value for 2009 and 2008, and the 2009 report shows the trading details for 2008 and 2007. For the overlapping reported figures, the latest ones are used. Some figures which are shown with – are not available due to different reporting styles, suspension of the old trading systems and the addition of new systems. Source: The World Bank Carbon Finance Unit annual carbon market report (The World Bank, 2007, 2009, 2011, 2013a).

Table 2.6 World carbon market (excluding EUAs) trading value breakdown

	Trading Value (USD million)									
	Other Allowance market	New South Wales	Chicago Climate Exchange	Regional Greenhouse Gas Initiative	Assigned Allowance Units	Project-based credits	Clean Development Mechanisms		Joint Implementation	Others /Voluntary Market
							Primary	Secondary		
2005	**63**	59	3	-	-	**2,894**	2,417	221	68	187
2006	**263**	225	38	-	-	**6,536**	5,804	445	141	146
2007	**296**	224	72	-	-	**13,641**	7,426	5,451	499	265
2008	**966**	183	309	198	276	**7,297**	6,511	-	367	419
2009	**4,349**	117	50	2,179	2,003	**3,370**	2,678	-	354	338
2010	**1,336**	-	-	458	626	**3,620**	2,675	20,453	624	414
2011	**1,033**	-	-	249	318	**3,889**	2,980	22,333	1,119	569

This table presents the detailed breakdown of other allowances markets (excluding EU ETS) and project-based transactions in terms of trading value (in USD million) each year. The header column indicates the year of trading recorded. The first content column shows the sub-total trading value of all other allowance markets (excluding EU ETS), the second column shows the trading value of the New South Wales GHG Abatement Scheme, the third column shows the Chicago Climate Exchange trading value, the fourth column is the trading value of the Regional Greenhouse Gas Initiatives of North America, the fifth column shows the trading value of the AAUs under the UNFCCC Kyoto flexible mechanism framework, the sixth column shows the sub-total trading volumes of project-based transactions, the seventh and eighth columns show primary and secondary CDM transactions (CERs), respectively, the ninth column shows the JI transactions (primary and secondary ERUs) and the ninth column shows all other transactions. The numbers are extracted directly from the annual carbon market reports published by The World Bank; the total numbers may not add up precisely due to rounding, as well as due to different presentations of carbon market segments in different years. Each annual report contains trading information for the previous two years, for instance, the 2010 report shows the trading volume and value for 2009 and 2008, and the 2009 report shows the trading details for 2008 and 2007. For the overlapping reported figures, the latest ones are used. Some figures which are shown with – are not available due to different reporting styles, suspension of the old trading systems and the addition of new systems. Source: The World Bank Carbon Finance Unit annual carbon market report (The World Bank, 2007, 2009, 2011, 2013a).

The specific knowledge of the fundamental and operational aspects of the EU ETS is required in order to better picture the research interests of this thesis, the environmental and financial implications of the EU ETS, in its theoretical and empirical context. A detailed review on this new regulation and its related issues is provided in the following sections and is structured as follows: Section 2.6 presents the origin of the EU ETS and is followed by a description of the regulatory framework of the trading scheme in Section 2.7. Section 2.8 discusses technical aspects of the EU ETS including its implementation and operation, and Section 2.9 provides an overview of the European carbon market, in particular the price development of the ‘commodity’ of carbon, the EU allowances. Section 2.10 reviews studies and reports that assess the effectiveness of the performance of the trading scheme.

2.6 The creation of European Carbon Market: the origins[10]

Emissions trading was not the first market-based instrument considered by the European Union to manage GHGs emissions. The European Commission proposed to impose a community-wide carbon/energy tax in early 1990s, however the attempt ended in failure. During the negotiations for the Kyoto Protocol concerning the legally binding emissions restriction for developed countries, European representatives were strongly opposed to the inclusion of emissions trading as a flexible mechanism in the Protocol. Nevertheless, with the insistence of US delegates to the negotiations, emissions trading between countries along with CDM and JI were eventually included in the Protocol as flexible mechanisms which Annex B countries could use to comply with their reduction commitment (Ellerman *et al*., 2010: 16-17).

Convery (2009) gives a detailed review on the legislative and institutional context of the EU ETS, and summarises the successful creation of community-wide emissions trading which can be attributed to the following two key points: first, the political foundations and second, the building of knowledge to turn emissions trading theory into practice. These two aspects are briefly addressed in the following paragraphs.

10 The references for this section are based largely on Convery (2009), Ellerman *et al.* (ed. 2010) and documentation from the European Union, which can be accessed at http://ec.europa.eu/clima/policies/ets/documentation_en.htm.

The Single European Act (SEA) in 1986 and the European Union Treaty (TEU) in Maastricht in 1993 provided the political and legal framework for the establishment of a European single market, which formed the first step for the creation of the EU ETS. The final key decision that prepared for the emergence of emissions trading in Europe was the Burden Sharing Agreement (BSA) in summer of 1998. On the basis of the EU-15's BSA (European Council, 1998), fifteen member states agreed on a varied emissions reduction target, which in total should amount to the 8% reduction committed to in the Kyoto Protocol (Convery, 2009).

Among the earlier literature that specified emissions trading as having a policy instrument status on the basis of the Coase theorem, Klaassen (1997, 1999) provides first comprehensive overview on the practicability and potential scope of applying emissions trading in the European Union, which formed the theoretical foundations of the adoption of such trading. The European Union has endeavoured to take the leading position in shaping global climate policies since the Kyoto Protocol and aimed to fulfil its commitment of reducing GHG emissions. The European Commission made the first major communications to the Council and European Parliament in 1998 with regard to the implementation of the Kyoto Protocol and specified how the community could set up an internal trading scheme of its own by 2005. The subsequent process of pushing the European Union from considering the establishment of an ETS to actually acting on it began officially in 1999 after the adoption of the second Commission communication in which the need for a sustained policy response was emphasised (Ellerman *et al.*, 2010: 18).

The Green Paper (EC, 2000) presented by the Commission in 2000 officially launched the discussion on the crucial policy options that were required to be resolved in order to construct the framework for implementing a European community-wide trading scheme. It received inspiration from three studies commissioned by the European Commission that focused on three main areas, including a study that examined the cost-saving potential of the EU ETS (Capros and Mantzos, 2000), experience of the US emission trading evolution, as well as the establishment of legal guidelines. The paper provided the fundamental implementation rules, and specifically addressed the issue of allowances allocation.

Another substantial input in drawing up the EU ETS was the establishment of the first European Climate Change Programme, which functioned as a multi-stakeholder consultation process. The first ECCP from 2000 to 2004, focused on exploring the potential policy sectors and instruments for effectively reducing GHG emissions (EC, 2013b).

The draft proposal of the ETS Directive was submitted to the Council and the Parliament for formal considerable after a feedback period and a public consultation with key stakeholders by the Commission in 2001. The making of the EU ETS was characterised as a quick and entrepreneurial process (Skjærseth and Wettestad, 2010; Wettestad, 2005; Ellerman *et al.*, 2010: 30). The legislative process of the EU ETS is outlined in Table 2.7.

Table 2.7 Timeline of EU ETS legislative process related events

Time	Event
2001	The draft proposal of the ETS was submitted.
October 2002	First reading of the proposal was completed by the Parliament.
March 2003	The common position was presented by the Council, and several points differed between the Parliament and the Council.
Spring 2003	The Parliament presented the Amendments based on the Council's position.
July 2003	The amended draft went through a second reading by the Parliament.
	The Linking Directive draft, which intended to link the EU and the international carbon market was proposed.
Late July 2003	The ETS Directive proposal was accepted by the Council.
October 2003	The ETS Directive was formally issued.
April 2004	The Linking Directive was agreed by the Council and the Parliament.
2008	The amendments concerning the reform of the ETS were adopted.

This table presents the procedure for the passage of the EU ETS. The first column lists the time the event occurred and the second column lists the respective event. Source: Ellerman *et al*. (2010).

2.7 The regulatory framework of the EU ETS[11]

The EU ETS remains rather unfamiliar to most people due to the fact that emissions trading is not a simplistic CAC instrument, but instead has some degree of complexity. Second, the current coverage of EU ETS focuses on the largest emitters, thus the direct impacts are upon industrial sectors while general public may experience very limited degree of influence.

2.7.1 The ETS Directive: what does the EU ETS regulate, and how?

The entire ETS mechanism is defined by and constructed upon the Directive 2003/87/EC (EC, 2003a). It has since been further amended by a number of directives and regulations for the improvement of the whole scheme (EC, 2009a). The EU ETS draws substantially on the US sulphur dioxide (SO_2) trading programme but is largely distinct from the latter program as it works in a relatively decentralised manner for the first two trading periods, meaning that the member states have been left a great degree of discretion on allowances allocation, monitoring and auditing, and management of sources (Kruger *et al*., 2007). Three main mechanisms work as gears of this community-wide trading scheme: monitoring, reporting, and verification. At the end of January 2004, the Commission decision on establishing the guidelines for monitoring and reporting was issued, which outlined the main responsibilities of member state with regard to these matters (EC, 2004a).

The EU ETS regulates CO_{2e}[12] emissions for installations used for activities specified in Annex I[13] of the ETS Directive. Activities covered include combustion, metal, minerals, pulp, and papers. The ETS Directive targets the larger emitters of industrial sectors, as indicated in the Annex I declaration that installations with thermal inputs or capacity exceeding specified standards are subject to EU ETS regulation (EC, 2003a, 2009a). The information on EU ETS participants regarding allowances holding, transfer, submission, and verified emissions is recorded at installation level. Every change in ownership of

11 Information regarding EU ETS is obtained from European Commission website, especially the Question and Answer section for each relevant topic.

12 CO_2 equivalent emissions

13 Details of the criteria for inclusion in the EU ETS can be seen in Appendix 2-B.

allowances for each installation is recorded within the National Registry, which works like a bank account for money. The Commission requires each member state to develop and maintain its registry to ensure the accurate accounting of the issue, holding, transfer, and cancellation of allowances (EC, 2003a: 37). In addition to National Registry, the European Commission runs and maintains the Community Independent Transaction Log (CITL),[14] a central administrator that records the issue, transfer, and cancellation of allowances. It also conducts automated checks on each transfer of allowances to ensure that transactions are free of irregularities (EC, 2003a: 38).

The process of compliance with emissions restriction is a annual cycle and comprises three major events:

1. Participants are expected to have their the actual carbon emissions report verified for the calendar year by 31 March of the following year. All emissions must be approved by independent verifiers. For example, the emissions for 2008 should be verified by the end of March 2009.
2. All installations are given one month, until 30 April to surrender a sufficient quantity of allowances in their accounts to cover their verified emissions.
3. The publication of the emissions data and surrendered allowances would be on 15 May, together with the cancellation of surrendered allowances, which must be finished by 30 June .

Article 16 defines the penalties, which shall be applied for failing to submit a corresponding amount of allowances to cover the verified emissions, which is 40 EUR (for the first trading period 2005–2007) and 100 EUR (for the second trading period 2008–2012), for each unit of that EUA installation operators fail to surrender (EC, 2003a: 37). From 2013 onwards, the excess emission penalty will increase commensurately with the European index of consumer prices (EC, 2009a: 79).

14 A European Union Transaction Log (EUTL) has replaced the CITL since 2012, which has been prepared for the more centralised third phase of EU ETS.

2.7.2 The Linking Directive

EU ETS was established as a domestic scheme for the European community. In order to increase the cost-effectiveness of reducing the committed amount of emissions, the Directive (EC, 2003a) states that the recognition of emissions reduction credits generated from the Kyoto mechanisms (CDM, JI) could fulfil such a purpose, and thus provide for linking EU ETS to international emissions trading and project-based mechanisms, which are recognised in the Kyoto Protocol. Internationally linked emissions trading is considered the most efficient in terms of overall abatement costs, a statement supported by Stern (2008) and Hepburn and Stern (2008).

The Directive 2004/101/EC[15] issued by the European Commission in 2004 (EC, 2004c) amends the Directive 2003/86/EC and outlines the rules regarding the use of Kyoto mechanism credits to achieve emissions reduction. The major points regarding usage are summarised as follows:

- The use of reduction credits will take place through their issuance and an immediate surrender of one allowance in exchange for one reduction credit.
- The limit on the use of project-based reduction credits by each installation should be specified in the member state’s National Allocation Plan (NAP) for each trading period.
- Reduction credits should not be issued for projects that are undertaken for installations covered in the trading scheme to avoid double counting allowances.
- The use of CERs by operators may be from 2005 while the use of ERUs is from 2008.

Based on an assessment report by Rathmann *et al*. (2006) and Betz *et al*. (2006), the proposed purchase of reduction credits from Kyoto mechanisms is around 5% of the total allowances within the scheme for the second trading period. Nevertheless, the planned limits on the use of Kyoto credits varies considerably across member states.

15 Also known as the Linking Directive EC (2004c), Directive 2004/101/EC, amending Directive 2003/87/EC establishing a scheme for GHG emissions allowances trading within the community,. Source: European Commission Strasbourg.

Current status of the Linking Directive

The Linking Directive is also subject to amendments as the ETS Directive for post-Kyoto trading for the beginning of post-Kyoto emissions reduction target. The European Union is actively working on linking EU ETS to other domestic trading schemes, and the European Commission has announced an agreement that aims to build a linking pathway with the Australian system, which should take place no later than 2018. The planned use of Kyoto credits is around 1.7 billion tonnes of emissions from 2013–2020, which represents 50% of the reduction that will be made and is under one-third of the limits that have been used by 2011 (EC, 2013e).

2.8 Technical Aspects of EU ETS

EU ETS is a cap-and-trade system to achieve the best possible outcome of the environmental goal and works in a decentralised manner, particularly for the first and second trading period as it is a preferred option of member states. A decentralised system leaves member states with a large degree of autonomy in certain critical decisions regarding the technical aspects of EU ETS (Kruger *et al*., 2007). The first technical point is to determine the cap. The following section introduces the main technical issues regarding the operation of the first and second trading periods of EU ETS, in the following order, cap-setting, allowances allocation method, and the Linking Directive. As several major changes have been made for the third trading period of EU ETS, the last part of this section will provide information on the changes made.

2.8.1 Cap-setting and National Allocation Plan (2005–2012)

The Commission decided to adopt a decentralised framework for the first and second EU ETS trading period, and as a result the overall cap on emissions is not directly determined by the central authority. Instead, each member state is required develop its own NAP, indicating the total quantity of allowances that is to be distributed for each trading period and how such allowances are to be allocated (European Commission, 2006). The NAP should be developed on the basis of objective and transparent criteria, which are specified in Annex III[16] of the EU ETS Directive (EC, 2003a) and summarised in Table 2.8.

Table 2.8 Annex III of Directive 2003/87/EC with regard to the National Allocation Plan

Criteria	Key information
1&2	The allowances allocation should be consistent with the EU Kyoto target.
3	The potential reduction target should be considered.
4	Legislation and laws within the community should be taken into account.
5	No discrimination between companies and sectors will exist in the plan.
6	Information regarding new entrants will be provided.
7	Information regarding early action may be included and how early action is taken into account.
8	Information regarding clean technology, including energy efficiency technologies will be included in the plan.
9	Provision for public comments and on incorporating them into the final decision should be included in the plan.
10	The list of installations covered in the ETS Directive and their allocation should be provided.
11	Information regarding international competition may be included in the plan.
12	The intention of using other Kyoto credits and the maximum percentage of the credits which can be used will be specified.

This table introduces the criteria on which each member state's NAP will be based, which is extracted from the Annex III of Directive 2003/87/EC (EC, 2003a). The key information in the content column is summarised from the original text by the author.

The principle of NAP guidelines derives from the Kyoto Protocol commitment of the EU members. The guidelines require the proposed total quantity of allowances to be in line with a member state's target on the Kyoto Protocol after consideration of sectors outside the ETS. In addition to guidelines from European Commission, it was suggested that public comments should be taken into account during the development of a member state's

16 The full content of Annex III of Directive is presented in Appendix 2-D.

NAP (EC, 2003a: 43). The Commission has the authority to reject a NAP for failing to fulfil certain criteria, but it is required to state clearly the grounds for a rejection. The member state should revise its NAP until the grounds for rejection has been removed or the allowances cannot be issued and distributed. The final amount of allowances from each approved NAP becomes the cap for each trading period (Ellerman *et al*., 2010: 33–34).

2.8.2 The NAP and the allocation method

The NAP determines not only the total amount of emissions allowances issued, but also the way these allowances are allocated. The majority of allowances were allocated for free in the first and second trading period, despite member states having the option to auction up to 5% (for Phase 1) and 10% (Phase 2) of total allowances approved, specified in Article 10 of the Directive 2003/87/EC (EC, 2003a: 36). A simple illustration in Figure 2.2 presents the procedure and the parties involved with regard to a NAP.

A number of studies have analysed the NAP and come to a conclusion that most allowances distributed are largely on the grandfathering basis, which essentially grants a certain amount of allowances for free to the regulated entities, in the sense of these entities inheriting the emission rights from the past. A report by Swedish Environmental Research Institute which analysed the NAPs of twelve countries pointed out that the NAPs of different countries were likely to differ in various aspects naturally, such as the choice of base year and allocation basis. Nevertheless, the historical emissions-based or production-based allocation are the most common methods adopted. The final allocation is often based on the projected demand, which results from historical data multiplied by a growth factor. The report also mentions that during the first phase (2005–2007) the NAP may favour the trading sectors after taking into consideration the overall Kyoto commitment (Zetterberg *et al*., 2004). Grubb *et al*. (2005) raise the concern that the first phase allocation plans appear weak due to the lack of coordination among member states as well as the fact that there is no substantial cutback from business-as-usual (BAU) level; this should be of concerns as weak allocation could impair the creditability of the entire scheme. An analysis of phase 2 NAPs by Betz *et al*. (2006) suggested that the NAP drafts submitted by eighteen member states showed limited progress in achieving more harmonised allocation rules. They also came to the conclusion that non-ETS sectors may need to bear an excess share of emissions reductions burden due to the allocation of allowances in favour of ETS sectors.

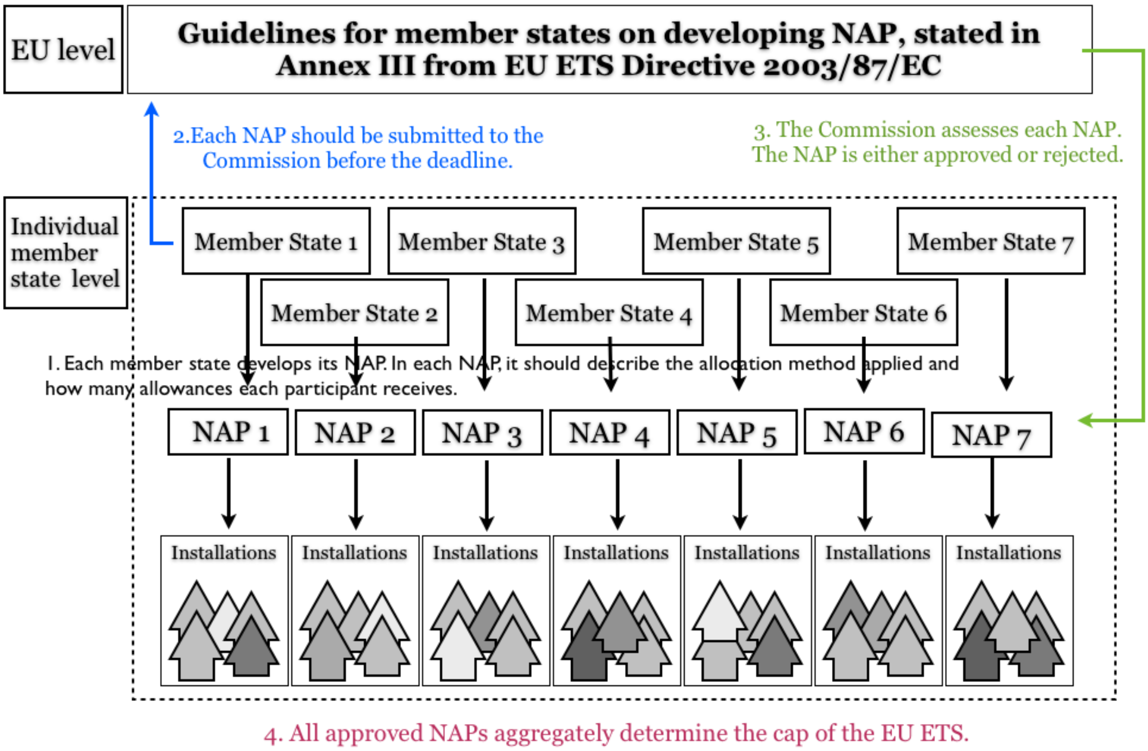


Figure 2.2 Allowances allocation for the first and second trading period of the EU ETS

- ***Post-Kyoto commitment period (2013–2020)***

The European Union has set up three plans for a low-carbon economy beyond the Kyoto Protocol commitment period and intends to carry on improving the overall emissions level. A single EU cap, instead of a NAP from each member state, is to be determined directly for the third trading period (2013–2020). Through the third trading period, the annual cap is designed to decrease each year by 1.74% of the average annual allowances for the second trading period (2008–2012). The power sector no longer receives free allowances but needs to acquire their allowances through auctioning, and 40% of the total allowances were acquired through auctioning in 2013, followed by a progressive rise in proportion throughout the following years. This is to ensure that the European Union reaches its 2020 climate and energy target (EC, 2013a).

2.8.3 Review of current allocation and alternatives

The allocation method is crucial to the effectiveness of an ETS as it can influence overall costs, including abatement and the indirect costs imposed on end consumers; as to the cost efficiency of the trading scheme (Burtraw *et al.*, 2002; Klepper and Peterson, 2004). Burtraw *et al.* (2001) demonstrate that different allocation methods result in different overall costs for the ETS based on the self-constructed electricity market model. The cost-effectiveness and distributional effects of three major allocation methods – auctioning, output-based and grandfathering – are investigated under the SO_2 trading program for the US electricity sector. The auction leads to the lowest overall costs and grandfathering, most preferred by regulated parties, would impose substantial costs on consumers. The output-based method has similar social costs as grandfathering; it yields the lowest electricity prices and the highest natural gas prices while auctioning does the opposite.

Many have proposed that auctioning is a superior method to grandfathering for allocating allowances within the trading scheme (Cramton and Kerr, 2002; Ehrhart *et al*., 2005; Hepburn *et al*., 2006); however, it was difficult to avoid free allocation, particularly in the initial stage of EU ETS. Free allowances can be considered a compensation for energy intensive sectors in order to reduce these adverse effects on production as well as competitiveness (Böhringer and Lange, 2005; Egenhofer, 2007). However, several issues can arise from free allocation using baseline emissions as a reference, such as distortion of scarcity rent and windfall profits (Martinez and Neuhoff, 2005; Neuhoff et al., 2006). Neuhoff *et al*. (2006) investigate the incentive effects and magnitudes of impacts from different allocation methods for the electricity sector in EU ETS using analytical models and simulations. Their results indicate that different allocation methods lead to different impacts and distortions, with auctioning showing the best efficiency while the baseline emissions method has the most negative impacts and distortions. Hepburn *et al*. (2006) explain in further detail that auctioning is evidently in the public interest; nonetheless substantial obstacles remain in the path of implementing large-scale auctioning in a EU ETS from a political economy perspective.

2.9 The European Carbon Market

The launch of the EU ETS in 2005 not only set up an illustrative example in shaping climate policy but also had a significant impact on global carbon markets. This section describes the main institutional aspects concerning the market development of European's carbon market, based on Convery and Redmond (2007), the Chapter 4 in Brohé *et al*.

(2009), Chapter 5 in Ellerman *et al*. (2010), and the annual state and trends reports published by The World Bank (2007, 2008).

2.9.1 An overview of market development

One aspect that substantially shaped the European carbon market was the establishment of institutional forms in addition to a regulatory structure, and thus the question arose: who were participating in the EUA market? The participants in the EUA market can be classified into two groups: first, the compliance players and, second, the intermediaries. The design of EU ETS means that the main compliance actors are installations with high emissions outputs, and in many cases several installations are owned by the same firm. Based on Trotignon and Delbosc's analysis of EU ETS participant data, it can be seen that aggregate allowances allocation has been largely concentrated at firm level (Trotignon and Delbosc, 2008). As aggregate-level data is not made available by the European Commission, the best approximation is provided by private data providers, such as Carbon Market Data,[17] and individual research studies.

There are currently more than 13,000 operator holding accounts active in the transaction log, while 1,000 firms account for around 94% of the allowances within EU ETS. Combustion activity is evidently the dominant factor among all participants, which amounts to more than 8,000 installations. There are four countries with more than 1,000 installations participating the trading scheme – Germany (with more than 1,900 installations), the UK, –France, and Spain (all with more than 1,100 installations). A more detailed analysis with regard to EU ETS participants is provided in Chapter 3.

The participation of financial intermediaries forms another notable feature of EU ETS. The main function of intermediaries is to ensure smooth transactions among the compliance parties. Derivatives products, which enable compliance players to more flexibly manage their exposure to allowance price associated risks, are provided by these mediators. Both brokers and traders can perform a role as an intermediary, with differences in the way they facilitate transactions. While brokers act purely on behalf of their clients, traders can own and operate their own accounts. It is possible that traders can profit from differences between purchases and sales, meanwhile the market liquidity can be improved as any

17 http://www.carbonmarketdata.com.

entity can more easily find a counterparty in case of either buying or selling (Ellerman *et al.*, 2010: 129–131).

Transactions can take place in the following three forms of trading: bilateral, over-the-counter (OTC), and open exchanges. Bilateral transactions are transactions directly between two parties without facilitation by mediators. These transactions are often large in trading size and prices remain undisclosed. They were the most common transactions at the initial stage of the EUA market and remain well received among major players. OTC transactions take place between two parties through an intermediary, either a broker or a trader. It saves the time for the party that wishes to buy or sell EUA to search for a suitable counterparty, and details on the transaction remain private for most transactions. Exchanges work as an organised marketplace for any party who wishes to trade on allowances. Buyers or sellers can submit orders and execute trades through electronic platforms developed by certified exchanges, thus the trading remains anonymous and bears minimal counterparty risk. In addition, exchanges offer a clearing service for both bilateral and OTC transactions as well as a block trade facility by which a large volume of EUA transactions can take place off the exchange (Ellerman *et al*., 2010: 132–133).

2.9.2 Performance evaluation of EU ETS

It is in many people's interests, particularly for policy makers, to evaluate and review the performance of EU ETS in order to mitigate its shortcomings and improve its overall effectiveness. Given the pioneering statue of utilising emissions trading to achieve GHG emissiosn reductions, EU ETS is by no means flawless. However, it is important to be aware of issues that may jeopardise the merits of EU ETS and reduce such issues. This section reviews studies that assess the general performance of, and major issues concerning, the EU ETS function.

Boemare and Quirion (2002) comment on the ETS proposal submitted by the European Commission on the basis of an extensive investigation of the discrepancies between existing trading schemes or similar instruments and the economic literature in order to understand how far practical experience can drift away from theory and reason. They pinpoint several issues that can substantially influence the overall effectiveness of a trading scheme – for instance, spatial and sectoral coverage, temporal flexibility (banking and borrowing), trading organisations, monitoring, and enforcement. The authors conclude that EU ETS Directive proposal has shown many positive provisions, including wide spatial and sectoral coverage, banking of allowances, and trading organisations without the need of governmental approval but mandatory registration. The provisions mentioned above make the EU's emission trading system stand on firmer grounds in the economic literature than most previous systems reviewed in the study.

Another discussion paper by Kruger and Pizer (2004), from the Resources for the Future institute, also comes down on the optimistic side and recognises the swift process of launching such a large-scale GHG trading scheme as an impressive political achievement. Most elements designed in the EU ETS Directive appear sound in the authors' opinion, nevertheless, they expect a bumpy initial stage due to the challenges that faced the first trading period of EU ETS. The challenges identified in the discussion include delay in meeting various deadlines (such as NAP submission and assessment), diverse allocation rules, and inconsistent enforcement regulation across member states, as well as uncertainty over the allowances market.

Convery *et al*. (2008) provide a comprehensive analysis on how EU ETS performed in the pilot phase, with a focus on functional aspects. Their results show that the 'pilot phase' of EU ETS demonstrated several merits, including successfully imposing carbon prices on a considerable segment of economic activity in Europe, and building an essential infrastructure for long-term carbon market. The ETS also provides incentives for emission reduction projects outside Europe and carbon price formed within European market can also become a valuation basis for pricing credits generated from CDM/ JI, as well as other opportunities.

Several controversial issues during Phase 1 of EU ETS are documented and discussed in Ellerman and Joskow (2008), with a cautious reminder from the authors that it should be kept in mind that the first trading period of EU ETS was set to be a learning period. The authors point out the most criticised aspects are the windfall profits, that result from free allocation and indicate that the cap for phase 1 is very far from having sufficient constraining power. Windfall profits, which are considered to originate from the free allowances received by entities, such as electricity firms who are able to pass the ETS-related costs to customers, has also been discussed in studies by Wettestad (2007), and Skjærseth and Wettestad (2009), and also been empirically investigated by Sijm *et al*. (2006a, 2006b). Another issue that is often raised regarding the first trading period is the significant price volatility, which was mainly caused by a mixture of uncertainty towards market fundamentals, oversupply, and insufficient intertemporal flexibility (Egenhofer, 2007; Convery and Redmond, 2007).

A few studies have focused on the performance of EU ETS in term of overall environmental commitment through examining specifically the existence of abatement behaviour or overallocation within the trading scheme. Similarly to the allocation issue raised above, Ellerman and Buchner (2008) empirically tested the existence of overallocation and abatement in 2005 and 2006 in their analysis. The authors indicate that judgement of overallocation or abatement should be made after consideration of economic activities, energy, and carbon intensity. With a self-constructed measure that empirically estimates the degree of overallocation by examining the ratio of an aggregate net position to the sum of the net position of all components from the aggregation, they reach a result that overallocation up to 125 million EUA occurred for the first two years of EU ETS. Anderson and Di Maria (2011) discover that overallocation, with a magnitude of approximately 280 million EUA, occurred along with abatement during the pilot phase. Clo (2009) takes a step further by analysing a number of inefficiencies caused by overallocation and finds that ETS sectors received subsidies from both national-level and non-ETS sectors as a consequence of member states' support for major industries. The author also shows that competition distortion can result from inconsistencies in allocation methods in different member states and concludes hat EU's emissions trading has not shown a sufficient level of effectiveness.

In summary, EU ETS has received positive opinions on its political feasibility and the first phase built the essential infrastructure for future trading activities as well as being a successful demonstrative example. The criticisms are mainly upon the overly generous cap and free allowances, which can seriously harm policy efficiency, as the scarcity that creates the market hardly exists (Clo, 2009). A lack of harmonised allocation methods across member state also raises the concern of inequality among firms as well as industrial sectors. Enforcement across member states is also an issue that needs to be addressed for a better functional trading scheme in the post-Kyoto period.

2.10 Concluding remarks

This chapter has reviewed the fundamentals of emissions trading as well as the main institutional aspects of EU ETS, and is intended to provide essential background information with regard to the subject to be studied in the empirical chapters in this thesis. The first four sections provide fundamental knowledge on the background of the problem, possible solutions and theoretical grounds of market-based instruments. It should be noted that there is no absolute right or wrong in deciding on a policy instrument, as stressed by Weitzman (1974): an instrument works towards its optimal outcome in an appropriate context. Market-based instruments have gained popularity among governments mainly for their cost-efficiency potential; as for emissions trading, it has tended to be better received by affected industries than taxation.

Sections 2.6 and 2.7 introduced the institutional aspects of EU ETS, including its origins and regulatory framework. The political foundation that enables the making of a single European market is one of the essential aspects for the implementation of a community-wide trading scheme. Section 2.8 provides a detailed explanations of relevant technical aspects with regard to the operation of the EU ETS. Cap-setting is through the aggregate of each member state's allocation plan, which is to be replaced by a single EU cap from the third trading period onwards. The large degree of grandfathering during the first and second trading period have been subject to considerable change. In particular, the power sector is required to obtain its allowances through auctions instead of free allocation.

In addition to policy effectiveness in terms of performance regarding environmental commitment, implications of EU ETS has been another relevant issue since the issue of the EU ETS Directive. Economic implications, such as effects on industrial competitiveness, and financial implications, like the interaction between the carbon and financial markets are both of interests to various groups including policy makers and affected (or potentially affected) industrial sectors. The implications of EU ETS, in particular with regard to the stock market, will become the main focus of empirical analyses in this thesis. Chapter 3 introduces the elements required for the empirical analyses planned, which will cover the data selection and sampling process.

Appendix 2-A

Annex I Parties to the UNFCCC

Australia	Greece	Norway
Austria	Hungary	Poland
Belarus**	Iceland	Portugal
Belgium	Ireland	Romania
Bulgaria	Italy**	Russian Federation**
Canada	Japan	Slovakia**
Croatia**	Latvia	Slovenia**
Cyprus	Liechtenstein**	Spain
Czech Republic**	Lithuania	Sweden
Denmark	Luxembourg	Switzerland
Estonia	Malta	Turkey**
(European Union)	Monaco**	Ukraine**
Finland	Netherlands	UK
France	New Zealand	USA
Germany		

** Party for which specific decisions have been made.

Source: http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php.

Appendix 2-B

Annex I to Directive 2009/29/EC replaced Annex I to Directive 2003/86/EC regarding the activities and GHGs to be covered in EU ETS. The types of activities covered include combustions, the production of metal, cement, pulp and paper. CO_2 is the main type of GHG subject to emission restrictions, with the following exceptions listed below.

Activity	Greenhouse gases
Production of primary aluminium	CO_2 and perfluorocarbons
Production of nitric acid	CO_2 and nitrous oxide (NO_2)
Production of adipic acid	CO_2 and NO_2
Production of glyoxal and glyxylic acid	CO_2 and NO_2

Note: Installations used for the purpose of research, development and testing of new products/processes are not covered in ETS Directive (EC, 2009a).

3 Data

3.1 Introduction

This chapter explains the data used in the empirical analyses in this thesis, which attempts to explore the impact of the European Union's emissions trading scheme (EU ETS) on companies subject to this regulatory context. More specifically, the research questions introduced in Chapter 1, which concern two aspects of potential EU ETS impact – first, the impact on emissions behaviour of firms regulated by the EU ETS and, second, the value impact on stock prices of firms regulated by the EU ETS – are empirically examined in the following chapters.

One key component needed for the empirical analyses is the company-level carbon[18] data, which need to be carefully accounted for. Compared with standard market data, such as the stock prices and accounting data of corporate operations, the firm's carbon emissions data is still a relatively new type of data used in empirical analyses, as the demand for such data has only becomes obvious with the growing concern about greenhouse gases (GHG)-related environmental issues in recent decades (Horster, 2013; CDP, 2013a; Trotignon and Delbosc, 2008).

The majority of company-level carbon emissions data available to date is produced primarily through the voluntary disclosure and reporting of companies, as the mandatory reporting of carbon for either public or private companies is not yet in place at a national level in all countries except the UK, which introduced it on 12 June 2013 for about 1,100 large listed firms (DEFRA, 2012). As a consequence of the increasing awareness of the necessity of making climate change-associated information more publicly available, a number of environmental disclosure programmes and regulations have emerged (Kolk *et al.*, 2008; Sullivan, 2006; 2iiInvestingInitiative, 2013). These include the EU-wide cap-and-trade scheme, the Carbon Disclosure Project (CDP), as well as other investor-orientated specialised private data providers. All, directly or indirectly, are positive actions in terms of increasing the availability of company-level carbon data. Based on these developments, this thesis intends to utilise reliable company-level carbon information to

18 The GHG specified in Annex 1 of Directive 2003/87/EC (EC18, 2003) indicates only carbon dioxide (CO_2) for all activities regulated. Annex 1 was only amended in 2009 by Directive 2009/29/EC to include perfluorocarbons for one activity and nitrous oxide (NO_2) for three activities. The majority of the GHGs regulated remains CO_2, and so does the focus of this thesis.

investigate the research questions proposed for the empirical chapters. The four most relevant data sources plus two newer private data providers are initially examined and assessed in this chapter for their capacity to provide the most suitable data.

This chapter is structured as follows. Section 3.2 introduces the background of carbon data, which includes the emergence of GHG[19] disclosure, and the data produced and utilised in the empirical research in this thesis. Section 3.3 describes in detail the carbon emission databases that currently exist, and their potential to offer suitable data for the empirical analyses planned. Section 3.4 presents the assessment process for selecting the principal database, which starts with a summary table containing information on each database candidate concerning their scope and method. The assessment continues with a discussion of the criteria concerning the abilities of the database to provide relevant and suitable data for the empirical analyses. Section 3.5 presents a numerical analysis with regard to the distinct features of the database which have been selected after the assessment process.

3.2 Background

This section comprises two parts. The first part briefly introduces the origin of the research interests in this thesis. It explains what type of data is required for the empirical analyses in the following chapters. The second part reviews a number of studies that empirically investigate carbon emissions-related topics, especially the topic of the relationship between firm-level carbon emissions and the 'financial' market. Particular attention is paid to which carbon emissions data are utilised in these studies in order to determine the most suitable type of data to be used in the empirical analyses.

3.2.1. Carbon emissions data: origin

According to the Stern Review on the economics of climate change (Stern, 2006) and the third and fourth IPCC assessment reports (IPCC, 2001a, 2007), climate change would not only severely damage our environment, but also cause substantial amount of loss to the value of the global economy, if mitigating action is not taken or taken too late. Climate

19 The main research interest of this thesis is the EU ETS, which at this moment regulates CO_2 equivalent emissions. As the term GHG is inclusive of various types of gases,of which CO_2 currently has the more rigorous coverage and political and economic implications, I use GHG, carbon, and CO_2 interchangeably.

change and its related issues are posing growing concerns to various stakeholders, including policy makers, academic researchers, investors, and the public, as substantial effort will be needed to avoid the catastrophic situation projected by the reports mentioned above.

Voluntary disclosure of environmental issues is one major step taken by both corporations and investors in order to understand and manage these risks better. With voluntary disclosure, the disclosure of information by the corporation is done on a non-compulsory, voluntary basis. When done properly voluntary disclosure is supposed to mitigate the 'information asymmetry gap' between corporations and stakeholders outside the corporation, such as investors, either individual or institutional. (Brammer and Pavelin, 2006). This reduction of information asymmetry enables a better valuation of corporations, and also enhances the opportunities for investors to influence corporations' performance regarding environmental issues with their investment decisions (Griffin *et al*., 2012; Reid and Toffel, 2009). Establishing the accurate carbon emissions management of firms has become a primary concern for investors, as carbon emissions can affect the firm substantially in various aspects, such as the direct and indirect costs that will occur due to required abatement or future environmental liabilities.

Voluntary disclosure of environmental impacts – or, specifically, of carbon emissions by corporations – is being done in two main ways. The company can simply decide itself what type of information is to be disclosed, either in its annual reports, or in a stand-alone, non-compulsory sustainability/ESG[20] report. The other way to make voluntary environmental/ carbon emissions disclosure is to become a signatory and provide relevant information for the specific disclosure initiatives that gather, organize, and publish such information, such as the CDP[21] and The Global Reporting Initiative (GRI).

At the other end of the reporting spectrum stands mandatory reporting. Currently, there are very few cases of a mandatory environmental disclosure requirement for companies at the national level. The UK Department for Environment, Food and Rural Affairs (DEFRA)

20 Environmental, Social and Governance.

21 The CDP has for over a decade worked with companies, investors, and communities to disclose GHGs as well as other environmental sustainability issues. Given the aim of this thesis, more detail on CDP's company and investor initiatives for GHG disclosure are provided in Section 3.3.

announced in June 2012, that the UK would become the first country to make it compulsory for large companies to report their GHG emissions for the entire organisation in their annual reports from 2013 (DEFRA, 2012). The Company Act 2006 (Strategic Report and Directors' Report) Regulation 2013 requires all UK companies which are quoted on the main market of the London Stock Exchange to make full GHG emissions disclosure in their annual Directors' Report. This is a milestone and an encouraging outcome, following the consideration of extensive evidence and detailed consultation with businesses and individuals, most of which supported mandatory reporting.

A degree of mandatory reporting of carbon emissions was also effected by the implementation of EU ETS, on the basis of the ETS Directive 2003/87/EC and the guidelines for monitoring and reporting (EC, 2003b, 2004b, 2007a). The ETS Directive specifies the conditions under which an installation shall be included in the EU ETS and requires that all installations monitor and report their emissions at the end of each compliance cycle. The EU ETS reflects the concern of investors, as well as of researchers, regarding the economic and financial effects of this unique mechanism, as they are keen to find out whether carbon emissions restriction-related risks have become substantial in terms of affecting firms' profitability and eventually equity value. A number of studies (Oberndorfer, 2009; Veith *et al*., 2009; Knight, 2011) have attempted to investigate the relation between stock price performance of EU ETS regulated firms, mostly utilities sector firms, and the carbon market created by the ETS regulations.

This thesis, following the previous literature that specifically explores the ETS-related economic and financial impacts on companies (Oberndorfer, 2009; Veith *et al*., 2009; Knight, 2011; Mo *et al*., 2012) and the carbon emissions effect (Bushnell *et al*., 2013; Chapple *et al*., 2013; Oestreich and Tsiakas, 2013), intends to explore a series of research questions regarding EU ETS' impacts, which were introduced in detail in Chapter 1, and briefly in Section 3.1 of this chapter. Similar to earlier literature, econometric techniques and real market data are used to examine these questions. The scope and depth of the sample dataset will be extended in terms of the number of firms, multi-sector context, and length of the sample period, which are presented in the following sections of this chapter.

Company-level carbon emissions data are one of the essential components needed in conducting the analyses planned in the following empirical chapters. Compared with standard market data, such as a firm's share price, the firm's carbon emissions data is still a relatively new type of data, as the demand for it has only becomes obvious with the growing concern about GHG-related environmental issues in recent decades. There is thus the need to specifically introduce and explain in detail such carbon emissions data and its availability, which begins in the next section by providing a concise review of the different types of carbon emissions data used in previous studies.

3.2.2. Carbon emissions data: usage

Since the implementation of the EU ETS in 2005, a small but growing body of literature has explored the financial implications of ETS regulation with empirical analyses. A number of these studies have focused on the relationship between firm value and the carbon emissions. While firm value can be proxied by several indicators, such as the firm's equity value reflected by its stock prices, or accounting measures, such as its profitability and assets, the accessibility of these figures for public companies is relatively simple. However, access to reliable company-level carbon emissions data can be less straightforward, as GHG emissions disclosure has not been made mandatory. The carbon emissions data produced from the EU ETS thus provides one of the very rare sources of data on regulated carbon emissions reporting. Although the original data kept in the EU's transaction log (EUTL) is at installation level, which includes over 100,000 installation-year data points, these installations can be manually matched to company level through the account holder's data. However, this is a time-consuming process and the quality and scope of the final data product is dependent on the accuracy of the account holder's databases.

Nevertheless, the data from the EUTL (formerly the Community Independent Transaction Log, CITL) has been utilised in some studies albeit, understandably, for only small and short samples. Bushnell *et al*. (2013) empirically examine the asset values of the emissions allowances holdings by regulated firms. They match the allowances and verified emissions data of 90 public firms for 2005, and examine whether the abnormal returns found in their event study analysis in the previous stage can be explained by the firms' allowances positions.

With a slightly different subject of research interest, Oestreich and Tsiakas (2013) also use data from the EUTL to examine whether the carbon premium created by the EU ETS regulation is significant, in the context of the German stock market. The authors pick 66 firms that are listed in two main German exchanges. The firms are separated into two groups, according to whether they receive free allowances, and the stock price performances of these two groups are estimated against the market benchmark in order to determine the extent of the carbon premium on which the study focuses. The EUTL data are used by the authors purely to indicate whether the firm is clean or dirty, depending on whether or not they receive free allowances. This approach appears slightly simplistic as the verified emission data, which are also a crucial indication of the firm's carbon emission profile, are not utilised at all.

Since the voluntary GHG disclosure, in particular the CDP, has gained an exposure and acceptance among companies world-wide, a body of literature has endeavoured to explore whether the information disclosed on the voluntary basis is value relevant from the investors' perspectives. Undoubtedly, the CDP provides good research opportunities and appears the most commonly used source for company-level carbon data, judging by the number of studies that have utilized such data.

An analysis focusing on the relationship between firm value and firm carbon emissions was conducted in the context of the proposed Australia ETS by Chapple *et al*. (2013), who investigated the impact of the ETS proposal in Australia on the stock market of firms listed on the major exchange (ASX[22]). They explicitly hypothesise that the firm value reflected in the stock market can be negatively influenced by the firm's carbon intensity profile. They rely on data sources from two private providers, as ASX listed firms are not obliged to report carbon emissions data. The authors specify in their study that the carbon data from one of their providers, Citigroup, was derived mainly from the CDP, and the data from the other provider, VicSuper,[23], involved a great proportion of estimated numbers so that the actual emissions data are not really provided: their empirical design needs to be altered given this caveat. The firms are categorised into high or low carbon intensity

22 Australian Securities Exchange.

23 The VicSuper Carbon Count (2007) is used in Chapple *et al*. (2013).

groups according to their carbon intensity measure, and the hypothesis is tested on an aggregated measure basis, instead of being tested on each firm's precise carbon intensity figure.

Griffin *et al*. (2012) explore how relevant the companies' GHG emissions disclosure is to investors in the North America financial market context. They construct large samples of American S&P 500 and Canadian TSE200 firms that voluntarily disclose their GHG emissions to CDP to investigate the valuation effect of such disclosure and non-disclosure for firms. As they investigate both disclosing and non-disclosing firms, the emissions data used in the regression analyses essentially contain self-estimated figures, which are produced by the authors' prediction model. Their analysis reveals that CDP disclosed and self-estimated emission levels are negatively associated with the stock prices of the sample firms, which points to the existence of a negative valuation effect. This effect appears more pronounced for S&P500 firms than for TSE200 firms, and the magnitude of the negative effect increases for emissions intensive industries. The authors consider the negative valuation effect to be at approximately the same level for the CDP disclosing and non-CDP disclosing companies in their sample, which suggests that the stock market also values GHG emissions information from mediums other than the CDP.

In a similar North American context, Matsumura *et al*. (2014) investigate the relationship between carbon emissions level and firm value for S&P500 firms that report voluntarily to CDP using hand-collected carbon emissions data for 2006–2008 from the CDP reports. After explicitly addressing the self-selection bias of the sample due to firm and industry characteristics related to the decisions made by the firms to voluntarily disclose, they find a negative relationship between carbon emissions levels and firm value measured by stock prices. The authors raise concerns on the limitations of their study due to the quality of the reported data in CDP reports, which include diverse methods of measuring emissions by firms even within industries, varying scopes of reporting, and the fact that firms' self-reported emissions lack external verification. In their opinion, the need for carbon emissions allowances information is self-evident, nevertheless due to the lack of a national trading scheme in the US, this type of information is not yet available, even for large public firms.

Ennis *et al.* (2012) utilise CDP data to examine a series of carbon emissions-related questions in the context of UK-based FTSE350 firms. The authors examine the relationship between the companies' emissions performance and their financial performance, in addition to the relation between the carbon disclosure and carbon emissions performance of firms, as well as the carbon emissions performance and the firm's operational performance. Their results show that at present the emissions performance of the firm appears less value relevant to investors, and conclude that the financial market is not yet responsive to companies' emissions performances, or that the information which is currently available has not been sufficient in terms of differentiating among companies' performance.

Other sources of GHG emissions data are also being utilised. Kim and Lyon (2011) explore the motivations and impacts of the strategic disclosure behaviour of firms that participate in the US Department of Energy's voluntary GHG registry.[24] The authors extract the data from the Registry and compare the self-reported reduction to the actual emissions. Their results reveal that participants in the voluntary disclosure programme adopt highly selective reporting practice, and in aggregate the participants even increase emissions over time, but report reductions. A number of critical caveats concerning its design are documented in the authors' review section on this voluntary reporting program. As they point out, the reductions in emissions can be reported at different levels (at entity or project level) in the voluntary scheme, and the choice of baseline emissions against which the reductions are measured appears liberal due to the lack of rigorous rules regarding how to report the reduction. These aspects inevitably impact the data quality as well as the extent to which the voluntary reporting program is environmentally effective.

Inevitable shortcomings face such voluntary/non-regulated reporting, despite the undoubted good intentions. The biggest issue facing data provided by CDP and other voluntary reporting schemes has to be the quality of GHG emissions in terms of accuracy and consistency across reporting firms (Sullivan, 2006, 2009). Several aspects regarding the quality of reported GHG inventories of firms in the CDP are raised in Sullivan (2009), which points out in particular that it is not certain that applications of the emissions

24 It is established by Section 1605(b) of the Energy Policy Act 1992, which is currently suspended. More information is available at http://www.eia.gov/oiaf/1605/index.html.

calculation protocols are strict and uniform in all cases. The unclear practice of establishing reporting boundaries is also an issue.

Another aspect concerns the degree of verification for the reported emissions data of the participating companies. In particular, the scope of the verification process reported on the verification statements is unclear. These issues reflect the concerns raised in previous studies (Sullivan, 2006; Kolk *et al*., 2008; Kim and Lyon, 2011; Matsumura *et al*., 2014) regarding the overall quality of the voluntary reported data. Kolk *et al.* (2008) explicitly point out that the major challenge that CDP faces remains the low level of comparability of the disclosed information, which is supposed to be the primary objective of the initiative. Similar opinions are seen in the practitioner field. Sullivan (2006) produced a report that stimulated the discussion on the future direction of companies' climate change disclosure standards and initiatives. The analysis was based on the author's experience with the design and implementation of climate change disclosure initiatives, including CDP and GRI. The report raises several caveats concerning current disclosure initiatives like CDP from the investors' angle – in particular, the poor quality and presentation of reported data, the confusion that can arise from the concurrent existence of multiple initiatives, and the lack of consistency and comparability among data.

3.3 Carbon databases of relevance

The following section introduces six databases that provide company-level carbon emissions data, which could potentially be the principal provider of the carbon emissions data needed for this thesis. The basic features, such as coverage in terms of geography and time, and level of data provided, for each database are described.

3.3.1 Carbon market data: EU ETS company database

As the interest of this thesis lies with the carbon emissions-associated impact on companies, the world's largest carbon emission trading scheme – the EU ETS – naturally becomes the most likely source of relevant data. The regulatory framework and operation of the EU ETS was introduced in Chapter 2, and so the following section focuses on data-related aspects.

To properly and effectively manage a legislative scheme of such relative novelty, a systematic and standardised mechanism is necessarily required. The EUTL [25] (formerly CITL), serves this purpose by keeping records of annual allowances allocation and verified emissions at the installation level for all installations in all participating member states. An example of the information recorded in the Allocation/Compliance section of the transaction log is provided in Table 3.1.

Table 3.1 Example of information provided in the European Union Transaction Log

Installation Number (1)	Installation Name (2)	Allowances Allocation (3)	Total Emissions Verified (4)	Allowances Surrendered (5)
6	Forties Charlie	154,936	295,349	295,349

The example is taken from the UK[26] Registry for 2010 in the EUTL. The log provides information on the assigned installation number (column (1)), the name of the installation (column (2)), the annual allowances allocation of the installation (column (3)), the total verified emissions of the installation (column (4)) and the total number of allowances surrendered at the end of the compliance cycle (column (5)).

While installation-level data are accessible from the EUTL, the EU log has no intention to make aggregated-level (firm, industrial, national) data publicly available. The installation-level data has been utilised by Trotignon and Delbosc (2008) to analyse the transaction patterns during the trial period of EU ETS; however, it is not directly usable in the analyses for firm-level investigations as proposed in this thesis as a company can own multiple installations in different locations. The authors point out in their study that the real market players would be the firms that own installations rather than the installations themselves due to the possibility for ‘pooling’ offered in the ETS Directive. Research questions and empirical analyses that aim to explore company-level data have in consequence a large potential to provide more insight into this unique trading scheme and its impacts.

After extensively surveying the available resources that could offer relevant company-level carbon data, Carbon Market Data is found to be the database that seems to provide the most essential data needed for the empirical analyses planned. There is a considerable

25 The log can be accessed from http://ec.europa.eu/environment/ets/.

26 The accounts had still been held in each National Registry before the suspension of national registries took place in June 2012.

amount of valuable data provided free of charge on its online World ETS database, most of which is at national level. There is also a small amount of company-level data, although restricted to iron and steel firms, as well as simple analytical tools of national-level compliance status for each trading year available free of charge. There are various types of paid products available through Carbon Market Data, including databases of different ETSs worldwide,[27] the Clean Develop Mechanism–Joint Implementation database and, most importantly, the EU ETS Company Database, all of which appear to contain essential data needed for the empirical investigation planned for this thesis.

Table 3.2 An Overview of the Carbon Market Data EU ETS Database

Number of Companies (1)	**Number of Installations (2)**	**Number of Activities (3)**	**Phase 1 Coverage (%) (4)**	**Phase 2 Coverage (%) (5)**
887	8410	18	92	89

The table describes the scale of the Carbon Market Data's EU ETS Company Database. Column (1) indicates the number of companies included in the database. Column (2) shows the number of installations included in the database. Column (3) shows how many types of operating activities for which the installations are subject to ETS regulations. Activity refers to the operating activities for which the installation is regulated, defined in Annex 1 of Directive 2003/87/EC (EC, 2003a). Column (4) and (5) show the coverage of the entire database. Coverage is calculated by the allowances allocated to companies in the database in relation to all allowances distributed within the EU ETS. The incomplete percentage of coverage results from small-scale installations/firms, such as independent power and heat plants.

As indicated in Table 3.2, the coverage of the EU ETS Company Database contains 887 participating companies. These companies in total account for more than 90% on average of the allowances issued within the entire EU ETS. The precise percentage of total verified emissions covered in the database is 92% for Phase 1 and 89% for Phase 2. The database provides the amount of annual allowances allocated to each company. An example of the original data provided in the database is presented in Table 3.3.

27 By the time this thesis was planned and the empirical analyses were conducted, the Carbon Market Data offered databases of EU ETS, RGGI, and part of CDM-JI. Their inclusion of the ETS database has extended substantially ever since.

Table 3.3 An example of the data points provided by Carbon Market Data

Company - E.ON		**Activity - Power & Heat**		**# of installations: 266**	
Year (1)	Allocated allowances (2)	Verified emissions (3)	Emissions-to-cap (= e–c) (4)	e–c ratio (as % of cap) (5)	Verified emissions evolution (%) (6)
2005	104,524,721	114,328,927	9,804,206	9.38	
2006	102,588,985	112,749,422	10,160,436	9.90	–1.38
2007	103,505,341	115,288,280	11,782,939	11.38	2.17
2008	77,552,319	107,446,707	29,894,387	38.55	–6.81
2009	76,192,522	93,558,007	17,365,485	22.79	–12.96
2010	79,155,014	94,664,817	15,509,802	19.59	1.20

This table presents an example of the original company-level data points provided by the EU ETS Database of Carbon Market Data. The activity refers to the installations' operating activity for which they are regulated by Directive 2003/87/EC. Column (2) shows the annual emissions cap as determined by its allowances allocation for the company. Column (3) shows the actual amount of CO_2 emissions for the company in each compliance year. Column (4) shows the differences between the emissions and the cap, which is calculated by Verified emissions (of the current year) – Cap (of the current year). Positive figures mean that the actual emissions are higher than the cap while negative figures mean that the company's emissions for the year are lower than the cap. Column (5) shows (the emission-to-cap)/the annual cap. This number shows the proportion of the difference between emissions and cap to the annual cap. For example, a 15% e–c ratio means that the company's position of actual emissions is 15% more than the annual cap. Column (6) shows the number that indicates the evolution of the company's actual emissions, compared with the previous year: –1.38% means that the actual amount of emissions for the company in the current year is 1.38% less than the emissions of the previous year.

3.3.2 Carbon Disclosure Project[28]

The Carbon Disclosure Project (CDP) is one of the first initiatives that promoted and specialised in corporate environmental information disclosure and sharing of climate change-associated risk. The CDP works closely with various groups with climate change concerns, such as institutional investors, shareholders, local communities, and governments. On behalf of these groups the CDP requires large companies world-wide to report on a voluntary basis information about GHG emissions, energy usage, climate

28 https://www.cdproject.net; https://www.cdp.net/en-US/Programmes/Pages/climate-change-programs.aspx

change strategies management, and risks and opportunities from climate change. The CDP aims for an ultimate systemic transformation of the global economy, which is required to induce the essential actions to prevent the severe consequences of climate change which would occur if the necessary actions were not taken. The following paragraphs explain how the CDP works using its Climate Change Program as an example.

The CDP gathers information by inviting companies to participate in responding to questionnaires specially designed to demonstrate the overall performance of companies in terms of combating climate change. The questionnaire contains questions that are categorised into three groups: management, risk and opportunities, and emissions. Participating companies utilise the CDP's Online Response System. As participation in the CDP is optional rather than mandatory, companies are encouraged to respond by emphasising reputational rewards and facilitating the company's future obligations to report similar information. CDP's scale to date is impressive; it works with more than 700 institutional investors holding 78 trillion USD, requests company climate change data, and produces disclosure scores. The number of responding companies has grown seventeen times, from only 235 in 2003 to more than 4,000 in 2012[29].

Although the questionnaires are designed with well-structured questions and the CDP also provides guidance on reporting, participating companies are given discretion on their disclosure in certain aspects and the CDP does not verify any disclosure itself. The assurance level of verification of the reported data can range from 'assurance not applicable' to 'high assurance'. The CDP also declares that it is not possible to explicitly reject a certain standard/methodology of GHG inventory calculation, so its scoring mechanism does not differentiate between methodologies used by companies to calculate their reported GHG inventory. The CDP's Online Reporting System through which companies respond to the questionnaire includes 54 standards/protocols/methodologies for GHG inventory calculation (CDP, 2013b).

The CDP began the Carbon Action Initiative,[30] another investor-led initiative, in 2011 to further encourage companies to adopt and implement GHG reduction action. This initiative

29 Data from CDP's Reports and Data section, accessed from https://www.cdproject.net/en-US/Results/Pages/overview.aspx.

30 https://www.cdp.net/en-US/Programmes/pages/what-is-cdp-carbon-action.aspx.

has a similar aim to that taken in the original CDP climate change programme, which is to invite companies to respond to a request to set year-on-year reduction targets, publicly disclose such targets, as well as produce ROI-positive investments in projects. Their Carbon Action Report (CDP, 2012) stated that 57% of the 256 companies in the emissions intensive industries had set up emissions reduction targets in 2012, and the initiative intends to work further with investors to promote company action to deliver cost-effective carbon emissions reduction. However, it appears the data produced from this initiative focused on the emissions reduction activities of companies, and no actual emissions data were found in both reports of the initiative (CDP, 2013a, 2013b).

3.3.3 ASSET4 Thomson Reuters[31]

ASSET4 now operates as a business under Thomson Reuters and specialises in corporate environmental, social, and governance (ESG) data. Annual CO_2 equivalent emissions at firm level are available under the environmental factors of the dataset. The coverage of ASSET4 is extensive, including listed firms on most major stock exchanges. The sources of data are all publicly available information, through company reports and other public sources. However, it is not clear from Thomson Reuters' description how the CO_{2e} emissions data are compiled, and thus research into this aspect is done mainly through digging in news archives as the original ASSET4 AG official website is no longer existent.

The origin of the CO_2 emissions data contained in the ASSET4 Thomson Reuters ESG/CSR database is presumably the ASSET4 Carbon Data and Estimates, launched in April 2009 by Asset4 AG before its acquisition by Thomson Reuters later in the same year. According to the news release[32] by ASSET4 AG, when the Carbon Data and Estimates were made available, their CO_2 emissions data come from two sources: company reports and self-constructed estimated models. Based on the comments in the news release made by Peter Ohnemus, a Swiss entrepreneur and co-founder of ASSET4 AG, the overall quality, including timeliness and completeness, of reporting total CO_2 emissions differs among sectors, industries, and companies. For non-reporting companies, ASSET4 AG

31 ESG/CSR content overview on the Thomson Reuters website, which can be accessed here: http://thomsonreuters.com/products_services/financial/content_news/content_overview/content_az/content_esg/#tab1.

32 Accessed at http://www.csrwire.com/press_releases/13695-ASSET4-Carbon-Data-Estimates-Available-Now.

produced estimated CO_2 emissions based on three self-constructed models: the CO_2 model, the energy model, and the median model.

3.3.4 Carbon Monitoring Action (CARMA)[33]

CARMA is a database dedicated to providing carbon emissions data of power plants and power companies world-wide. It is financed by Confronting Climate Change Initiative within the Center for Global Development (CGD)[34] and declares itself to be non-partisan.

Table 3.4 An example of data points provided by CARMA

Name (1)	Year (2)	Tons CO_2 (3)	MWh Energy (4)	Intensity (5)
E.ON AG Germany	2004	145,520,000	251,210,000	579
	2009	120,280,000	238,770,000	504
	Future	184,280,000	304,230,016	606
ENEL s.p.a. Italy	2004	148,230,000	226,370,000	655
	2009	107,290,000	193,910,000	553
	future	133,840,000	240,150,000	557

This table shows the company-level data provided by CARMA database. Columns (3) and (4) show two years' of historical data of CO_2 emissions and energy produced by the company for 2004 and 2009. Column (5) shows the intensity, which is defined in CARMA's methodology as estimated amount of CO_2 a plant emits for each MWh of energy produced (kgCO2 / MWh). For companies that do not report accurate data, the projected figures of emissions, energy produced, and intensity are recorded using CARMA's internal statistical model. Source: http://www.carma.org.

The coverage of CARMA appears huge, containing the carbon emissions of more than 60,000 power plants and 20,000 power companies world-wide. According to its Frequently Asked Questions section, the data are compiled from various sources, which can be approximated by the geographic location and reporting activity of power plants. For reporting plants and companies, the data is sourced from official reports, governmental departments, such as US Environmental Protection Agency (EPA), International Energy

33 Information on CARMA can be accessed from http://carma.org/blog/about/.

34 Founded in 2001 and based in Washington, D.C., CGD aims to provide independent research and practical ideas for global prosperity. CGD's information is obtained from http://www.cgdev.org/section/about/.

Agency (IEA), and International Atomic Energy Agency (AEA). For non-reporting plants, the emissions figures are estimated based on CARMA's internal statistical model, which is fitted to a comprehensive dataset of US facilities with disclosed carbon emissions (Ummel, 2012).

The CARMA database provides good opportunities for empirical analyses that require huge cross-sectional datasets; however, two aspects limit the utilisation of the CARMA dataset for the proposed analyses in this thesis. First, the coverage of two separate years, one of which is outside the EU ETS trading period, limits the use of emissions data on planned investigations into the relationship between firm emissions performance and firm stock price changes. Second, CARMA data contain both reported and estimated figures, so emissions data from different plants can come from different sources. This can impose inconsistency problems among plants and the aggregate-level data could be subject to bigger estimation errors arising from plant-level data. CARMA currently provides emissions data at plant and aggregated level for 2004 and 2009 and the future based on development and retirement plans. An example of company-level data provided by the CARMA database is shown in Table 3.4.

3.3.5 Other private data providers: Trucost and South Pole Carbon

There are a number of private data providers that have started to build up sets of carbon-related information on companies and underlying investments, as investors world-wide are becoming more aware of global climate change-related risks and their potential impact. Two are identified as possible sources of carbon emissions data. Trucost is a company that specialises in assisting various stakeholder groups to understand the economic consequences of natural capital dependency, which covers not only carbon but also other natural resource-related issues, such as land use, water, and waste. The centre of Trucost's methodology is an advanced environmental profiling model for calculating the environmental impact across various sections of business operations. It offers an academic research portal service for subscription, which contains the Trucost Environmental Registry, the databases of natural capital metrics, and natural capital performance metrics. The database provides an extensive coverage of environmental impact data, including carbon and other GHG emissions of more than 4,500 companies gathered from various, often self-reported information sources (Trucost, 2013).

Another provider that maintains a substantial GHG database is South Pole Carbon, which targets climate change even more specifically and provides specialised services for helping companies achieve sustainability aims. South Pole Carbon also specialises in developing emissions reduction projects, creating novel climate change solutions as well as managing carbon. It is stated on their website[35] that South Pole Carbon maintains a unique database of company GHG emissions, which is the largest world-wide, and also possesses several merits such as transparency and affordability. The highlights of the database include the coverage of more than 40,000 companies, which include self-reported and modelled data points, the scope of emissions, transparency and measurement regarding data usage and, most crucially, plausibility checks on self-reported carbon data.

While the databases described above all seem to have the potential to provide relevant data for empirical analyses, criteria checks need to be done for each database to ensure that the the data obtained meet the requirements specifically established for the research questions proposed in this thesis. This assessment process is described in the Section 3.4.

3.4. Assessment of available databases

Six database sources with carbon emissions data available were introduced in the previous section and the information on each database is summarised in Table 3.5. This section presents the assessment process of examining each database and details the selection criteria and process of determining the most suitable carbon database for the empirical investigation designed in the following chapters. Each database is assessed on the basis of two main aspects: the first concerns the scope of the database and the second concerns the method adopted by the database in compiling its company-level carbon data.

3.4.1. Assessment of scope

The databases are first assessed by their scope, which could determine not only the scale of the empirical analyses to be conducted, but also the relevance of the results produced. The scope comprises three assessment criteria, which are coverage in terms of geography, the

35 http://www.southpolecarbon.com/solutions/finance_solutions/ghg_emissions.

coverage in terms of time, and level of reported data; other relevant information is discussed when appropriate.

The coverage of the database concerns the amount of data that are available to be used to construct the sample dataset for the analysis. Six out of seven databases announce an extensive global coverage of company carbon/GHG emissions data, while the EU ETS Company Database provide by Carbon Market Data has a specific European coverage, which is the minimum requirement to be met. It should be noted that as a carbon data provider, Carbon Market Data has a comprehensive coverage of global carbon data, and chooses the EU ETS database, the RGGI database, and the CDM-JI database[36].

In terms of length of time covered, CDP's climate change programme has the longest coverage. However, it should be noted the spatial coverage of CDP varies substantially through time progresses. The EU ETS Database of Carbon Market Data covers eight years which spans two separate trading periods (2005–2012); only the first six years (2005–2010) of data are used in this thesis after considering the state of the EUA market during the last two years of the second phase. The last two years of EU ETS coincided with the period that saw '[t]he marked reduction of prices in the second half of 2011 to levels below € 10' (EC, 2012: 5), which led commentators to doubt the functionality of the market. For instance, The Economist considered that ETS allowances will remain below the level of junk bonds (Economist, 2013). The average price of spot contracts during 2011–2012 was marginally over the €10 mark, at €10.08,[37] which is only 1/10 of the penalty for failing to surrender one unit of EUA. Hence, the choice of 2005–2010 for the EU ETS scheme as the sample period appears reasonable, as this represents the period during which emissions allowances prices were not criticised for their functionality. The CARMA database, however, has a relatively limited coverage of two individual years, which restrict the types of analyses that could be done.

36 A full list of Carbon Market Data products can be seen at https://www.carbonmarketdata.com/en/products/world-ets-database/presentation.

37 Source: European Energy Exchange EUA daily futures closing price.

Table 3.5 An analysis of carbon databases

DATABASE	METHOD		SCOPE		
	Regulated?	Source / Accuracy / Verification	Coverage		Reporting Level
			Spatial	Temporal	
CDP – Climate Change Programme	Not regulated	Data is collected from responses to CDP questionnaires from invited companies, of which some claim to have been verified by third parties against a verification fee (CDP, 2013a)	Global	2000–present	Company-level; CDP does not verify the information in any company response
CDP – Carbon Action Initiatives	Not regulated	Data is collected from responses to self- designed questionnaires from invited companies; the focus of the project appears to be emissions reduction actions (CDP, 2013a, 2013b)	Global	2011–present	Company-level; CDP does not verify the information in any company response
EU ETS Database – Carbon Market Data	Mandatory reporting to the European Commission	Data is aggregated from the EUTL; calculation, reportin, and verification requirements of reporting emissions are specified in EC (2003a, 2004a, 2007a)	28 EU member states plus 3 EEA countries	2005–present	Company-level; reporting verified CO_2e emissions; subscription required
Carbon Monitoring Action	Not regulated	Data is compiled from original reports, various organisations, and internal statistical model, see Ummel (2012)	Global	2004, 2009	Company/Plant; reporting CO_2 emissions (tonnes); Publicly available

ASSET4 ESG – Thomson Reuters	Not regulated	Data is collected from publicly available company reports; estimated figures are produced by self-constructed models for non-reporting companies	Global (3,400+ companies)	2009–present	Company; reporting CO_2e emissions; Subscription required; CDP data partner
Bloomberg	Not regulated	Data is collected from company reports or CDP responses	Global	2009–present	Company-level; emissions of scopes 1 and 2 plus supply chain emissions; subscription
Natural Capital Metrics – Trucost	Not regulated	Data is collected from company reports, CDP responses, and direct engagement with companies	Global	Up to 10 years historical	Company; emissions of all scopes in GHG Protocol; subscription required
South Pole Carbon	Not regulated	Database combines self-reported GHG emissions data with plausibility checks and approximated data for non-reporting companies	Global	2005–present	Company; scope 1 and scope 2 emissions; subscription required

This table analyses carbon emissions databases from two aspects: the methodology undertaken in establishing the database and the scope of the database. The names / providers of the databases are listed in the first column from the left. In the method section, the first column states the regulation status of the carbon emissions data, and the second column explains how data is obtained and levels of verification. In the scope section, the first column describes the geographic coverage of the database, the second column shows the length of time coverage, the third column shows what level of carbon emissions has been reported, and the fourth column contains other information of relevance for the empirical analyses in this thesis. The table is based on the following sources of database information: CDP-Carbon Disclosure Project (https://www.cdp.net/en-US/Results/Pages/All-Investor-Reports.aspx; https://www.cdp.net/Documents/Guidance/CDP-2013-Scoring-Methodology.pdf); Carbon Market Data (https://www.carbonmarketdata.com/en/products/world-ets-database/eu-ets); Carbon Monitoring Action (http://carma.org/blog/about/faq/); Asset4 (http://cdn1.im.thomsonreuters.com/wp-content/uploads/2012/04/ASSET4-ESG-Data-Factsheet.pdf) (http://www.csrwire.com/press_releases/13695-ASSET4-Carbon-Data-Estimates-Available-Now); Bloomberg terminal; Trucost (http://www.trucost.com/_uploads/Academic%20pages/ Trucost%20Academic%20Services.pdf) (http://www.trucost.com/publications); and South Pole Carbon (http://www.southpolecarbon.com/solutions/finance_solutions/ ghg_emissions).

The reporting level shows whether the data are ready to be used or need further processing, which eventually affects the efficiency of conducting the analyses. All databases provide company-level carbon emissions data, and the CARMA database additionally has installation and national-level data available. In terms of the level of carbon reported, all databases except one appear relatively inconsistent, as different scopes of emissions are measured and reported. The one exception is the EU ETS Company Database. The other information mainly concerns the accessibility and costs of the database. Most CDP reports, such as the climate change reports of S&P500 and Global 500 are accessible free of charge online; however the full Carbon Action Initiate reports are provided for signatory access only. The CARMA database is also freely available while the other databases require paid subscriptions. Three private providers, including Asset4 ESG, Bloomberg, and Trucost are data partners of the CDP, which indicate that a certain proportion of the company data of these providers may be of the same origin, with inconsistent verification practices.

3.4.2. Assessment of the method underlying the database

The method adopted by the database plays the most crucial role in directly shaping the quality of the data, which itself essentially influences the empirical analysis and the relevance of the empirical finding. Thus, the databases need also to be assessed by the method they adopt, which comprises two assessment criteria.

The first aspect concerns whether the carbon emissions data produced and reported is on a mandatory basis. Mandatory reporting is rated higher in the assessment process as it ensures a higher degree of scrutiny and reduces any uncertainty over the creditability of the reporting quality (DEFRA, 2012; Erion, 2009; Matsumura *et al*., 2014). Empirical evidence provided by Kim and Lyon (2011) indicates that the flexibility in voluntary reporting programmes can considerably compromise the creditability and effectiveness of the results. Other concerns about non-regulated carbon emissions reporting have also been discussed in Section 3.2 and it is interesting to compare carbon with financial reporting. As of 2005, the European Union requires all listed companies to prepare their financial reports in accordance with International Financial Reporting Standards adopted by International Accounting Standards Board (IASB). This is to enhance the confidence in international financial markets as well as to offer better protection for investors (EC, 2002). Reports prepared under the same standards can more easily be compared and can be utilised to produce more meaningful analyses (Sullivan, 2006). While carbon reporting is nowhere near the level of these procedures for financial accounting, the carbon accounting and reporting issue has raised considerable concern and become more urgent since the development of the emissions trading scheme in Europe (Bebbington and Larrinaga-Gonzalez, 2008). The UK has become the first country in the European community to impose compulsory disclosure requirements for GHG emissions levels for the entire organisation, which came into force in April 2013 and was targeted at businesses listed on the main market of London Stock Exchange. The consultation response from businesses and individual has been positive on the implications of a compulsory measure, as it can increase the transparency for companies and provide a single consistent standard (DEFRA, 2012).

Based on the survey of all databases, the EU ETS Database appears the only one which exclusively offers regulated carbon emissions data. The CDP is evidently a voluntary-based reporting portal which requests, collects, and organises the data reported by the voluntarily responding companies. The other databases do not seem to distinguish between regulated and non-regulated carbon emissions data.

The second criterion concerns the sources of data, the accuracy of the data points, and their reliability, which is judged by the level of verification of the data reported. The source of data concerns whether the final ‘data product’ is in its original state or has been processed by certain methods. Reported data is preferred in terms of accuracy over estimated data produced by the provider’s own estimation models, while independent verification and assurance are also value-added to the overall quality of the carbons emission data. CDP relies solely on companies’ responses to their questionnaire to obtain the GHG emissions data. The methodologies of GHG inventory calculation and measurement, and the verification of reported data are determined by the responding companies rather than CDP, which can cause difficulties in making consistent comparisons among companies. The EU ETS Database of Carbon Market Data sources installation-level data from the EUTL and produces aggregated-level company data, for which no estimation is involved. The emissions data reported by each installation to the EUTL is subject to the principles and guidelines specified in ETS Directive 2003/87/EC and related European Commission documents (EC, 2003a, 2004a, 2007a). This ensures that the reported data of companies is produced under the same standards and can be consistently compared.

The other databases adopt similar approaches to producing their finished data points, which involve both collecting self-reported data and producing estimated figures for non-reporting companies. The CARMA database makes its methodology more clear than others, specifying that the compilation of its database involves collecting carbon data for installations and companies from various sources, including original reports and governmental agencies, in particular the environmental department. It also incorporates commercial databases, and data from international organisations, such as the IEA, in conjunction with its own statistical models for non-reporting facilities and companies (Ummel, 2012).

It should be noted that essentially these databases are assessed on the basis of meeting the requirements of the analyses planned, and thus the assessment criteria are made on a customised, qualitative basis and do not necessarily reflect the absolute quality or value of the specific database. Overall, Carbon Market Data provides company-level data points with sufficient geographical and temporal coverage as well as the assured level of verification, which meets all the requirements set for the empirical analyses. Most importantly, the emissions data from the EU ETS Database is produced within a regulated context, which provides a solid base for the empirical analyses to be conducted.

3.5 Comparative and descriptive statistics for Carbon Market Data

This section provides a numerical analysis concerning the features of the database selected after the assessment process of Section 3.4. As concluded there, the EU ETS Company Database provided by the Carbon Market Data seems the most suitable option for the analyses in this thesis, given the criteria checks for each database's capacity. Carbon Market Data is chosen is for its EU ETS specialisation, which provides a good coverage of firm-level allowances and emissions data for all trading periods. To the best of the author's knowledge, Carbon Market Data is currently the data provider with exclusive aggregate-level data that is sourced directly from the central-administrated EUTL of the EU ETS. The reliability and comparability of data is assured for the data are submitted to the EUTL following the standards and guidelines established by European Commission. The detailed presentation of the Carbon Market Data is given in this section, and the distinct features of the EU ETS-based database are also analysed.

It should be kept in mind that the EU ETS is unique for its multi-sectoral coverage, in comparison with other ETSs such as the US SO_2, and the Australian NSW Greenhouse Gas Reduction Scheme.[38] A closer look at the companies' distribution and allowances allocation patterns across different industrial activities of the database could reveal the most emissions intensive sectors, as well as which industry is expected to experience more impacts than others and could become the main players in the European carbon market.

As described in Section 3.3.1, the Carbon Market Data company database contains 887 companies regulated under EU ETS. These companies account for more than 90% on average of the allowances issued in the entire ETS. The first feature of the database is the vast differences in scale in terms of the number of companies covered by the ETS , which is revealed by the number of installations owned by a single company. The number of installations owned by one company ranges from 1 to 656, with a mean of 9.5 and a standard deviation of 33. It should be noted that the number of installations owned serves as a proximate indicator as EU ETS currently excludes installations with lower emissions intensity.

Another feature revealed in the database is that the firm-level allowances allocation shows a considerable degree of concentration, which is also demonstrated in Trotignon and Delbosc (2008). The overall cap, which is the amount of allowances approved and issued to the regulated firms, together with the average annual cap, are shown in the Table 3.6 below. The Phase 2 sees a more stringent emissions restriction, as expected, than Phase 1 with a 6.5% reduction in annual cap.

38 The scheme started in 2003 and has since been closed.

Table 3.6 Allowances distribution within the EU ETS Database

Phase (1)	**Emissions Cap**		
	Total (2)	**Annual average (3)**	**Annual average per firm (4)**
Phase 1	6,321,069,007	2,107,023,002	2,375,449
Phase 2	9,845,746,393	1,969,149,279	2,220,010

This table shows the allowances distribution within the database companies for separate trading periods in units of EUA. The emissions cap is determined by the aggregated amount of allowances allocated in each National Allocation Plan (NAP). Column (2) shows the Emissions Cap Total, which is the total allowances allocated to database companies in Phase 1 (Phase 2). Column (3) shows the Cap Annual Average, which is the average allowances allocated to database companies each year in Phase 1(Phase 2). Column (4) shows the Cap Average per company, which is the average annual allowances allocation of each company in Phase 1 (Phase 2).

Table 3.7 shows the company distribution across different operating activities[39] along with the proportion of the allowances allocation each activity segment receives in relation to the entire database. The four largest sectors, which total 612 firms, account on average for 90% of the allowances issued through the two phases of the EU ETS. While the power and heat activity segment receives nearly 7% fewer allowances in Phase 2 than in Phase 1, the other three sectors see a 2% increase in the allowances received.

A closer look at the biggest emitting segment, the power & heat companies, reveals a staggering level of allowance allocation concentration, as seen in Table 3.8. The power & heat sector, which comprises large electricity producers, predictably accounts for the largest segment of allowances issued within the trading scheme. The allowances' allocation concentration can also be seen within the sector, as the analysis below reveals that the top 100 firms within the 273 firm-strong power sector account for more than 90% of the overall sectoral allowances allocation, and on average more than 50% of the total allowances allocated to the participating firms in the database.

39 The activity refers to the installations' operating activity for which they are regulated by Directive 2003/87/EC. The activity type is defined in Annex I of the ETS Directive (EC, 2003a). They are not equivalent to the commonly used equity index sector classification.

Table 3.7 Database overview at activity level

Activity (1)	**Company Counts (2)**	**% of Total Companies (3)**	**% of Allowances in Phase 1 (4)**	**% of Allowances in Phase 2 (5)**
Power & heat	271	30.55%	60.935%	53.771%
Iron & steel	157	17.70%	10.216%	12.418%
Oil & gas	96	10.82%	10.598%	12.641%
Cement & lime	88	9.92%	9.789%	11.62%
Others	69	6.99%	1.404%	1.56%
Chemicals	45	5.07%	3.345%	4.125%
Pulp & paper	41	4.62%	1.324%	1.278%
Food & drinks	29	3.27%	0.662%	0.642%
Glass	20	2.25%	0.717%	0.897%
Motor industry	20	2.25%	0.275%	0.265%
Pharmaceutical	10	1.13%	0.056%	0.062%
Bricks & ceramics	9	1.01%	0.131%	0.159%
Coke ovens	9	1.01%	0.165%	0.158%
Aluminium	6	0.68%	0.261%	0.261%
Mining	6	0.68%	0.109%	0.129%
Waste management	4	0.45%	0.001%	0.001%
Water utilities	4	0.45%	0.003%	0.004%
Education	3	0.34%	0.010%	0.007%
Total	887		*92% of total EU ETS coverage	*89% of total EU ETS coverage

This table provides information on company and allowances distribution within the database at activity level. Column (1) lists the activities for which each installation is regulated by the ETS Directive. Column (2) counts the number of companies that own installations of specific activity in the database. Column (3) shows the percentage count of a specific activity in terms of the number of companies relative to the total companies in the database. Columns (4) and (5) show the percentage of allowances allocated to the specific activity in relation to total allowances in the database in Phase 1 and Phase 2, respectively. The activity 'Others' refers to companies which are not subject to ETS regulation but choose to opt-in the trading scheme.

Table 3.8. Firm-level allowances allocation within Power & Heat activity segment

Firms (1)	% of allowances allocated to all power and heat companies		% of allowances allocation to all companies	
	PHASE 1 (2)	PHASE 2 (3)	PHASE 1 (4)	PHASE 2 (5)
Top 100	93.20%	90.62%	56.79%	48.71%
Top 133	96.260%	93.83%	58.660%	50.44%
Total 271	100%	100%	60.94%	53.77%

This table presents the concentration of the allowances allocation within power & heat activity operating firms. Columns (2) and (3) show the % of allowances received by the Top 100 and Top 133 companies in relation to total allowances distributed to power & heat companies in Phase 1 and Phase 2, respectively. Columns (4) and (5) show the % of allowances received by Top 100, Top 133 power and heat companies in relation to total allowances distributed to the whole database in Phase 1 and Phase 2, respectively.

Table 3.9 provides the firm-level allowances allocation for the top emissions intensive firms, most of which predictably belong to the power & heat sector. This analysis can show more clearly the degree of allowances allocation concentration analysed similarly in Trotignon and Delbosc (2008). In addition, the average annual cap for each of the top 6 firms is also calculated for comparison with the average annual cap for firms within the database. The result that the top 6 firms account for on average a quarter of the total allowances issued within the database show the extreme emission intensity of certain sectors and large-scale companies. One implication that can be drawn is these emissions intensive firms would be expected to influence the demand side for allowances.

Table 3.9 Allowances allocation analysis in top 6 firms

			Phase 1			Phase 2		
Company (1)	**Activity (2)**	**Number of Installations (3)**	**Allowance allocation % (4)**	**Firm-specific annual cap (5)**	**Position to Avg. cap (6)**	**Allowance allocation % (7)**	**Firm-specific annual cap (8)**	**Position to Avg. cap (9)**
RWE	Power & Heat	131	7.15%	150,610,811	6,340.0%	4.56%	89,862,866	4,048.0%
E.ON	Power & Heat	266	4.91%	103,539,682	4,359.0%	3.92%	77,189,617	3,477.0%
Vattenfall	Power & Heat	161	4.47%	94,223,472	3,967.0%	3.08%	60,622,850	2,731.0%
ArcelorMittal	Iron & Steel	87	4.12%	86,737,124	3,651.0%	4.45%	87,637,398	3,948.0%
Enel	Power & Heat	78	3.85%	81,202,059	3,418.0%	3.71%	73,013,806	3,289.0%
EDF	Power & Heat	656	3.59%	75,739,032	3,188.0%	3.07%	60,517,758	2,726.0%
Sub-total	**1379**		**28.09%**			**22.79%**		

This table presents the concentration of the allowances allocation in large companies that each received more than 3 % of all available allowances in both periods in the whole database. The cut-off rate in relation to total allowances is determined in a similar manner as seen in Trotignon and Delbosc (2008). Column (1) lists company names. Column (2) indicates which activity the company mainly involves. Column (3) shows the number of installations owned by the company. Columns (4) and (7) show the % of allowances the company accounts for in relation to the total allowances in Phase 1 and Phase 2, respectively. Columns (5) and (8) indicate the firm-specific annual cap and the position of the average cap in all database companies for Phase 1. Columns (6) and (9) show the equivalent for Phase 2. Annual cap is the average amount of allowances allocated to the firm each year during the respective phase. Position to average cap is calculated by the ratio of 'firm-specific annual cap' to 'average annual cap per firm of the whole database', to indicate the relative position of the firm-specific allowances allocation

3.6 The price trend in the EUA market[40][41]

Another key element in the overall dataset used in this thesis is naturally the EU emissions allowances (EUA) price. The EUA price will serve as one of the explanatory variables that directly captures the relationship between the stock and carbon market and reveals to what extent the variation in the stock prices of ETS-exposed firms is associated with that of EUA prices. The implementation of distinct phases of EU ETS results in an inevitable gap between Phase 1 and Phase 2, especially in terms of the EUA price trend. This section presents the trends in EUA prices and trading activities from the beginning to the recent state of the EUA market.

- *The supplementary commitment period (2005–2007)*

The Phase 1 of EU ETS has been largely characterised by uncertainty, which was reflected in two price shocks through the three years of trading. The EUA market experienced rapid growth after the launch of EU ETS, with 3.5 times as many allowances traded in the first three months of 2005 as were traded in the whole of 2004. The demonstrative trades in EUAs had been carried out in 2003, with an estimated trading volume of 650,000 tCO_{2e} in 2003 and 9 $MtCO_{2e}$ in 2004, respectively. The overall value of the global carbon market summed to over 10 billion USD in 2005, among which 8.2 billion USD worth of EUAs was traded. The amount of carbon dioxide equivalent (CO_{2e}) traded in EU ETS was 322 million tonnes, a forty-fold increase over the volume of previous years (The World Bank, 2005, 2006). The EUA unit price stayed below €10 for the first 3 months in 2005, but it rose to nearly €30 in the same year. The demand for EUA during this period was fairly uncertain and there was an imbalance between potential buyers and suppliers in the market. The EUA price remained steadily above €20 before April 2006 without drastic fluctuation (The World Bank, 2006, 2007). As the demand for allowances for compliance remained at a certain level, this was not beyond expectations (Ellerman *et al*., 2010: 141).

40 Data on trend analysis is obtained from the annual carbon market report published by the World Bank carbon finance unit and Tendances Carbone, a montly bulletin specialising in European carbon prices in partnership with CLIMPACT METNEXT.

41. The EUA price trends analysis in this section benefits largely from de Perthuis in Ellerman *et a*l. (2010) and Ellerman and Joskow (2008) as well as The World Bank's annual global carbon market reports.

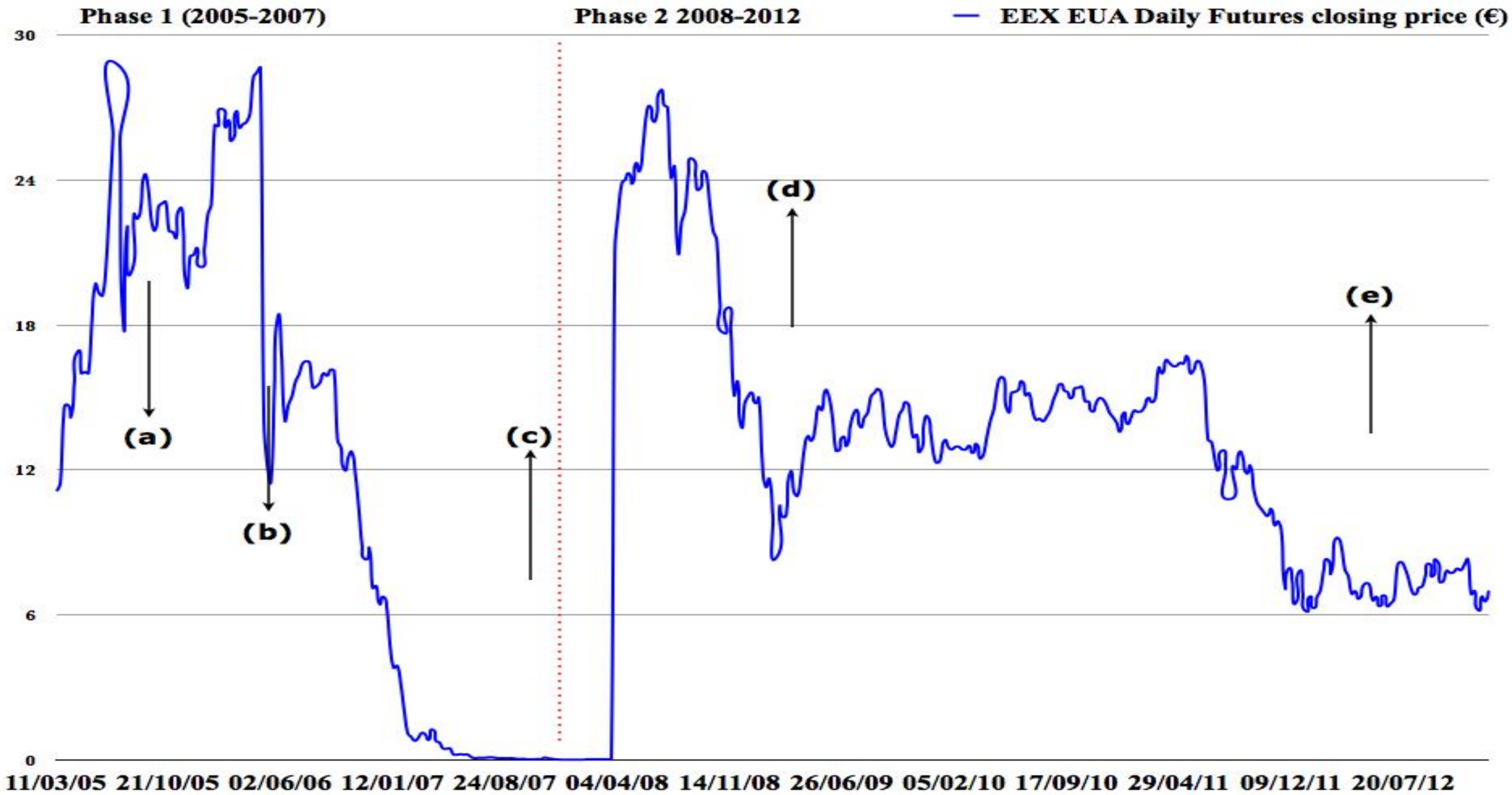


Figure 3.1 The price trend of EU allowances, 2005–2012.
Source: European Energy Exchange's EUA daily futures (spots) closing price (extracted from DataStream).

The EUA price dropped drastically to €10, one-third of its highest price, following the submission of installation compliance information in April 2006, as the information revealed a clearly overall long position in allowances for the ETS sectors. The expectation of demand and supply was quickly adjusted during this period of time, as the demand for phase 1 allowance was no longer large. This was characterised as the ‘information shock’ (Ellerman *et al*., 2010: 141). The price of Phase 1 allowances saw a mild rebound after the information shock and remained around the €15 mark during this stage until October 2006, before entering the last year of Phase 1. Trading for Phase 1 allowances came to an end in 2007 as the completion of Phase 1 approached, as marked out by point (c) in Figure 3.1. The compliance data and allowances surrendered made it clear that a net-long position in allowances for Phase 1 was certain. The value of spot and futures contracts in Phase 1 allowances ended near zero due to the banking restrictions between different trading periods (Alberola and Chevallier, 2009).

- *The first commitment period (2008–2012)*

The second trading period of EU ETS coincides with the EU commitment period of the Kyoto Protocol. The European Union set a target of 8% emissions reduction compared with 1990 emissions level, from 2008 to 2012 and therefore a more stringent cap than Phase 1 was imposed (Egenhofer, 2007). The Phase 2 EUA opened in 2008 with the price slightly higher than €20 and maintained a slow but steady climb until it reached its peak in July 2008 at €29. However, the price level was not sustained for long as the global economy faced a substantial ‘cool-down’ period (marked as (d) in Figure 3.1). The global financial crisis, associated largely with the US sub-prime mortgage, started to have a global impact after mid-2007 and led to the global financial crisis, which lasted nearly two years. The financial crisis ultimately led to an economic recession and had a huge impact on economic conditions in several European countries. These inevitably affected the demand side of emissions allowances through the impact on industries and led to a downward movement of EUA prices (The World Bank, 2009).

The allowances price experienced a continuous decline from the summer of 2008 and was down to below €10 in February 2009. This could be attributed to constantly low energy prices and deteriorating economic conditions and, as a result, decreasing industrial output affected the demand for emissions allowances. In addition, firms with more free allowances available sought to cash in by selling EUA on the market, which boosted supply and thus depressed allowances prices. This has been a typical response in industrial sectors (The World Bank, 2010). The price of allowances appeared to stabilise after the crisis and bounced back in 2009. The price has remained steadily within the range of €10 and €16 since March 2009 and ended 2009 above €13.

The spring of 2010 saw the rebound in the EUA price, reaching above €15, which could mainly be attributed to the slight easing in the global financial crisis. Nevertheless, this particular period of time was still characterised by great volatility due to global political and economic turbulence. The EUA trading volume experienced a marginal growth while the global carbon market overall shrank by $2 billion (The World Bank, 2011; cdcClimat, 2010: No.45–No.53). The trading volume continued to grow in 2011 though the average price of EUA dropped nearly 13%, ending the year at €13, the same price level at the beginning of the financial crisis. The World Bank annual report suggests that strong trading activities despite the reducing verified emissions and declining prices can be due to hedging against future restrictions, and strategic considerations on portfolio adjustment as well as arbitraging. However, opinions remain less optimistic on the demand side of allowances, due to the current weak industrial recovery. Additional factors that need to be accounted for concerning EUA development include the high level of allowances supply outside Europe, as well as growing national investment in renewable energy capacity in recent years. As marked at (e) in Figure 3.1, the EUA market began to see the end of the second trading period from mid-2011, with the monthly average price dropping more than 17% in July and never exceeding the €10 mark since October 2011 (The World Bank, 2012).

4 The stock price performance of EU's emission trading-exposed firms

4.1 Introduction

The EU ETS was implemented by the European Union as one of its key climate policies. It aimed to alleviate the damage of climate change, environmentally and economically. It is suggested that the carbon emissions reduction can be more cost-efficient through emissions trading (Ellerman and Decaux, 1998; Labatt and White, 2007; Brohé *et al*., 2009; Böhringer *et al*., 2009; EC, 2010). The scale and coverage of the EU ETS are groundbreaking. Despite the EU ETS being not the first mandatory emissions trading scheme, it is by now the largest scheme in the global carbon market and it is still expanding (Skjærseth and Wettestad, 2009; The World Bank, 2012, 2011).

The main purpose of this chapter is to examine the effect of the planning and implementation of the EU ETS on the stock market performance of directly exposed firms. The basic expectation is that the planning and implementation of the EU ETS would have a negative effect on the share price performance of such firms, as it would force them to pay, directly or indirectly, for their emissions. Hence, compliance with the ETS regulation is expected to cost the participating firms more financial resources than a business-as-usual (BAU) scenario without a direct economic cost for carbon (Baumert *et al*., 2003; Burtraw *et al*., 2001; Diltz, 2002; Laurikka and Koljonen, 2006; Pope and Owen, 2009; Linn, 2010; Chapple *et al*., 2013). In other words, the companies used to emit CO_2 and other GHGs at no financial cost, and so externalised the costs on society. However, the right to emit more than their given allowances needs to be purchased at extra cost after the implementation of the EU ETS, which forces the firms to internalise these costs. If this chapter found no significant negative impact of the EU ETS on stock market performance, the firms, and eventually their shareholders, would not internalise sufficient costs to justify a significant reduction in shareholder value. This would imply one possibility, that neither the firm nor its investors would financially contribute in a meaningful way to climate change mitigation, though it is argued that the limited contribution and internalised costs of firms would still be more cost-effective eventually than being non-responsive towards climate change (Stern, 2006, 2008b; Guo *et al*., 2006; EC, 2009c). More specifically, by analysing whether there is a negative impact of the EU ETS on share price performance and what extent this effect might have, this chapter can relate the overall shareholder value reduction of EU ETS-regulated firms to the expected cost of climate change mitigation, to gauge the degree to which these firms and their shareholders contribute financially. Certainly, another possibility, that the investors have not fully realised and taken into consideration the ETS-related costs, cannot be ruled out. This chapter makes a relatively novel attempt to explore this aspect by incorporating the criterion that distinguishes the ETS-exposed firms with potentially lower ETS-related costs from the firms with potentially higher costs in the second part of the analysis.

Previous empirical studies of the relationship between emissions-related regulation and the stock market have largely focused on the SO_2 market operating in certain regions of the US from 1995 until 2011,[42] to investigate the impact of the regulation on stock prices (Hughes, 2000; Diltz, 2002; Kahn and Knittel, 2003), or they focused on small sub-samples of all listed firms participating in the EU ETS (Oberndorfer, 2009; Veith *et al*., 2009; Knight, 2011; Mo *et al*., 2012). They have all been inconclusive, as some find no carbon emissions induced performance penalty (Oberndorfer, 2009; Veith *et al*., 2009) while others identify evidence of a negative impact on firms' equity prices (Mo *et al*., 2012; Diltz, 2002)[43]. This range of these findings from the previous empirical-based EU ETS studies indicates that the allowances market is not yet integrated as a determinant relevant from the equity market perspective. Besides the small datasets of previous EU ETS studies, another explanation for this range in the previous findings, is the fact that the carbon market created under the EU ETS is still an emerging market with the first phase of EU ETS being labelled a trial phase (Betz and Sato, 2006; Ellerman and Buchner, 2007; Convery *et al*., 2008). In this trial phase, the EUA price failed to sustain a level necessary to promote a low-carbon economy, and collapsed several times due to regulatory uncertainties as well as substantial reductions in demand in the context of the economic crisis (Alberola *et al*., 2008; Abadie and Chamorro, 2008; Hoffmann, 2007; Declercq *et al*., 2011; Creti *et al*., 2012).

42 It was replaced by the Cross-State Air Pollution Rule. Details available at www.epa.gov/crossstaterule/.

43 Oberndorfer (2009) does not find significant results in his time series market models; however, he finds significantly positive though relatively small intercepts in the pooled regressions, which have considerably lower explanatory power despite them artificially increasing the degree of freedom.

To thoroughly examine the effect of the planning and implementation of the EU ETS on the stock market performance of the regulated firms, the analyses of this chapter comprise two parts: the first tests the impact of the EU ETS on the stock market performance of participating firms. This analysis intends to reveal whether the equity prices of ETS-exposed firms in aggregate are influenced in the expected negative or the unexpected positive direction at any statistically significant level. The estimation result shows that the firms regulated by the EU ETS display the expected underperformance at the highest statistical significance level, but only in the period 2001–2004 during which the EU ETS was proposed and in development but not yet launched (Ellerman *et al*., 2010; EC, 2003b). Once the EU ETS began in 2005 regulated firms did not experience any subsequent negative effects on their stock market performance. These results are in line with those previous studies that observed no performance penalty for regulated firms during the EU ETS (Oberndorfer, 2009; Veith *et al*., 2009), as the performance penalty appears to have arrived ex ante in terms of reduced investor expectations (Chapple *et al*., 2013; Hughes, 2000).

The second part takes the investigation one step further, by testing whether the emissions status of participating firms influences the EU ETS effect on their stock return performance. For this purpose, access to a so far unexplored database, Carbon Market Data's ETS Company Database, was bought for the years 2005–2010. The results of this second empirical analysis are intended to reveal whether the financial performance of the participating firms is associated with their emissions management performance, as indicated by their emission-to-cap status. The emission-to-cap status is based on the difference between the firm's verified emissions and its allocated European Union Allowances (EUA). A negative sign indicates an under-emitting status, while a positive sign indicates an over-emitting one.[44]

The results show distinct differences in the performance of over-emitting firms and under-emitting firms. Over-emitting firms underperform substantially in Phase 2 of the EU ETS but do not seem endure a shareholder value loss in the first 'trial' phase. In contrast, firms with surplus allowances even benefit slightly during the entire EU ETS sample period.

44 Both concepts, verified emissions and EUA, are widely discussed in the EU ETS literature (i.e., Alberola *et al*., 2008; Hintermann, 2010) though have not yet been related to each other supposedly due to a lack of accessible and reliable data.

These results highlight the fact that the corporate management of carbon can have a material impact on a firm's stock market performance in the expected direction. In other words, caring for carbon emissions reductions is a shareholder value driver in the EU ETS context. This finding confirms those seeing potential positive effects of the EU ETS for some firms (Sijm *et al*., 2006b; Zachmann and von Hirschhausen, 2008). It also generally indicates that there can be a business case for corporate environmental responsibility (Klassen and McLaughlin, 1996; Cohen *et al*., 1997; Cormier and Magnan, 1997). The substantial discrepancy between over-emitting and under-emitting firms also highlights the fact that during the EU ETS trading period it is necessary to go beyond analysing regulated firms (Oberndorfer, 2009; Veith *et al*., 2009; Mo *et al*., 2012) and study reliable data on corporate emissions performance, as done in this chapter.

There are two main contributions of this chapter. First, the size and scope of the dataset used in this chapter have been substantially extended compared with previous empirical-based studies researching this particular topic (by far the largest in terms of the number of ETS-exposed firms examined). The sample dataset comprises 153 European listed firms, which is at least seven times bigger than the samples used in previous studies. The expanded dataset allows an understanding of how major ETS-exposed firms, rather than being limited to electricity firms, are valued by the stock market in a broader context. More insights into how these firms are perceived in terms of their profit prospects are gained from this chapter. The integration of firm-level verified emissions data from the EU ETS for six years also advances previous studies, by extending the length of the sample period.

The remainder of the chapter is structured as follows: Section 45.2 provides the background to the empirical analyses proposed, which includes a review of the relevant literature and establishing the research questions. Methods, model specifications, and data are presented in Section 45.3. The results of the estimations, and the discussion of major findings and implications from investors' and policy makers' points of view follow in Section 45.4. Section 45.5 concludes and discusses the limitations of the analysis in this chapter, followed by proposing future research opportunities.

4.2 Background and research questions

This section provides an overview by reviewing the literature that specifically explores how ETS is associated with the stock market, and how regulated firms can be influenced in terms of their value reflected by their share prices. The main question in this chapter is whether the firms that are or will be subject to the mandatory emissions restrictions introduced by the EU ETS experience any significant impact in terms of their stock market performance. The basic expectation is that the planning and implementation of the EU ETS would have a negative effect on the stock market performance of regulated firms, because it requires them to internalise the cost for their pollution. Consequently, compliance with ETS regulation is expected to cost the participating firms considerably more than the BAU scenario before the ETS was proposed and implemented (Laurikka and Koljonen, 2006; Pope and Owen, 2009; Linn, 2010). In other words, the companies that used to emit CO_2 and other GHGs at no cost have had since 2005 to purchase the right to emit more than their given allowances. Furthermore, through the introduction of an ETS, firms are increasingly subject to potential future environmental liabilities and compliance costs (Bushnell *et al*., 2013; Bode, 2006; Hughes, 2000).

However, while the EU ETS is expected to have a negative shareholder value effect for the average regulated firm, there is an argument that the most carbon efficient firms actually have the opportunity to profit from the ETS. This argument rests on the two aspects: first, firms with effective and efficient carbon management might benefit from the ETS as they are more likely to emit under their designated cap and hence possess an allowances surplus. This allowances surplus represents a valuable asset that can lead to a positive shareholder value effect, either through selling the additional allowances or reducing the compliance costs of purchasing extra allowances (Johnston *et al*., 2008). The second aspect is the cost pass-through of firms, which describes the ability of firms to pass the compliance costs, such as for purchasing emissions allowances, to the end consumers. Given that firms receive their allocated amount of allowances for free, in particular during the Phase 1, firms could even profit from the ETS if they passed a cost of carbon through to the consumer which they do not pay themselves (Sijm *et al*., 2006b; Zachmannm and von Hirschhausen, 2008). Hence, while the average firm is expected to have a negative stock market performance as result of the EU ETS, and below average carbon efficient firms are expected to experience an even worse stock market effect, carbon efficient firms may well enhance their shareholder value.

The previous literature on the effects of EU ETS on the stock market has predominantly focused on fairly small sub-samples of all participating listed firms; in particular, four studies that empirically examined the impacts of aspects of the EU's ETS on the share prices of affected companies (Oberndorfer, 2009; Veith *et al.*, 2009; Knight, 2011, Mo *et al.*, 2012). Oberndorfer (2009) conducted the first econometric analysis that specifically investigated the relationship between European carbon price changes and stock returns of twelve selected major energy providers. A capital asset pricing model (CAPM) framework is applied to test the hypothesis that EU allowances price changes affect stock returns in the electricity industry. Utilising the firm-level data of 12 major electricity providers in Europe and aggregating them within an equal-weighted portfolio, Oberndorfer's results provide supportive evidence to the hypothesis at statistically significant levels. This shows that the corporations tested in the analysis during the first phase of EU ETS experienced an increasing shareholder value in the context of allowances price appreciation, while their shareholder value decreased when allowances prices dropped. It could be interpreted that the EU ETS had an impact on the stock market and hence affected the shareholder value of firms covered by the trading scheme.

Veith *et al*. (2009) investigated the capital market response to emission allowances price changes. Using a sample dataset of 22 major firms from the power sector in Europe and the arbitrage pricing theory (APT)-style market model, they find a positive correlation between stock returns and emissions allowances price variation during the period April 2005 to mid-2007, which covers most trading activities of emission allowances during the pilot phase. A very similar finding was made by Knight (2011: 824), who studied a sample size of 19 electricity companies and considered the sample size comparable to similar studies in the literature (Oberndorfer, 2009; Veith *et al*., 2009) based on an extended CAPM model. He found that seven of his nineteen companies saw a significantly positive relationship between EUA price and stock market performance in the first years of EU ETS operations, while only one of these positive coefficients remains in the following year (i.e. the Finish company Fortum).

A more recent study with empirical analyses covering the first five years (2005–2009) of the EU ETS by Mo *et al*. (2012) aimed to measure of the impact of EU ETS on electricity firms in terms of their shareholder value. They relied on the modified multi-factor market model to estimate the sensitivity (beta) of stock returns of 12 electricity firms to allowances price variation. Their findings revealed that the allowances price effect on stock returns changed from Phase 1 to Phase 2. EUA prices appreciation tends to be accompanied by corporate value appreciation in Phase 1, while the opposite is observed in Phase 2. This result is consistent with Oberndorfer (2009), Veith *et al*. (2009), and Knight (2011) regarding Phase 1, which indicates that the companies seemed on average to have benefitted from EU ETS operations in Phase 1, which counters the policy intention of having the companies internalise their costs of emissions (EC, 2009a).

Support from studies with a maximum sample size of 22 firms, however, cannot really be generalized even when it is consistent, as the sample selection effects can be severe. The results of Mo *et al*. (2012) cannot be confirmed by any other previous studies regarding Phase 2, as none examined this period. It is also very interesting that none of the previous studies investigated if investor expectations in the period between the EU ETS proposal and its launch affected stock price performance, though Hughes (2000), Diltz (2002), and Chapple *et al*. (2013) studied a similar question in the US and Australian context. The reason for this lack of interest in the pre EU ETS period might result from these studies focusing on the effect of emissions prices on stock market performance rather than the effect of being regulated by the EU ETS itself, since emissions prices were only available after the launch of the EU ETS, whereas regulated firms could be examined from the proposal of the EU ETS (Skjærseth and Wettestad, 2009). In light of this, this chapter poses the following two research questions: (i) How does the EU ETS impact stock market performance of regulated firms on aggregate? (ii) How does the impact of the EU ETS on stock market performance differ across the pre-EU ETS period (2001–2004), Phase 1 (2005–2007), and Phase 2 (2008–end of data sample)?

Studying the stock market performances of regulated firms during the pre-EU ETS period in particular might be rather promising, as both Hughes (2000) and Chapple *et al*. (2013) find significant expected stock market performance penalties as a consequence of proposed emissions trading (as a form of environmental regulation) legislation. These results confirm Barth and McNichols' (1994) finding that future environmental liabilities affect share price performance.

However, it is unlikely that the impacts of the EU ETS on corporate stock performance are homogeneous across companies. Johnston *et al*. (2008) study 58 firms in the US SO_2 market from 1995 to 2000 and provide empirical evidence that an emissions permits surplus is related to an increase in the market value of firms. In their view, SO_2 emissions allowances have two elements linked to valuation in equity markets. One is the asset value of the permits, which is realised through selling permits. The other is the real option value, which is related to deferred capital investment. Both elements are expected to generate positive shareholder value. Similarly, Chapple *et al*. (2013) finds that in the context of the proposed Australian ETS among their 58 sample firms, higher levels of carbon intensity significantly reduce shareholder value.

Within the EU ETS, Bushnell *et al*. (2013) conduct an event study of the carbon price crash impact on 25 April 2006 using the daily stock returns of 90 carbon intensive stocks. They that find firms in carbon or electricity intensive industries are hurt the most by the collapse in carbon prices that indicates the ineffectiveness of the trial phase. However, they also find that firms' specific reactions depend substantially on the emissions status of their industries. In industries that are net long in permits, the firms with the most emissions allowances granted to them at no charge experienced the greatest loss as the result of the carbon price crash. Conversely, in industries that are net short of carbon emissions rights, the cleanest firms are hurt more relative to their peers.

Hence, the question arises whether firms with different emissions status experience different impacts on their share prices. If the EU ETS is effective in setting incentives for the reduction of carbon emissions, firms with an allowance surplus should show a better stock market performance than firms with an allowances shortage. Addressing this question enables this chapter to provide empirical evidence on the relevance of firms' carbon exposure and management, a research opportunity raised in Bebbington and Larrinaga-Gonzalez (2008). In light of this, this chapter poses the third research question: (iii) How are EU ETS-exposed firms valued by the stock market when they emit more (over-emitters) or less (under-emitters) than they are allowed to?

4.3 Method and data

This section describes the methods, models, and data utilised in this chapter. The principal research method and estimation models to be applied are described first, followed by the data and variable preparation process, including sample formation and portfolio construction model specification for each analysis to be conducted in the chapter.

4.3.1 Portfolio research

Portfolio research is one of the most commonly applied methods for estimating corporations' stock market performance. It allows the possibility of comparing groups of firms (equities) with specific characteristics and has the advantage that the portfolios can easily be customised according to the need of the research question (Wagner and Wehrmeyer, 2002). As the objective of this chapter is to examine the performance of a group of firms with the characteristic of being subject to the EU ETS, portfolio research is a suitable tool. In addition, portfolio research approach, with its monthly or weekly observation interval, has a much high statistical power and consequently yields more explanatory power than the alternative (i.e., panel) approach. It is unsurprising that many studies have employed this approach to examine the corporate environmental and financial market performance relationship for the strengths mentioned above, such as Cohen *et al*. (1997); Derwall *et al*. (2005); Kempf and Osthoff (2007); Statman and Glushkov (2009).

4.3.2 Model specification

The Fama–French three-factor pricing model, which has been widely applied and empirically tested in the area of equity pricing, is selected as the baseline model. It is reasonable and appropriate that the estimation model used in analyses in this chapter builds on the Fama–French three-factor model, for two reasons. First, the dependent variable in the analyses is the return of a self-constructed equity-based portfolio, and hence an equity pricing model is an appropriate choice. Second, the risk factors in the Fama–French model have been extensively tested and proven robust in providing good explanatory power for average equity returns (Fama and French, 1993, 1996, 2012). Moreover, a momentum-styled factor that controls for fund performance similar to Carhart (1997) is also included in the model to better capture the effect caused by the potential trend towards a strategy that emphasises momentum.

Thus, the variation in portfolio return that is associated with common risk factors, such as size, book-to-market value of firms, and momentum, are adequately controlled for. The Carhart four-factor model can be written as follows:

Eq (4-1)

$$R_{p,t}(ETS) - R_{Riskfree,t} = \alpha + \beta_1 (R_{m,t} - R_{Riskfree,t}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \varepsilon_t$$

where $R_{p,t}(ETS)$ denotes the logged weekly return of an equal-weighted Portfolio (ETS) in excess of the risk-free rate and R_{mt} represents the logged weekly return of the market benchmark proxied by the MSCI Europe Market Index. $R_{riskfree,t}$ is weekly risk-free rate constructed geometrically from the stated rate of the three-month EURIBOR. SMB_t is the return differential between the MSCI Europe Small Cap and the MSCI Europe Large Cap indices, HML_t is the return differential between the MSCI Europe Value and the MSCI Europe Growth indices. The MOM_t is manually adjusted using the difference between the return of the MSCI Europe Momentum Index and R_{mt} multiplied by 2, as a pan-European control factor is more desirable in this case. According to the description of MSCI methodology (MSCI, 2014), the Momentum Index is designed to reflect the performance of the winning stocks. However, the Momentum factor in the Carhart model is expected to capture the difference in performance between winning and losing stocks. Thus the MOM factor used in this chapter is a hand-configured version, which is calculated by 2*(Return of Momentum Index minus Return of Market Index) to better simulate the effect of winners minus losers. ε_t is the error term that captures all unexplained randomness.

Following estimation with the basic three-factor market model, an additional factor that controls for the variation of emissions allowances price, which is intended to measure the firm's exposure to emissions trading, is added to the estimation model. This enables the investigation of the stock market–carbon market linkage while the portfolio performance can be measured more precisely with the variation in carbon allowances prices captured. This analysis is inspired particularly by Oberdorfer (2009) and Veith *et al.* (2009), who add the emissions allowances price factor to a simple market model without controlling for Fama–French factors. They also investigate the relationship between the EUA price and stock returns only for a small sample of electricity firms regulated by EU ETS, whereas this chapter applies the model to a much larger sample across multiple sectors. The second model extends ***Eq (5-1)*** by including the emission allowance price, and can be written as:

Eq (4-2)

$$\boldsymbol{R_{p,t}(ETS) - R_{Riskfree,t} = \alpha + \beta_1\left(R_{m,t} - R_{Riskfree,t}\right) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \beta_5 EUA_t + \varepsilon_t}$$

where EUA_t is the logged emissions allowances price return and all other variables are defined as above. It is constructed using the EUA spot settlement price quoted from the European Energy Exchange (EEX), which offers the most data points starting from late March 2005, and is calculated as:

$$REUA_t = \ln\left(\frac{P_{EUA,t}}{P_{EUA,t-1}}\right)$$

The estimation equation so far allows only the examination of a contemporary relationship between the portfolio return of EU ETS-regulated firms and the allowances price, and it should also be taken into account that the reaction of the stock market to emissions allowances price changes might not be reflected instantly. Hence, a lagged EUA return factor is added to capture this relationship, which could indicate how much of the variation in the examined portfolio return is associated with lagged EUA price changes, a similar factor also controlled for in Mo *et al.*'s (2012) analysis of another small sample of electricity companies. The resulting equation ***Eq (5-3)*** can be written as:

Eq (4-3)

$$\boldsymbol{R_{p,t}(ETS) - R_{Riskfree,t} = \alpha + \beta_1\left(R_{m,t} - R_{Riskfree,t}\right) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \beta_5 EUA_t + \beta_6 EUA_{t-1} + \varepsilon_t}$$

where $REUA_{t-1}$ is the emissions allowances price of the previous week and all remaining variables are defined as above. All three models are analysed for the first phase of the EU

ETS (2005–2007), the second phase of the EU ETS until the end of the available carbon emissions data (2008–2011), and for the period from the proposal of the EU ETS to its launch (2001–2004) (EC, 2003a). The full available EU ETS sample (2005–2010) is also studied.

All financial data have been collected from Datastream. Given the length of the sample period, the observation of a weekly frequency is preferred in this chapter as it avoids the daily data noise while able to provide more than twice the statistical power (i.e., square-root of the degrees of freedom) than the alternative monthly data would. All estimations are conducted using the OLS with a Newey–West estimator, which is intended to manage the potential autocorrelation in error terms (Newey and West, 1987).

4.3.3 Data and sampling preparation

The objective of the analyses in this chapter is to understand the effect of the EU's ETS on stock prices by examining firm-level data, and thus the access to a reliable database is the key to achieving a robust research design that tackles the research questions. Liesen *et al.* (2013) provide evidence that voluntarily reported carbon data are not fully reliable, as about 85% of the 431 European listed corporations studied by them used footnotes to identify the issue that their self-reported carbon data described an insufficient scope of corporate-wide activities. Hence, a database of companies which are subject to mandatory carbon reporting is preferable. The only viable choice when this research project was planned and conducted, Carbon Market Data's EU ETS Company Database, [45] was selected, as explained in detail in Chapter 3.

After the Carbon Market Data's EU ETS Company Database was chosen as the source of company-level data, the data preparation process began with identifying the listed firms to be included in the sample. The full database provided by Carbon Market Data contains 885 firms, including listed and private firms. All firms were checked for their properties via

45 Full description in Chapter 3 Data. CMD sources the official EUTL installation-basis emission data and aggregates them into company-level data.

various sources[46] and listed firms were identified through this process. After checking the data availability through Datastream, 153[47] European listed companies that fulfilled all requirements of the analysis in this chapter were selected to form the principal sample dataset. The primary requirements for a firm to qualify was the accessibility of data on share prices at least for parts of the period from 2005–2010 and domicile in Europe. The focus on European firms ensured that the analysis was done with more precise European benchmarks and was fully in line with previous literature (i.e., Oberndorfer, 2009; Knight, 2011; Mo *et al*, 2012; Veith *et al*., 2009). In terms of sample size, this chapter represents a major improvement compared with the previous literature, as a sample of 153 firms is at least seven times bigger than the samples of each of the previous four papers studying the stock market effects of the EU ETS (Knight, 2011; Mo *et al*., 2012; Oberndorfer, 2009; Veith *et al*., 2009).

Table 4.1 Allowances allocated and emissions of the 153 firms in *Portfolio(ETS)*

Year (1)	Allowance (EUA) (2)	% of Total (3)	Verified Emissions (3)	% of Total (4)
2005	1,047,120,205	43.79	1,045,368,626	44.60
2006	1,029,341,624	43.60	1,052,184,657	44.50
2007	1,055,823,697	43.45	1,089,344,233	44.38
2008	932,366,567	43.52	1,064,557,107	44.56
2009	935,170,264	43.45	932,798,841	44.35
2010	939,481,395	43.36	945,348,694	44.35

The table shows the proportion of allowances and emissions the sample firms account for. Allowances allocated is the 'cap' of regulated firms, verified emissions is the actual amount of emissions produced by regulated firms, % of total is the respective amount relative to the total amount of the entire Carbon Market Data Company Database

Table 4.1 shows that the 153 listed European firms account for over 40% of the allocated allowances and verified emissions covered in the full Carbon Market Data's ETS

46 Companies Research by Financial Times (http://markets.ft.com/research/Markets/Companies-Research), Bloomberg market data (http://www.bloomberg.com/markets/companies/), and Datastream are the sources to check whether the company is listed and for their main listing markets.

47 As this chapter is primarily interested in the stock prices of ETS-exposed firms, only listed companies are included in the sample dataset.

Company Database from which data is sourced. In each year, the listed firms represent a slightly higher percentage of verified emissions than emissions allowances, indicating that they are a little more polluting than the average firm in the database. This is unsurprising as the ETS Directive (EC, 2003b)[48] does indicate that the emissions restriction is imposed on the installations with thermal inputs or capacities exceeding the specified threshold. That is to say, the EU ETS essentially targets the bigger installations that tend to produce higher emissions, which are in general owned by bigger firms. It can be reasonably inferred that the listed firms are on average bigger, and thus more emission intensive, than the non-listed firms, with the differential between being small though consistent.

While the first analysis in this chapter examines the impact of the EU ETS on the stock market performance of exposed firms based on the equal-weighted portfolios of all sample firms, the second analysis attempts to further explore whether the stock market is able to identify the firms which are supposedly facing additional ETS-related costs and price accordingly. This is conducted by forming annually updated equal-weighted portfolios of two sub-groups of the ETS-exposed firms based on their emissions compliance status, a criterion that is most directly related to the ETS regulation and clearly differentiates the firms. The rationale behind this criterion is the firms that produce emissions exceeding their assigned cap will need to acquire additional allowances to comply with the ETS regulation, from which additional costs incur. On the other hand, the firms with a surplus of allowances will be facing no cost or have the opportunity to profit from the allowances, and thus it is expected these firms will not experience any negative impact.

The first sub-group includes those regulated firms that have more verified emissions than their emissions allowances in any given year, which indicates that their emissions status is over their cap, and thus this sub-group portfolio is labelled ***Portfolio(Emissions Over-Cap)***. Similarly, the second sub-group comprises the firms that have fewer verified emissions than their emissions allowances in any given year, and hence have the status of emissions under the cap. This second sub-group portfolio is labelled ***Portfolio(Emissions Under-Cap)***. This allows the investigation of the third question: is the stock market impact of being EU ETS regulated dependent on the emissions status (i.e. verified emissions over-

48 The Annex I of the Directive. The details are documented in Appendix (2-B) in Chapter 2.

cap vs. under-cap) of the regulated firms? The components in each portfolio are updated annually to reflect the new data on verified emissions.

The total number of firms in each portfolio is presented in Table 5.2. It can be noted that the percentage of all regulated firms classified as over-cap increases gradually from 23.2% in 2005 to 30.4% in 2008 but experiences a sharp drop which coincides with the economic crisis in 2008-2009 to only 18.4% although it bounces slightly to 22.3% in 2010.

Table 4.2 The number of firms in portfolios with emission over (under) cap

	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Emission-over-cap	35	38	43	45	27	33
Emission-under-cap	116	113	107	103	121	115
Percentage of over-cap firms in sample	23.2%	25.2%	28.5%	30.4%	18.4%	22.3%

Emission status is determined by the reported verified emissions of each firm relative to its cap, which is made available annually, thus the portfolio constituents are updated annually accordingly. The number of firms for each portfolio during different sample period varies slightly due to accessibility of emission data. Some companies, such as Eastern Sugar, Greencore, Linde, and Valeo appear to drop out from the EU ETS Phase 2.

4.4 Results and discussion

This section presents the estimation results for each of the two major analyses. The first analysis examines the impact of the EU ETS on the stock market returns of regulated firms, while the second analysis investigates the stock market impact on two groups of EU ETS regulated firms with a different net position of allowances, i.e., over-emitting and under-emitting firms. These two analyses are expected to reveal two aspects of interest. First, the stock market impact of the EU ETS on regulated firms estimated by their portfolio performance is discussed. More specifically, the result shows whether there exists an abnormal return of the portfolio that could not be captured by the common risk factors. The second aspect concerns the degree to which the European carbon market and the stock market interact with each other and is revealed by the EUA factor-added models.

4.4.1 Effects of EU ETS on the stock market performance of regulated firms

Table 4.3 summarises the main results of interest from the first analysis of this chapter. The extended regression results are detailed in Tables 4.4–4.6. The main results include the alpha coefficient of the portfolio of EU ETS regulated firms, which can be defined as the portfolio's abnormal performance *vis-à-vis* the benchmark and the standard control factors (e.g., SMB and HML). They also comprise of the coefficients on the concurrent and lagged EUA variables, which indicate the relationship between current and lagged emissions allowances prices and the stock price performance of the EU ETS regulated firms. The alpha coefficient is available for all sample periods while the EUA coefficients are unavailable for the pre-EU ETS phase.

Table 4.3 Summary of *Portfolio(ETS)*'s alpha and coefficients of EUA price factor

Portfolio(ETS)	**2001–2004**	**2001–2011**	**2005–2011**	**2005–2007**	**2008–2011**
Portfolio performance (annualised alpha)	-30.7%***	-7.9%***	-0.77%	3.67%	-4.43%
EUA			-0.001	0.003	-0.001***
EUA(-1)			0	-0.002	0.001**

Portfolio performance is estimated by the constant in the ***Eq (4-1)*** and annualised into the per annum rate. The per annum rate is the aggregate alpha from weekly estimations ($\alpha * 52$). The link to EUA is estimated by the coefficients of EUA and EUA(-1) in ***Eq (4-2)*** and ***Eq (4-3).*** ***, ** and * represents 1%, 5%, and 10% significance levels, respectively.

The first stimulating result displayed in Table 4.3 shows that the firms eventually regulated by the EU ETS experience a statistically and economically significant underperformance during the pre-EU ETS period. This signals that the stock market appears to account for the expected costs of internalising carbon emissions of firms through the EU ETS and down-values their stocks before the EU ETS started. This is in line with the results found by Hughes (2000) and Kahn and Knittle (2003) for the US SO_2 market and Chapple *et al.* (2013) for the announcements of a proposed Australian ETS. Barth and McNichols (1994) also find a similar forward-looking behaviour of stock markets in the context of accounting for potential environmental liabilities of firms. This result thus implies that the EU ETS acted as a meaningful signal towards the internalisation of carbon emissions in stock markets during the pre-EU ETS estimation period.

However, the EU ETS regulated firms do, as an aggregated subject, not perform statistically differently from the benchmark during the entire EU ETS period studied in this chapter or the separate first and second phase sample period. This indicates that no further performance penalty could be found as the result of being regulated by the EU ETS after the initial underperformance during the pre-EU ETS period. This result of no impact of the EU ETS on the stock market performance of the average regulated firm appears in line with the small sample studies of Oberndorfer (2009) and Veith *et al*. (2009), but does not fit Mo *et al*.'s (2012) finding of underperformance in a sample of 12 firms. However, none of these three papers studies the pre-EU ETS period and hence none displays the more detailed finding that this chapter does, which indicates that the expectation of being subject to ETS regulation leads to a substantial underperformance of participating firms while the operations of the EU ETS after its launch does not lead to any further underperformance.

Tables 4.3–4.6 also present another interesting result with respect to the coefficients that indicate the relation between the (lagged) emissions allowances price and the stock market performance of ***Portfolio(ETS)***. As seen in the previous literature, a positive coefficient between the contemporaneous carbon emissions price and the portfolio stocks return is identified, although the coefficient is not of statistical significance in contrast to most of the previous small sample studies (Oberndorfer, 2009; Knight, 2011; Mo *et al*., 2012; Veith *et al*., 2009). Like Mo *et al*. (2012), this chapter finds that this contemporaneous relationship turns around entirely in Phase 2 when the allowances price changes are accompanied by a reaction in the opposite direction in the stock market performance of regulated firms. However, the analysis in this chapter adds an additional level of complexity to the interpretation of the relationship between emissions allowance prices and the stock market performance of the regulated firms, as it is also revealed that the lagged emissions allowance price coefficient is highly significant at a commonly accepted statistical level during Phase 2 (2008-2011) only, with the opposite sign of the contemporaneous relationship coefficient in Phase 1 and Phase 2 sample periods.

Table 4.4 Estimation Results *Portfolio(ETS)* for total trading period (2005–2011)

Dependent variable	R_P(ETS)				
Model specs	***Eq (4-1)***			***Eq (4-2)***	***Eq (4-3)***
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Sample period	12/1/2001 31/12/2004	12/1/2001 6/1/2012	7/1/2005 6/1/2012	18/3/2005 6/1/2012	25/3/2005 6/1/2012
Alpha	-0.006 (-7.15)***	-0.002 (-2.66)***	-0.0003 (-0.58)	-0.0005 (-0.79)	-0.000 (-0.74)
R_M	0.817 (54.81)***	0.928 (58.76)***	0.974 (64.82)***	0.974 (65.05)***	0.974 (64.78)***
SMB	0.379 (14.06)***	0.453 (16.67)***	0.448 (11.94)***	0.448 (11.93)***	0.448 (11.88)***
HML	0.204 (4.08)***	0.241 (6.92)***	0.115 (2.05)*	0.100 (1.79)*	0.103 (1.84)*
MOM	0.196 (5.7)***	0.237 (8.75)***	0.162 (3.9)***	0.149 (3.60)***	0.152 (3.66)***
EUA				-0.001 (-0.67)	-0.000 (-0.64)
EUA(-1)					-4E-05 (-0.08)
Observations	208	574	366	356	355
Adjusted R^2	0.92	0.96	0.97	0.97	0.97
P-value (F-statistic)	0	0	0	0	0

This table reports the full regression results of estimating ***Portfolio(ETS)***'s performance with the Fama–French model under OLS with a Newey–West estimator for four sample periods. R_S is the risk premium measured by sector index logged return in excess of the risk-free rate; SMB and HML control for the investors inclined towards size and book-to-market value of firms; EUA is the logged weekly return of EEX EUA spot while EUA(-1) represents the allowances return of the previous observation. Columns (1) to (3) report the result from the four-factor model ***Eq (45-1)***; column (4) reports the results from the estimation model ***Eq (45-2)*** with an added allowances price factor; column (5) presents the results from estimation model ***Eq (45-3)*** with two added factors testing the allowances price-related risk. ***, ** and * represents 1%, 5%, and 10% significance levels, respectively.

Table 4.5 Estimation Results *Portfolio(ETS)* Phase 1 (2005–2007)

Dependent variable	R_p(ETS)		
Model specs	***Eq (4-1)*** **(1)**	***Eq (4-2)*** **(2)**	***Eq (4-3)*** **(3)**
Sample period	31/12/2004 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007
Alpha	-0.000 (-0.39)	-0.001 (-0.92)	-0.001 (-0.81)
R_M	0.949 (37.0)***	0.939 (36.1)***	0.942 (37.4)***
SMB	0.354 (9.36)***	0.356 (9.51)***	0.361 (9.35)***
HML	0.047 (0.53)	-0.002 (-0.03)	0.010 (0.13)
MOM	0.347 (5.85)***	0.316 (5.24)***	0.317 (5.02)***
EUA		0.002 (1.11)	0.003 (1.38)
EUA(-1)			-0.002 (-1.24)
Observations	157	146	145
Adjusted R^2	0.94	0.94	0.94
P-value (F-statistics)	0	0	0

This table reports the regression results of estimating ***Portfolio(ETS)***'s performance with the Fama–French model under OLS with a Newey–West estimator for 2005–2007, the pilot phase of EU ETS. R_M is the risk premium measured by the sector index logged return in excess of the risk-free rate; SMB and HML control for the investors inclined towards size and book-to-market value of firms; EUA is the logged weekly return of EEX EUA spot while EUA(-1) represents the allowances returns of the previous observation. Column (1) reports the result from the four-factor model ***Eq (45-1)***; column (2) reports the result from the estimation model ***Eq (45-2)*** with an added allowances price factor; and column (3) presents the results from estimation model ***Eq (45-3)*** with two added factors testing the allowances price-related risk. ***, ** and * represents 1%, 5%, and 10% significance level, respectively.

Table 4.6 Estimation Results *Portfolio(ETS)* Phase 2 (2008–2011)

Dependent variable	R_p(ETS)		
Model specs	***Eq (4-1)*** **(1)**	***Eq (4-2)*** **(2)**	***Eq (4-3)*** **(3)**
Sample period	04/01/2008 30/12/2011	04/01/2008 30/12/2011	04/01/2008 30/12/2011
Constant	-0.001 (-1.58)	-0.001 (-1.50)	-0.001 (-1.52)
R_M	0.982 (59.9)***	0.982 (59.8)***	0.983 (59.8)***
SMB	0.462 (10.3)***	0.465 (10.3)***	0.466 (10.3)***
HML	0.090 (1.50)	0.090 (1.49)	0.088 (1.45)
MOM	0.113 (2.50)**	0.111 (2.44)**	0.110 (2.41)**
EUA		-0.001 (-2.34)**	-0.001 (-2.37)**
EUA(-1)			0.001 (2.12)**
Observations	209	209	209
Adjusted R^2	0.98	0.98	0.98
P-value (F-statistics)	0	0	0

This table reports the regression results of estimating Portfolio(ETS)'s performance with Carhart four factor-based models under OLS with Newey-West estimator for 2008-2010, the first years of EU ETS phase 2. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of the previous observation. Column 1 reports the result from 4-factor model ***Eq(4~~5~~-1)***; column 2 report the result from the estimation model ***Eq(4~~5~~-2)*** with added allowance price factor; and column3 presents the results from estimation model ***Eq(4~~5~~-3)*** with two added factors testing the allowance price related risk. ***, ** and * represents 1%, 5%, and 10% significance levels respectively.

The significantly negative coefficients for lagged EUA prices indicate that the rising (falling) allowance prices are related to falling (rising) share prices of ETS-exposed firms, which can reasonably be explained by the gradual maturity of the European carbon market, a perspective shared by Mo *et al.* (2012). In other words, investors have slowly incorporated the allowance prices into the stock valuation process for ETS-exposed firms with the progress of the trading scheme as information becomes clearer and more available, which reduces the uncertainties surrounding the actual demand-supply of the emission allowances. The results also imply that the relationship is more complex than currently acknowledged and a separation of specific firm characteristics within the EU ETS regulated firms might be needed, which is also done in this chapter by investigating those firms that emit over their designated cap and those that under-emit.

4.4.2 EU ETS effect on share prices for firms with different emissions status

After examining the estimation results of the performance the ***Portfolio(ETS)***, which represents the ETS-exposed firms collectively, the analysis is taken a step further to investigate whether EU ETS has different impacts on share prices of firms with different net allowances positions at the end of each compliance cycle. The estimated alpha coefficients and coefficients of allowances price controls of both over-cap and under-cap portfolios are summarised in Table 4.7, and the full results are presented in Tables 4.8–4.10.

The first finding to be noticed is the stark difference in the stock market performance of the two portfolios. Through all three estimation periods, the over-cap portfolio, which consists of firms with an allowances deficit, sees a constant significant underperformance against the market benchmark while the under-cap portfolio, which consists of firms with a surplus of allowances at the end of each compliance cycle sees a positive estimated alpha, though the latter is not at any commonly accepted significance level. The underperformance of the over-emitting firms over the longer estimation period (2005–2010) that covers both Phase 1 and Phase 2 is merely at the 10% level, but it appears in Phase 1, and over-emitting firms are adversely hit on their share prices even after controlling for the allowances price.

Table 4.7 Summary of the estimation results for emissions status-based portfolios

(a) *Portfolio(over-cap)*	**2005–2010**	**2005–2007**	**2008–2010**
Portfolio performance (alpha)	-12.34%* p.a.	-20.22%*** p.a.	-13.44%** p.a.
EUA	-0.001	0.005*	-0.001**
EUA(-1)	0.000	-0.001	0.001
(b) *Portfolio(under-cap)*	**2005–2010**	**2005–2007**	**2008–2010**
Portfolio performance (alpha)	3.96% p.a.	1.64% p.a.	0.79% p.a.
EUA	-0.001	0.003	-0.001*
EUA(-1)	0.000	-0.005***	0.001***
(c) Paired Different T-test (on alpha)	0.122*** (6.224)		
(d) *Portfolio(L-S)*	16.31%***	21.91%**	13.88%**

This table summarises the estimations results from testing the emissions status-based portfolios. (a) and (b) present the performance of Portfolio(over-cap) and Portfolio(under-cap), respectively. The performance is estimated by the constant in ***Eq (45-1)*** and converted into a per annum rate. The per annum rate is calculated by the formula: constant*52. The estimated coefficients of EUA and EUA(-1) from ***Eq (45-2)*** and ***Eq (45-3)*** indicate the relationship between the variation of portfolio performance and EUA prices. (c) shows the mean difference (t-stat) from a paired difference t-test on the performance of the over-cap and under-cap portfolios, which intends to test whether the difference in the performances of the two portfolios is at any statistically significant level. (d) shows the estimated alpha of Portfolio(L-S), which is a arbitraging-mimicking portfolio with a long position in Portfolio(under-cap) and a short position in Portfolio(over-cap). This is intended as a second test on the difference in the performance of Portfolio(under-cap) and Portfolio(over-cap). ***, ** and * represents 1%, 5%, and 10% significance levels, respectively.

This is interesting, for two reasons. First, the cap was commonly regarded as being too generous for Phase 1 (Ellerman and Buchner, 2008; Ellerman and Buchner, 2007; Anderson and Di Maria, 2011), and thus it is reasonable to assume that the excessive emissions are due to rather high production outputs, which should be a signal of a sound business operation. Second, the coefficients of the EUA price factors, both contemporary and lagged, are positive but insignificant at a statistically meaningful level. Despite being somehow counterintuitive in the context of over-cap portfolio, the positive link is consistent with Oberndorfer (2009), Veith *et al.* (2009), and Mo *et al.* (2012), given that their selection of sample firms contains exclusively electricity firms, which are predominantly short in allowances. It appears that the cost impacts of ETS regulation are not influencing investors' valuations of the exposed firms with allowancs shortage in general, as the EUA price appreciation is accompanied by an equity price appreciation. The explanation for this counterintuitive result provided by Veith *et al*. (2009) is that the extremely cheap allowances, particularly in the second half of Phase 1 provides the firms with fairly inexpensive compliance costs. In Phase 2, the over-cap portfolio still experiences a statistically significance underperformance of 13% per year relative to the market benchmark, which is slightly less severe than in Phase 1.

The findings are generally conceptually similar to those of Chapple *et al*. (2013), who shows that firms with higher levels of carbon intensity among their sample experience a significant reduction in their shareholder value. The results of performance estimation in this section also imply that the overall shareholder value impact of EU ETS regulation on exposed firms does depend considerably on their emissions state (i.e., allowances surplus vs. allowances deficit), and the impacts are substantially more adversely severe for the over-cap firms.

No abnormal returns in relation to the market benchmark are identified for any under-cap portfolios in all three estimation periods. Although there is a clear directional indication that the allowance deficit and allowances surplus might affect performance as indicated by the signs of the coefficients, some further tests are done to verify the magnitude of this effect to be statistically significant. Two additional tests make it more assuring that the differences between the performance of ***Portfolio(over-cap)*** and ***Portfolio(under-cap)*** are of statistical significance. The first test, as presented in Table 5.7 part (c), indicates that the performance of the under-cap portfolio is on average 12.2% higher than the over-cap portfolio, and the difference is of a 1% significance level. This outcome supports the initial proposition that it is likely that the ETS-exposed firms are priced differently due to their emissions compliance status. The second test further explores the pricing differentiation through constructing a portfolio that reflects the arbitraging strategy of holding a long position of under-cap firms and a short position of over-cap firms. This approach is applied in the empirical socially responsible investment literature, such as Kempf and Osthoff (2007). The significantly positive estimated alpha indicates this long–short portfolio has an outperformance, which is also in line with the expectation that the portfolios formed based on different allowances holding positions would perform differently. Results from these two tests jointly verify that the stock market seems able to differentiate the over-emitting ones from the under-emitting ones among the ETS-exposed firms when the firms are examined collectively.

The performance of the under-cap portfolio tested here does not seem entirely consistent with the value relevance of allowance theory of Johnston *et al.* (2008). Further estimations of the EUA price-related factors also indicate that the value relevance of the emissions allowances hardly holds in the EU ETS context. If the proposed value relevance theory holds, a negative coefficient of EUA factor would be a reasonable outcome for firms short in allowances, while a positive coefficient is a reasonably expected outcome for firms with an allowances surplus, if any statistical significance level is found. A negative coefficient indicates that the valuation process of equity and that of carbon allowance move in the opposite directions, and thus a rise in allowances price is accompanied by a fall in equity price, which is identified only in the estimation for the over-cap portfolio in Phase 2.

While the study by Johnston *et al*. (2008) provides a very rare empirical analysis on the subject of emission rights and their value relevance, its design relies largely on accounting measures, with the dependent variable being the scaled market value of the firm. It also seems only to takes into account firms with an allowance surplus, as the number of allowances held by each firm (scaled by their sale) is used as one of the explanatory variables. This chapter approaches the research question regarding the potential value relevance of emission allowances by utilising the price series that are generated directly from the markets and extensively tested equity pricing models, which allows a clear interpretation of the results.

When looking at the results for the EUA coefficients of the under-emitting portfolios, two aspects appear of interest. First, the sign of the coefficients of the EUA price-related factors has completely reversed from Phase 1 to Phase 2, which is also seen for the over-cap portfolio. The EUA price factor that indicates the contemporary relationship changes from positive to negative, and the coefficient indicating the association of the one-period-lagged EUA price factor with the portfolio return changes from negative to positive. The opposite moving direction of the EUA price factor and the under-emitting firms in Phase 1 is not fully in line with the initial expectation, as an appreciation of the allowances is expected to be also accompanied by an appreciation in the share prices for firms with an allowances surplus. However, this could likely be attributed to the low value of the allowances, especially through the last two years of Phase 1 due to the over-allocation of allowances and their disrupted inter-phase compatibility.

The change for the lagged EUA price factor appears sensible and of at least 10% significance level in Phase 1 and 1% level in Phase 2. This positive coefficient in the second phase agrees with the value relevance of the allowances as high emission prices should benefit firms with allowances surpluses, and given that the cap is considerably tightened in Phase 2. Second, the strongly significant EUA coefficients for the under-emitting portfolio are not the contemporaneous coefficients but the lagged ones. This not only justifies the inclusion of a lagged EUA variable as also done by Mo *et al*. (2012) but also implies that markets might be reacting quicker to emissions allowance price changes when assessing firms with allowances deficits than those with allowances surpluses.

In brief summary, the second part of the analysis in this chapter reveals how ETS-exposed firms with different emission compliance statuses are priced. The over-cap portfolio is constantly valued down by the stock market through the EU ETS trading period. The long–short strategy shows that at a statistically acceptable level, the under-cap portfolio is regarded as outperforming the over-cap portfolio. The estimated coefficients of EUA price-related factors indicate that the relationship between the allowances prices and firms' stock prices appears to be differentiated by time, as the signs of the coefficient change entirely from Phase 1 to Phase 2, which also shows consistency with Mo *et al*. (2012), who also find that the level of sensitivity of corporations' value development differs from Phase 1 to Phase 2. An explanation provided by Mo *et al*. (2012) for this change is the adjustment of the allocation policy and the fact that the cap became more stringent in Phase 2, which also appears to apply in the context of this chapter. Nevertheless, the ETS-exposed firms do not seem significantly sensitive to the variation in the allowance prices. The results are not entirely surprising, as the uncertainties surrounding the scheme and over-supplied allowances may have suppressed the significance of the value relevance of emissions allowances within EU ETS.

Table 4.8 Estimation results of *Portfolio(over-cap)* and *Portfolio(under-cap)* for full sample period (2005–2010)

Dependent Variable	***R_p(over-cap)***			***R_p(under-cap)***		
Model specifications	***Eq (4-1)***	***Eq (4-2)***	***Eq (4-3)***	***Eq (4-1)***	***Eq (4-2)***	***Eq (4-3)***
Sample period	07/01/2005 24/12/2010	18/03/2005 24/12/2010	25/03/2005 24/12/2010	07/01/2005 24/12/2010	18/03/2005 24/12/2010	25/03/2005 24/12/2010
Constant	-0.002 (-1.77)*	-0.002 (-1.93)*	-0.002 (-1.93)*	0.001 (1.48)	0.001 (1.23)	0.001 (1.30)
R_M	0.917 (28.3)***	0.916 (28.0)***	0.916 (27.9)***	1.003 (70.9)***	1.003 (71.5)***	1.003 (71.3)***
SMB	0.221 (4.44)***	0.220 (4.37)***	0.220 (4.36)***	0.538 (11.8)***	0.537 (11.9)***	0.537 (11.8)***
HML	0.054 (0.63)	0.048 (0.54)	0.048 (0.54)	0.114 (1.75)	0.100 (1.52)	0.104 (1.57)
MOM	0.358 (3.41)***	0.355 (3.28)***	0.355 (3.27)***	0.153 (2.90)***	0.140 (2.63)***	0.144 (2.69)***
EUA		-0.000 (-0.40)	-0.000 (-0.40)		-0.000 (-0.39)	-0.000 (-0.36)
EUA(-1)			0.000 (0.09)			-0.000 (-0.17)
Observation	312	302	301	312	302	301
Adjusted R^2	0.92	0.92	0.92	0.97	0.97	0.97
P-value (F-statistics)	0	0	0	0	0	0

This table reports the regression results of estimating the performance of *Portfolio(over-cap)* and *Portfolio(under-cap)* with Carhart four-factor models using OLS and a Newey–West estimator for 2005–2010. R_M is the risk premium measured by sector index logged return in excess of the risk-free rate; SMB and HML control for the investors inclined towards size and book-to-market value of firms; MOM controls for the momentum factor. EUA is the logged weekly return of EEX EUA spot while EUA(–1) represents the allowances return of the previous observation. ***, ** and * represents 1%, 5%, and 10% significance levels, respectively.

Table 4.9 Estimation results of *Portfolio(over-cap)* and *Portfolio(under-cap)* for Phase 1 (2005–2007)

Dependent variable	***Rp(over-cap)***			***Rp(under-cap)***		
Model specifications	***Eq (4-1)***	***Eq (4-2)***	***Eq (4-3)***	***Eq (4-1)***	***Eq (4-2)***	***Eq (4-3)***
Sample period	07/01/2005 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	07/01/2005 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007
Constant	-0.003 (-1.88)*	-0.004 (-2.72)***	-0.004 (-2.67)***	0.001 (0.58)	0.000 (0.09)	0.0003 (0.23)
R_M	0.881 (25.7)***	0.861 (26.7)***	0.859 (25.1)***	0.981 (31.5)***	0.970 (30.5)***	0.975 (31.7)***
SMB	0.246 (3.59)***	0.243 (3.53)***	0.239 (3.38)***	0.405 (10.9)***	0.405 (11.0)***	0.416 (10.9)***
HML	0.101 (0.78)	0.108 (0.78)	0.112 (0.80)	0.024 (0.24)	-0.018 (-0.18)	-0.008 (-0.08)
MOM	0.459 (5.02)***	0.479 (4.68)***	0.488 (4.66)***	0.328 (4.85)***	0.301 (4.35)***	0.292 (3.94)***
EUA		0.005 (1.79)*	0.004 (1.58)		0.002 (0.89)	0.003 (1.22)
EUA(-1)			0.001 (0.41)			-0.004 (-1.84)*
Observation	156	146	145	156	146	145
Adjusted R^2	0.87	0.88	0.88	0.92	0.92	0.93
P-value (F-statistics)	0	0	0	0	0	0

This table reports the regression results of estimating the performance of *Portfolio(over-cap)* and *Portfolio(under-cap)* with Carhart 4-factor models using OLS and Newey-West estimator for 2005-2007. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum factor. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of the previous observation. ***, ** and * represents 1%, 5%, and 10% significance levels respectively.

Table 4.10 Estimation results of *Portfolio(over-cap)* and *Portfolio(under-cap)* EU ETS Phase 2 (2008–2010)

Dependent variable	***Rp(over-cap)***			***Rp(under-cap)***		
Model specifications	***Eq (4-1)***	***Eq (4-2)***	***Eq (4-3)***	***Eq (4-1)***	***Eq (4-2)***	***Eq (4-3)***
Sample period	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010
Constant	-0.003 (-2.04) **	-0.003 (-1.98) **	-0.003 (-1.98) *	0.000 (0.12)	0.000 (0.18)	0.000 (0.13)
R_M	0.930 (25.24) ***	0.931 (25.2) ***	0.931 (25.1) ***	1.013 (66.6) ***	1.014 (66.7) ***	1.014 (66.5) ***
SMB	0.201 (3.07) ***	0.204 (3.07) ***	0.204 (3.06) ***	0.578 (11.5) ***	0.580 (11.5) ***	0.582 (11.6) ***
HML	-0.004 (-0.04)	-0.005 (-0.04)	-0.006 (-0.05)	0.091 (1.25)	0.090 (1.24)	0.086 (1.18)
MOM	0.150 (2.12) **	0.298 (2.10) **	0.297 (2.09) **	0.097 (1.74) *	0.095 (1.70) *	0.093 (1.66)
EUA		-0.001 (-1.66) ***	-0.001 (-1.66) *		-0.001 (-1.62)	-0.001 (-1.65)
EUA(-1)			0.000 (0.38)			0.001 (3.62) ***
Observation	157	157	157	157	157	157
Adjusted R^2	0.93	0.93	0.93	0.98	0.98	0.98
P-value (F-statistics)	0	0	0	0	0	0

This table reports the regression results of estimating the performance of *Portfolio(over-cap)* and *Portfolio(under-cap)* with Carhart 4-factor models using OLS and Newey-West estimator for 2008-2010. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum factor. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of the previous observation. ***, ** and * represents 1%, 5%, and 10% significance levels respectively.

Table 4.11 Estimation results of *Portfolio(Long-Short)*

Dependent variable	$R_p(L_{under\text{-}cap}\text{-}S_{over\text{-}cap})$		
Model specs	***Eq (4-3)*** **(1)**	***Eq (4-3)*** **(2)**	***Eq (4-3)*** **(3)**
Sample period	3/25/2005 12/24/2010	3/25/2005 12/28/2007	12/28/2007 12/24/2010
Constant	0.003 (2.84)***	0.004 (2.49)**	0.003 (2.23)**
R_M	0.087 (2.79)***	0.117 (2.68)***	0.084 (2.16)**
SMB	0.317 (7.71)***	0.177 (2.50)**	0.378 (7.26)***
HML	0.056 (0.53)	-0.120 (-0.72)	0.092 (0.64)
MOM	-0.106 (-1.72)*	-0.098 (-1.54)	-0.102 (-1.29)
EUA	6E-05 (0.10)	-0.002 (-0.50)	0.000 (0.35)
EUA(-1)	-0.000 (-0.19)	-0.005 (-1.27)	0.001 (1.88)*
Observation	301	145	157
Adjusted R^2	0.21	0.07	0.25
P-value (F-statistic)	0	0.01	0

This table reports the regression results of estimating the arbitraging Portfolio(L-S)'s performance with Carhart four-factor -based model ***Eq (45-3)*** under OLS with Newey–West estimator. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of the previous observation. Column (1) reports the result of the full sample period 2005–2010; column (2) reports the results from the first sub-sample period 2005–2007, the first phase of EU ETS; and column (3) presents the results from the second sub-sample period 2008–2010, the second phase of EU ETS. ***, ** and * represents 1%, 5%, and 10% significance levels, respectively.

4.5 Conclusion

This chapter empirically examined the effect the planning and implementation of the EU ETS may have on stock market performance of exposed firms. In the past, the amount of CO_2 and other GHG emissions produced by most installations was not subject to any mandatory restriction, and the costs associated with these emissions were externalised on society. Since 2005, a mandatory emissions cap has been imposed on the firms who own the installations subject to the EU's Emissions Trading Directive, which means that the right to emit more than their designated cap needs to be purchased at extra cost. In other words, the firms are forced to internalise these emissions-associated costs. Hence, it is expected that the EU ETS would have a negative effect on the stock market performance of regulated firms, as it makes the firms pay, directly or indirectly, for their emissions (Baumert *et al*., 2003; Burtraw *et al*., 2001; Chapple *et al*., 2013).

Previous empirical studies of the effect of the EU ETS on the stock market performance of regulated firms have only utilised small samples comprising a limited number of listed firms participating in the scheme (Oberndorfer, 2009; Veith *et al*., 2009; Knight, 2011; Mo *et al*., 2012). The findings from the previous literature also appear inconclusive, as some identify the negative impacts from the ETS on firms' equity prices (Mo *et al*., 2012; Diltz, 2002) while others find that the ETS regulation-induced performance disadvantages are inconsequential (Oberndorfer, 2009; Veith *et al*., 2009). The analyses in this chapter advance previous studies by utilising a more comprehensive dataset of 153 European listed firms covering more than a single sector.

The analysis is designed to specifically examine the effect of the planning and implementation of the EU ETS on stock market performance of exposed firms and whether the impact on share prices is differentiated by a criterion directly associated with the EU ETS. The first part of the analysis examines the share price performance of the ETS-exposed firms by constructing an ETS portfolio and estimating its performance with the extended Carhart model. This is followed by examining whether the participating firms' emissions status (i.e., whether a firm emits CO_2 higher or lower than its allocated allowances) is a factor distinguishing the share price performance of these firms. This analysis is an original attempt to utilise the verified emissions data reported to the EU ETS

EUTL as a screening process and explicitly testing the extent to which it is associated with pricing the EU ETS-exposed firms.

The estimation results of the first part of the chapter show that the ETS-exposed firms see a significant underperformance at 1% significance level in the sample period 2001–2004 during which the EU ETS was proposed and going through the negotiation and legislative process before its launch in 2005 (Ellerman *et al*., 2010; EC, 2003a). This original finding is the first piece of empirical evidence concerning the ex-ante performance impact caused by reduced investor expectations in the EU ETS context. Once the EU ETS officially started in 2005, regulated firms did not experience any subsequent negative effects on their stock market performance. This chapter therefore concludes that no significant negative contemporaneous impact of the EU ETS on stock market performance can be identified, but a significantly negative ex ante impact of the EU ETS on the stock market performance of emissions intensive firms seems clear. This finding casts doubt on whether firms and eventually their shareholders are internalising sufficient costs to contribute in a meaningful way to the proposed climate change mitigation. It appears that the irony of the forward-looking nature of the financial market is while firms might have internalised sufficient cost during the period before the EU ETS (2001–2004), they have not done so during the EU ETS operational period based on the estimated outcomes of this chapter. Since meaningful climate change mitigation requires consistent effort, it seems fair to argue that firms are currently not internalising sufficient costs associated with their emissions (EC, 2009a; Stern, 2006, 2008).

The results of the second part of the chapter tell a distinctly different story concerning stock market performance with regard to the firm’s emissions status. The over-cap portfolio underperforms significantly in both Phase 1 and Phase 2 but the under-emitting firms do not seem to be rewarded in terms of significant outperformance. These results highlight that the corporate management of carbon emissions could have material and adverse impacts on a firm’s stock market performance, which generally indicates that a business case for corporate environmental responsibility should be of concern for the ETS-regulated firms as better emissions performance leads to improved stock price performance.

As the analysis conducted in this chapter is intended to be straightforward and thus relies on the fundamental asset pricing framework, it is inevitably susceptible to certain limitations. The future research opportunities include further refining the design of the framework that captures other potential risk factors associated with the pricing process in order to more specifically pinpoint whether the impacts can be largely attributed to ETS. Future research could also investigate whether the relationships studied in this chapter are homogeneous across sectors, which is made feasible with the multi-sector dataset utilised in this thesis, and conducted in next chapter.

5 The differentiation of EU's emission trading effect on share prices: a sector-level analysis

5.1 Introduction

In Chapter 4, ETS-regulated firms were examined as one aggregate subject and the impacts of the emergence and existence of the EU ETS on share price performance were explored. Having ETS-regulated firms as one subject is then adjusted to further examine whether the impact on share prices is dependent on the firms' emissions status. However, the fact that firms with distinct business models and activities operate in different sectors and hence are likely to experience different levels of impacts from the EU ETS has not been widely explored so far. The sectoral carbon emissions statistics given in Chapter 3 show that some sectors produced more emissions than their allocated allowances while others had more allowances than they emitted. Having emissions rights should represent a potential economic value following Johnston *et al.* (2008), and consequently lacking them should represent potential costs.

The sector differentiation aspect in the European context is further elaborated by Hourcade *et al*. (2007), who suggest that the carbon emissions-related characteristics of a sector, which essentially determine the sector's exposure to the EU ETS, depend on their (i) energy intensity, (ii) ability to pass costs through to consumers and (iii) carbon abatement opportunities. While they do not analyse each industry separately on these characteristics, they make simple predictions that the health care and consumer discretionary sectors are less energy intensive than the energy, utilities, and materials sectors and hence should be less affected by the EU ETS. Among the three more affected sectors, they consider that the utilities sector is in a better position due to its improved opportunity to pass the costs associated with the emissions restriction through to the consumers given its relatively low international competition compared with the materials sector. Lund (2007) further argues that the EU ETS' cost impact on the materials sector would be 3–4 times higher than its impact on the energy sector and hence the materials-related industries should be heavily affected by the EU ETS. However, neither of these two papers investigated the relationship between the carbon characteristics of these participating sectors and stock market returns.

Chapter 5 The differentiation of EU's emission trading effect on share prices – a sector-level analysis

After studying the effects of the EU ETS on the stock market performance of the entire universe of regulated firms in Chapter 5, and finding a significant difference in the carbon emissions characteristics of sectors in Chapter 4, it appears sensible to extend the investigation by further exploring the effects of the EU ETS on stock market performance at the sectoral level. Hence, this chapter takes a substantial step further than Chapter 5 by empirically examining whether the EU ETS imposes different effects on the stock market performance of firms in different regulated sectors.

The previous literature has often studied solely the utilities sector, with sample sizes of 12–22 firms and focused more on the effects of emissions prices on the stock prices of participating firms than on the potentially differentiated effects of the EU ETS on different sectors (Oberndorfer, 2009; Knight, 2011; Mo *et al*. 2012; Veith *et al*, 2009). Kahn and Knittle (2003) studied the utilities and coal mining sectors in the context of the major impact on firms that results from the decision to launch the US SO_2 market. They found that the coal mining sector experienced significantly negative stock returns while the utilities sector was not affected, explained by the better ability of the utilities sector to pass the additional costs through to the consumer.

The only empirical analysis of EU ETS-related effects on the stock market returns of different industries has been published by Bushnell *et al*. (2013). They focus on one specific event, the carbon price crash on 25 April 2006, and investigate the responses of various industries. They find, somewhat counterintuitively, that carbon or electricity intensive industries are hurt most in their share price performance due to the carbon price crash. They explain their finding by the predominantly grandfathered emissions in the 'trial' Phase 1 and the fact that the asset value of these emissions allowances held in large quantities by the carbon and electricity intense firms crashed on 25 April 2006. In other words, they believed that investors were more concerned with the potential revenue reduction than the cost reduction of carbon or electricity intensive industries, which was reflected in the share prices of the firms. This finding is contrary to the carbon emissions mitigating intentions of the EU ETS policy makers. Hence, it seems very worthwhile to study, if this effect also holds beyond the specific event for the full first phase and extended trading periods.

To investigate the effects of the EU ETS on stock market returns at sector level, this chapter utilises a Carhart model with additional controls for current and lagged carbon emissions prices. The model achieves the adjusted R-squared values between 71% and 94% for each of the seven sectors studied (Energy, Materials, Utilities, Consumer Discretionary, Consumer Staples, Health Care, Industrials), which signals a high degree of explanatory power of the models. The robustness of the models is further confirmed by the fact that the coefficients estimated remained fairly stable across different specifications. As predicted by Hourcade *et al*. (2007), EU ETS-regulated firms in the consumer discretionary sector are not negatively affected by the EU ETS. In fact, their estimated alpha is even significantly positive, which strongly suggests that the EU ETS does not harm them in the slightest way. However, the EU ETS-exposed firms in the Consumer Staples and Health Care sectors underperform during the first and second phases.

Contrary to Hourcade *et al*. (2007), regulated firms in the Utilities sector are not better off but worse off than the Energy and Materials sectors. While all three sectors significantly underperform in the pre-EU ETS period, only the firms in the utilities sector significantly underperform subsequently during both EU ETS periods. The significant underperformance of EU ETS-regulated firms in the Utilities sector could be due to the sector being the only one that is, as a whole, consistently producing more verified emissions than their given allowances. Hence, this sector should experience the greatest cost burden of the EU ETS (Johnston *et al*., 2008). Such an explanation based on the emissions status of the overall sector appears to explain this chapter's results considerably better than the reasoning of Hourcade *et al*. (2007) and Lund (2007), since the firms in the materials sector, which was a constantly under-emitting sector, did significantly outperform the market benchmark regardless of the firms' actual emissions status. An explanation based on emissions status and the value of having emissions rights following Johnston *et al*. (2008) could also explain why the regulated firms in the energy sector had a positive alpha coefficient during the first phase when they emitted below their allowances on average and a negative alpha coefficient in the second phase when they emitted more than their allowances, although both coefficients were statistically insignificant at common levels.

These results are also not really consistent with Bushnell *et al.*'s (2013) carbon price crash event-based finding, which demonstrated that polluting industries were hurt more than cleaner ones. Beyond this finding, Bushnell *et al*. (2013) also investigated the emissions status of sectors and its relevance to share price valuation. In this case, they found results in line with carbon mitigating intentions. They observed that the carbon price crash affected industries differently depending on their emissions status. In industries that had an allowances deficit, the cleanest firms were penalised the most in terms of stock prices as a result of the crash. In contrast, in industries with an allowances surplus, the firms that had been granted the most free allowances through grandfathering, and so the originally dirtier firms, are hurt the most in their shareholder value by the crash.

However, since this finding refers only to one specific event, it appears an exciting opportunity to study what the relationship between emissions status and stock price performance is at the sectoral level in a long-term perspective. Bushnell *et al.* (2013) point out in their concluding section that their data does not allow them to investigate the emissions status of firms within the sector, i.e. under-emitting vs. over-emitting firms within a certain sector. This chapter extends the previous literature by empirically examining the verified net allowances holding effect on the stock prices of the regulated firms, as the company database acquired from Carbon Market Data contains firm-level emissions data until 2010. This enables the analysis of the stock market effects of EU ETS regulation on firms with different emissions status (i.e. over-emitting or under-emitting) in the larger sectors, which include a sufficient number of firms (i.e. the Energy, Materials, and Utilities sectors). This is the first attempt to explore with real market data the asset value of allowances within the EU ETS context to date.

The main findings in this chapter reveal first, as also demonstrated in Chapter 3, that the utilities sector has been net short of emissions in both phases while the materials sector has been net long during both phases, and the differences are statistically significant. The energy sector has been net long during the first phase but net short during the second phase. Hence, following Johnston *et al*. (2008), one would expect underperformance of the over-emitting firms in the Utilities sector in both phases and in the energy sector in the second phase. Similarly, an outperformance of under-emitting firms in the Materials sector and the first phase of the energy sector can be expected. If the results turn out similar to

Bushnell *et al*. (2013), one would see under-emitting firms in over-emitting sectors (i.e., the Utilities) underperform and being positively affected by carbon price changes. Interestingly, the results of this chapter indicate that both perspectives depend on the sector. The under-emitting energy firms significantly outperform their benchmark in the second phase, which is directly in line with expectations when the Johnston *et al*. (2008) perspective is applied. Similarly, the over-emitting firms in the materials sector underperform, which provides supporting evidence for the view of the asset value of emissions allowances. Even the result that the under-emitting energy firms also significantly outperform in the first phase can be broadly related to this perspective, which subsequently describes the Energy and Materials sectors well.

However, the Utilities sector seems to behave more in line with Bushnell *et al*.'s (2013) findings. The portfolio consisting of under-emitting Utilities firms significantly underperformed during both phases while the over-emitting Utilities portfolio significantly outperformed during the first phase. In the first phase, the relationship between the emissions allowances prices and return of under-emitting portfolio was positive, and thus the carbon price crash seem to have taken away the financial appeal of these firms for possessing excessive emissions allowances. Equivalently, the over-emitting portfolio is negatively influenced by the emissions allowances prices, which is also in line with Bushnell *et al*. (2013), indicating that the price crash lifted these polluting firms' performances. Consequently, the European Union probably needs to avoid such carbon price crashes if it wants to establish the Johnston *et al*. (2008) view that carbon emissions rights possess a positive asset value from the financial market perspective.

This chapter contributes to the empirical literature on EU ETS-related share price impacts in three aspects. First, it provides evidence that among the ETS-exposed firms, the effect of the trading scheme on share price can be differentiated at the sectoral level. Second, it reveals that the differences in the share price performance of the ETS and non-ETS-exposed firms can be identified in certain sectors, such as Energy and Materials, while the two types of firms seem to be priced similarly in the other sectors, namely Utilities, Industrials, and Health Care. Third, the sector-based investigation of the association between the emissions status of firms within the respective sector and their share performance presents an original contribution in the EU ETS literature context, as emissions data have rarely been utilised at this specific level. The findings suggest that the stock market has not yet been able to fully take into account the disaggregated emissions data in the valuation process.

The remainder of this chapter is structured as follows: Section 5~~6~~.2 provides the background to the analyses proposed, which includes a review of relevant literature and establishing the research questions. Methods, model specifications, and data are presented in Section 5~~6~~.3. A discussion of the major findings and relevant implications, from investors' and policy makers' points of view, follows in Section 5~~6~~.4. The final Section 5~~6~~.5 concludes and discusses the limitations of the analysis in this chapter, which is followed by proposing future research opportunities.

5.2 Background and research questions

The following section provides the information background of this chapter, which consists of three parts. The first part discusses the underlying conceptual foundation of the research questions proposed, and is followed by a review of the relevant literature. The last part poses the research questions of this chapter.

5.2.1 Differences in carbon emission-related sectoral characteristics

In Hourcade *et al*. (2007), it is explicitly noted that sectors should expect to experience different economic impacts from the EU ETS. The reason lies in the fact that the intrinsic potential exposures of a sector to the emissions reduction regulation, i.e. EU ETS, which determine the level of impacts, depend on each sector's (i) energy intensity, (ii) ability to pass costs associated with compliance on to consumers and (iii) carbon abatement opportunities. They illustrate an analytical prediction of the EU ETS' economic impacts by sampling a range of affected sectors and drawing up simple metrics and indicators on the basis of cost pass-through ability. To construct the illustrative matrix and indices, they define net value at stake (NVAS) as the net impact of the EU ETS on sectors in terms of costs over the sector's value-added, which is used to represent the magnitude of the economic impacts of the EU ETS for each sector. They further designate two scenarios, which represent two extreme levels of free allowances allocation to sectors (from zero to business-as-usual (BAU) equivalent) as the lower and upper end of each sector's NVAS.

The resulting illustrative matrix shows varying degrees of economic impacts on sectors; the health care and consumer discretionary sectors are less exposed to the direct costs due to their less energy intensive business models. The impacts on the energy and materials sectors appear more volatile according to the level of free allowances as well as to electricity prices. Among the three more affected sectors, the utilities sector is considered to be in a better position due to its better opportunity to pass costs through to the consumers, including other regulated industrial sectors, given its relative lack of international competition compared with other industries, such as the cement, iron, and steel industries in the materials sector.

Lund (2007) also raises the differentiated ETS effects on industries from the overall cost impact perspective. He starts the analytical process from the micro-economic valuation of the costs from the ETS, which is determined by aggregating the direct and indirect costs. The direct cost of a regulated industry is calculated by the product of the emissions reduction target factor, the marginal cost of reduction (the price of EUA), and the CO_2 emissions intensity. The indirect cost would depend on the potential increase in electricity prices due to the cost pass-through behaviour of the utilities sector. Lund relies on a series of industry-level studies (Bode, 2006; Gadalla *et al*., 2006; Szabó *et al*., 2006; EUROFER, 2000), which specifically focus on different sectors and their characteristics in order to obtain sector specific emission intensity information, which is then used to estimate the direct cost of each sector. It is concluded from the final estimation that the industrial sectors are affected by different levels of impact from the ETS. It is shown that the materials sector would experience impacts several times higher than the energy sector and hence the materials industry should be affected most by the EU ETS.

The two studies reviewed above are inspiring in terms of their conceptual grounds for sectoral differentiation. However, it should be noted that neither of these papers investigated the relationship between the carbon characteristics of these participating industries and stock market returns. The empirical studies with EU ETS company-level data are still relatively limited to date, as reviewed in Chapter 5, and it is necessary to rely largely on the economic, conceptual, and theoretical-based literature to build the foundations of the sectoral differentiation assumptions in this chapter. A review of a number of sector-specific studies regarding the economic impact of the EU ETS should further enhance the assumption of the heterogeneity of the EU ETS effect across regulated sectors. It is noticeable that a body of literature exploring in particular the economic impacts of the EU ETS at an industry-specific level has emerged (Reinaud, 2004; Smale *et al*., 2006; Demailly and Quirion, 2006, 2008; Baron in Ellerman *et al*., 2010: 193–234).

Prior to the official launch of the EU ETS, Reinaud (2004) conducted a full ex ante assessment that shed light on the potential impact of the emissions trading scheme on the covered sectors. The short-to-medium term effects of emissions trading on industrial competitiveness are the main focus of investigation in this study. The main conclusion is that the trading scheme is not likely to impose any substantially negative impacts on industrial competitiveness in the near term. Certainly, one should interpret these results with caution due to their underlying assumptions, such as the ability of certain industries to pass the CO_2 emissions-related costs through to end consumers, the interaction between the power market and other sectors, the allocation method, as well as the visibility of the policy framework.

An ex post examination of industrial competitiveness within the EU ETS-regulated sectors, which is conducted in a similar manner to Reinaud (2004) in Ellerman *et al*. (2010: 193–234), suggests that certain industries may be expected to experience a higher degree of effects on their competitiveness due to the nature of their operating activities. Theoretically, sectors that are more electricity intensive and heavily trade-exposed, such as the aluminium, iron, and steel industries, are profoundly more vulnerable under the carbon emissions restriction imposed by the regulations. On the basis of industry-level characteristics and data, the overall profit projections and economic impact analysis shows that each sector examined experiences the minimal level of impact from the EU ETS during the first trading period.

Smale *et al*. (2006) investigate the economic impacts of the EU ETS on five UK energy intensive industries. They rely on a modelling approach that simulates an oligopoly market for five energy intensive sectors – cement, newsprint, steel, aluminium, and petroleum – and input the empirical data to obtain results under three projected emissions allowance prices scenarios. Their analyses aim to reveal the effects of the EU ETS on three dimensions: the profits, production output, and emissions of the affected sectors. Their results suggest that four out of the five sectors examined, including cement, newsprint, petroleum, and steel, could potentially benefit from the trading scheme from the profit point of view. The earnings are even higher under tougher scenarios with higher allowances prices. To look more closely, the magnitude of the impact on profits from the simulation results also varies considerably among sectors; while the profit impact on cement and steel is significant, the impact on petroleum appears more marginal. However, their discussion section also notes that the metal sectors, including iron and aluminium, could face a certain degree of harmful effects, from a modest loss of market share to entire closure.

Demailly and Quirion (2006, 2008) provide two sets of sector-specific economic modelling analyses with regard to the industrial competitiveness issue arose due to the EU ETS. Their analyses also rely on economic modelling, which projects the outcomes under different scenarios and examines how the costs of emissions allowances affect industrial competitiveness. In their 2006 study, they investigate how the competitiveness of the cement industry was affected by different allocations approach by applying a self-modified trade model[49] to project a series of competitiveness measures, including the profits, production costs, prices, and output, as well as the emissions, for the cement industry for 2008–2012.

It is shown that the profits of the cement sector would only be negatively affected when the rate of free allowances allocation was under 50%. In their 2008 paper, they shift the interest of competitiveness impact to the iron and steel sector with a modified industry model, a similar approach used in Demailly and Quirion (2006). Again, multiple dimensions of competitiveness measured by the profitability and production are projected for the sector with their own modelling assumption, which specifies the allowances prices and allocation methods. It is shown that the profitability of the iron and steel sector depends on the amount of free allowances allocated, which certainly, as pointed out by the authors in the concluding section, is highly sensitive to assumptions. Results from both studies (Demailly and Quirion, 2006, 2008) seem to suggest that from the competitiveness and profitability perspectives, the cement, iron, and steel sectors appear indifferent to the

49 CEMSIM-GEO is a modified model of the authors that links the trade model of homogeneous product with high transportation cots (GEO) (Demailly and Quirion, 2006) and a bottom-up model of the cement industry (CEMSIM) (Szabo *et al.*, 2006).

emissions regulation as these sectors are all unlikely to experience any substantial adverse impacts on their profitability given the current EU ETS context. It is interesting to reflect these estimations in the analyses in this chapter, which will reveal the ETS impacts on the affected sector from the stock market investors' perspective.

To briefly sum up, the assumption that a certain environmental regulation imposes different levels of effects on different sectors appears sound, as studies including Reinaud (2004), Smale *et al*. (2006), and Ellerman *et al*. (2010) suggest from the economic and profit impact perspective. Although sector-specific studies by Demailly and Quirion (2006, 2008) imply that under the current setting of the EU ETS, some sectors, such as the cement, and the iron/steel sectors, are likely to benefit from the trading scheme, the magnitude of the impact experienced by different sectors is not likely to be at the same level. As the stock markets reflect investors' expectations of firms' profit (Kahn and Knittle, 2003; Hughes, 2000; Bushnell *et al*., 2013), this body of economic impact literature forges an important links between the ETS regulation impact and the stock market.

5.2.2 Previous studies of ETS effect on stock market returns at the sector level

The previous literature with empirical analyses has focused predominantly on the utilities sector, with sample sizes of 12–22 firms. The objectives of these studies have also focused more on the effects of emissions allowances prices on the stock market performance of participating firms than on the effect of the ETS regulation on the sector. For instance, four studies which are reviewed in detail in Chapter 4 share a similar focus on the effect of the allowances price variation on the stock price changes of utility firms (Oberndorfer, 2009; Knight, 2011; Mo *et al*., 2012; Veith *et al*., 2009).

The only study that empirically examines EU ETS-related effects on stock returns of different industries has been published by Bushnell *et al*. (2013), in which the concept of different industries showing various levels of exposure toward ETS regulation is also recognised. Their argument stems from the volatility of the regulatory costs to which regulated firms are exposed under the ETS. They suggest that changes in allowances prices could alter the overall input costs, output revenues, and the asset value of the allowances, which will eventually affect the regulated firms' profits. This particular profit effect could vary across industries and firms given different levels of abatement costs, output price sensitivity, and allowances allocation methods. The conceptual foundation raised shares very similar ground with Lund (2007), Hourcade *et al*. (2007) and Johnston *et al*. (2008).

Bushnell *et al*. (2013) rely on the event study approach and choose to focus on a significant event, the 25 April 2006 carbon price crash during the pilot phase, and investigate the responses of firms from various sectors, including the mining, utilities, and consumer-related sectors. They study how much the event impacted the expectations of stock market investors on firms' profits with a sample size of 90 stocks in the carbon intensive industries by examining the variation in stock prices of the sample firms during the event window with regard to the carbon price collapse. They find, interestingly, that firms producing electricity with relatively low emissions output experience the severest drop in their share price due to the crash. This is explained by the predominantly grandfathered, free allowances in the trial period and the fact that the asset value of the allowances held in large quantities by the carbon and electricity intensive firms crashed on 25 April 2006. In other words, they believe that the revenue impact is more pronounced than the cost reduction of carbon or electricity intensive industries from the investors' perspective. This finding is contrary to the intention of the climate change mitigation target set by the EU ETS policy makers that ETS regulation should internalise the costs of emissions for the heavy emitters. Hence, it offers a promising research opportunity to explore if this revenue effect also holds beyond the specific event in the first phase, and if it appears equivalent in Phase 2 for all the EU ETS-regulated firms in the sample in this chapter.

Bushnell *et al*. (2013) conduct further analysis by taking into consideration the emissions status of the industries in order to disentangle the effect of the value relevance of such allowances. They examine whether the abnormal returns of the estimated firms can be explained by their allowances holdings and emissions. They project that firms with a net long position of allowances will experience a bigger loss in profits, which should be reflected in the share prices given the sharp decline in the allowances prices. However, the net holding position does not appear significant in explaining the abnormal returns in all three specifications of estimation, with or without industry fixed effects. They attribute this insignificance to the lack of accessible market information in terms of allowances trading available for the investors. In fact, the official verified emissions data at the installation level is made available only at the end of May each year. The estimation results with industry fixed effects do distinguish between the power sectors and the others. They observe that in the sector that is net short of allowances, namely the power sector, the cleanest firms (in relation to more emissions intensive power firms) are penalised the most as result of the carbon price crash. In contrast, in sectors that are net long of emissions allowances, firms that receive the most free allowances through grandfathering are hurt most in their shareholder value by the carbon price crash. The fact that dirtier firms in the net-long sectors see a worse decline in their share prices is consistent with their initial projection, as these firms suffer a greater loss in the aggregate asset value of the allowances.

However, since Bushnell *et al.*'s results refer only to one specific although substantial event, it appears worthwhile to study how the relationship between emissions status and stock price performance at the sectoral level appears in the full EU ETS trading period. In fact, the authors point out explicitly that their data do not allow them to investigate in more detail the net holdings effect which could result from the emissions status of firms within the sector – i.e., under-emitting vs. over-emitting firms. They believe that this net holding effect could be related to the stock market's response toward the carbon price fluctuation. As the Carbon Market Data's EU ETS company database provides annually updated emissions data for regulated firms available until 2010, this particular net allowances holdings effect could be empirically examined. By studying the stock market effects of portfolios of under-emitting and over-emitting firms within the larger sectors with sufficient observations, this chapter extends the previous literature in terms of the depth of the subject investigated and provides empirical evidence on the asset value of allowances in the EU ETS context.

By providing empirical evidence of the differentiated regulation effects on industries outside the EU ETS, Kahn and Knittel (2003) show that the US SO_2 emissions trading system imposes different impacts on the equity prices of the utility generating and coal mining sectors. Similarly by utilising a typical event study, Kahn and Knittle (2003) examine the stock market reaction to several major announcements regarding the launch of the US SO_2 market. They suggest that the new information about future environmental regulation should be reflected in the change in firms' expected profits from the stock market perspective. The differentiated effects across sectors are investigated by examining the abnormal returns of 35 firms with regulated electric utility plants and 12 firms in the coal mining sector in the event windows spanning from 24 August, 1988 to 4 August 1989, roughly one year before the official passage of the Clean Air Act Amendments (CAAA) that aimed to reduce SO_2 emissions. Their results provide affirmative support for their prior expectation that the two sectors experience largely different impacts from the proposed environmental regulations. Firms in the Coal Mining sector display significantly negative stock returns while the Utilities sector is not adversely affected at any statistical significance level. Only one out of 35 electric companies has a statistically significant response to the events surrounding the passage of the CAAA, and the response is positive instead of the expected negative response. This finding is explained by the better ability of the Utilities sector to pass the additional costs through to consumers. On the other hand, more than 80% of firms in the coal mining sector analysed respond negatively to the same events of legislation-relevance, and three cases are at statistically significant levels. In addition to the cost pass-through opportunity, the authors also attribute the larger impacts on the coal mining sector to the differences in demand elasticity for different products, in this case the electricity and high sulphur coal. As the results suggest, the differentiated effects of environmental regulation on the share prices of the regulated sectors appear prominent in the case of the US SO_2 regulation.

To briefly sum up, the main assumption that inspires the analysis in this chapter lies in the existence of heterogeneity of EU ETS effects on regulated firms' share prices across different sectors. This fundamental notion originates from the speculation that different sectors are subject to different levels of intrinsic exposure to the emissions restriction, as expressed in Hourcade *et al*. (2007) and Lund (2007). It is suggested that this exposure could be determined predominantly by factors such as the nature of operating activities, which is related to energy demand and the cost pass-through capability (Hourcade *et al*. 2007; Bushnell *et al*., 2013), and the differences in the level of exposure are likely to drives the sectoral differentiation of EU ETS effects. Thus, the assumption specifying that the impact of ETS regulation in terms of equity valuation is not homogeneous across sectors appears sound.

5.2.3 Research question

Based on the literature reviewed above, it appears rather likely that the EU ETS effect can be differentiated at the sector level, although views and findings differ substantially as to the sectors and types of firms that are impacted more beneficially or detrimentally than others. Similarly, it also seems likely that firms in a given sector are impacted by the EU ETS depending on their emissions status (Bushnell *et al*., 2013; Hourcade *et al*., 2009; Johnston *et al*., 2008; Lund, 2007).

As both possibilities have been discussed but have so far only been empirically tested in Bushnell *et al*.'s (2013) event study, whose results are informative for the carbon price crash of 25 April 2006, but are not necessarily generally applicable especially outside the first phase of the EU ETS, this chapter conducts an econometric analysis to answer the following research questions:

(1). Can the effect of the EU ETS on the stock market performance of regulated firms be differentiated at the sector level?

(2). Are the stock market performances of EU ETS-exposed firms and non-ETS-exposed firms significantly different at the sector level?

(3). Does the effect on the stock market performance of EU ETS-regulated firms depend on their emissions status (i.e., over-emitting vs under-emitting) at sector-level? If yes, the following questions will be further investigated:
(3-a). Is the effect on the stock market performance differentiated by the overall sectoral emissions status? That is to say, are sectors with different emission statuses (over-emitting sectors vs. under-emitting sectors) valued significantly differently? (3-b). Is the effect on stock market performance differentiated by the emissions status at firm level within the same sector?

5.3 Data and method

The portfolio approach appears the most suitable method for this analysis as the subject of the examination shares the fundamental characteristics with Chapter 4 and consists of firms with the same features. Specifically, the subject of examination in this chapter also lends itself to the creation and comparison of hypothetical investment portfolios of a group of firms that share certain characteristics (i.e., regulated by the EU ETS). The sampling and portfolio formation process for the two analyses planned in this chapter are described in this section. The first part presents the preparation for the sectoral analysis, which examines the performance of ETS-exposed firms at sectoral level and is unique in this area of research. It is followed by the preparation process for the second analysis, that tests the emissions status effect within specific sector. The model applied, which is an extended Carhart model with contemporaneous and lagged carbon emissions price controls, is presented in the final part of this section.

5.3.1 Sectoral analysis

The first objective of the analyses in this chapter is to discover whether firms from different sectors experience different levels of impact on their share prices within the same environmental regulation scheme. This part of the analysis is complemented by an investigation of the performance of firms that are not covered by the EU ETS (hereafter, Non-ETS firms). The Non-ETS firms are selected through a sampling process that ensures comparability between the two sample datasets.

5.3.1 (a) A sectoral analysis of ETS-exposed firms: the sampling process

The main sample dataset formed in Chapter 5 is also used here and two sets of sub-sample datasets are constructed out of the principal one for the analyses in this chapter. The first set of sub-samples is designed to investigate the EU ETS effect on stock prices at the sector level. 153 listed firms from the principal dataset need to be classified and assigned an appropriate sector. A universal industry classification standard that applies to all the sample companies is required to ensure a certain degree of homogeneity in the portfolio construction. As the European Union does not have its own industry classification standard as North America or the UK (i.e. (NASIC, UKSIC), the Global Industry Classification Standard (GICS) developed by the MSCI[50] and Standard & Poor's appears to be the most suitable option, following Chapple *et al*. (2013), for the sector classification process.

50 www.msci.com/products/indices/sector/gics/.

Table 5.1 Distribution of firms and allowances allocations in each sector

Sector (1)	**Number of firms (2)**	**2005—2007 (3)**	**% of total (4)**	**2008–2010 (5)**	**% of total (6)**
10 Energy	29	533,143,289	7.41%	576,435,870	8.91%
15 Materials	64	931,814,499	12.96%	996,010,189	15.39%
20 Industrials	10	31,793,516	0.44%	37,493,112	0.58%
25 Consumer Discretionary	7	5,598,370	0.08%	4,883,909	0.08%
30 Consumer Staples	10	10,299,356	0.14%	8,775,572	0.14%
35 Health Care	5	7,565,900	0.11%	7,291,035	0.11%
55 Utilities	28	2,331,080,893	32.41%	1,825,445,301	28.21%
Total	**153**	3,851,295,823	53.55%	3,456,334,988	53.41%

This table shows the result of sector classification and presents the percentage of the allowances allocated to each sector in each trading period. Column (1) lists the sector in which the sample firms operate, column (2) shows the number of firms classified into the respective sector, and fifth columns (3) and (5) show the number of allowances receive by each sector and the allowances in units of EUA, and columns (4) and (6) show the percentage of the allowances each sector accounts for in relation to the total allowances within the entire EU ETS Database.

An additional advantage of employing GICS as the classification standard is that the MSCI provides a wide range of equity indices that could suitably serve as the market benchmark for the analyses planned in this chapter. Among the sample companies, 111[51] are in the MSCI World index, which allows a straightforward classification. 42 firms remain unclassified as a result of their exclusion from the MSCI World index, so they could not be directly assigned the correct GICS-based sector. These firms are categorised in the author's discretion by cross-checking their main activities defined in the EU transaction log (EUTL) with the sample firms that are in the MSCI World index. The 153 companies in the sample operate across seven sectors based on GICS, and the result of classification is presented in Table 6.1, which shows the number of firms in the respective sector and, additionally, shows how many allowances each sector accounts for.

51 The number was correct at the time the data sample process was carried out. The market index constituents are updated periodically.

5.3.1 (b). Non-ETS-exposed firms: the sampling process

To further verify whether the performance of the ETS-exposed firms can be attributed to the emissions restriction, if any significant abnormal return is observed, a supplementary analysis is planned to test the performance of a peered control group. The group will consist of firms from the same universe, in this case, the MSCI Europe Index, but not subject to the emissions cap. Ideally, the firms should be picked directly from the index constituents, however the access to the complete MSCI constituents' lists is beyond the author's capacity. Therefore, an alternative source which is freely accessible is utilised to compile the peered group. First, the holdings lists of iShare's[52] MSCI Europe Exchange-Traded Fund (ETF) from 2007 to 2011 are obtained, which also covers the full sample period of the original dataset of ETS-exposed firms. The iShares MSCI Europe ETF aims to approximate the performance of the MSCI Europe Index and thus its stock holdings makes the best alternative to the MSCI index constituents. After excluding the ETS-exposed firms and firms outside the seven sectors identified in Section 6.3.1 (a), 240 firms remain and are assigned a sector accordingly. The distribution of the number of firms in each sector is detailed in Table 6.2.

5.3.1 (c) Portfolio formation for the sectoral analysis

The portfolio is constructed with firms from each sector identified in the first step described in Section 5.3.1(a) and 5.3.1(b), which results in seven ETS-exposed portfolios and seven Non-ETS-exposed portfolios. The performance is measured by the average logged return of $\boldsymbol{Portfolio(sector_i)}$ calculated on the weekly, equal-weighted basis for the time period 2001–end of 2011. The number of firms in each sector-based portfolio and the main operating activities of each sector are shown in Table 5.2.

52 Managed by BlackRock. All information can be accessed on its website www.ishares.com.

Table 5.2 Number of firms and main operating activity within the sector-based portfolio

Sector (1)	ETS-exposed (2)	Non-ETS-exposed (3)	Main Activity (4)
10 Energy	29	13	Oil and gas
15 Materials	64	22	Cement and lime, iron and steel, pulp and papers, chemicals
20 Industrials	10	80	Glass, iron and steel
25 Consumer Discretionary	7	63	Motor industry
30 Consumer Staples	10	27	Food and drink
35 Health Care	5	19	Pharmaceuticals, chemicals
55 Utilities	28	16	Power and heat
Total	**153**	**240**	

This table presents the information on the sector-based portfolio regarding the constituent firms. Column (1) lists the sector, column (2) shows the number of EU ETS-exposed firms used in constructing each sector-based portfolio, column (3) gives the number of the firms used in constructing each sector-based portfolio with no ETS exposure, and column (4) shows the main operating activities of each sector according to the original data points.

5.3.2 Analysis of the emissions status effect by sector

The second focus of this chapter now switches to exploring whether stock market investors value the ETS-regulated firms differently on the basis of their allowances holding positions. This part of the analysis examines whether the effect of the EU ETS on stock prices is differentiated by the different emissions compliance status of firms at the end of the EU ETS compliance cycle within the same sector. More specifically, this analysis intends to find out whether the share price performances of firms differ by the annual verified emissions-to-cap status of firms within the specific sector. To start with, the major sectors, in terms of allowances received and the number of firms regulated, are identified. The main reason to concentrate on the major sectors is to obtain a sufficient numbers of observations and maintain the representativeness of the sub-sample sets. According to Table 5.1, which shows essentially the size of each sector after the classification process, it can be clearly seen that the energy, materials and utilities sectors are the largest sectors among the seven sectors in terms of allowances allocation as well as the number of firms included.

Table 5.3 The number of firms distribution in *Portfolio(Sector$_i$)$^{emission\ status}$*

Portfolio	***Energy***		***Materials***		***Utilities***	
	Over-Cap	***Under-Cap***	***Over-Cap***	***Under-Cap***	***Over-Cap***	***Under-Cap***
2005	6	22	11	53	15	13
2006	10	18	9	55	18	10
2007	10	18	12	52	19	9
2008	16	12	7	56	20	8
2009	8	20	2	61	17	11
2010	9	19	6	57	17	11

This table shows the number of firms that constitute the over-cap/under-cap portfolios within the Energy, Materials, and Utilities sectors. Emissions status is determined by the reported verified emissions of each firm relative to its cap, which is made available annually, thus the portfolio constituents are also updated annually.

The second analysis is conducted by examining the share price performances of firms within the same sector with different emissions-to-cap status. The firms of each sector are therefore grouped into two portfolios: firms that emit over their caps form ***Portfolio(Sector$_i$)$^{over\text{-}cap}$*** and firms that emit under their given caps form ***Portfolio(Sector$_i$)$^{under\text{-}cap}$***; i denotes each major sector included in this analysis: Energy, Materials, and Utilities. Returns of the portfolios are calculated on a weekly, equal-weighted basis, components of each portfolio are updated annually according to published verified emissions data. Table 5.3 shows the changes in the number of constituents in each portfolio throughout the total sample period. Essentially, the result indicates whether the stock market investors are able to pick out the firms with lower (higher) ETS-related costs and price accordingly.

5.3.3 Model specification

For estimating the performance of equity-based portfolios, the Carhart four-factor model makes an appropriate baseline model, as it has been extensively applied and takes into account the most common risk factors associated with the variation in equity prices. An additional factor of the EUA spot price return is introduced to the model for the purpose of examining the links between the carbon market and the financial market. Four sets of regression analyses are conducted in this chapter in order to obtain a clear picture of how EU ETS effects on financial performances differ among sectors during different time periods. First, performances of sector-based portfolios are estimated using the basic three-factor model for the estimation period 2001–2004, which coincides with the EU ETS proposed and negotiating period. This ex post analysis is intended to provide results that show how the capital market value the prospects of the upcoming emissions regulation. The first estimation equation, ***Eq (5~~6~~-1)***, can be written as follows:

Eq (5-1)

$$R_{p,t}(Sector_i) - R_{Riskfree,t} = \alpha + \beta_1 RM_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \varepsilon_t$$

where ***$R_{p,t}$(sector$_i$)*** denotes the return of ***Portfolio(sector$_i$)*** in excess of the risk-free rate and RM_t represents the return of the market portfolio in excess of the risk-free rate. The risk-free rate used in all the analyses is the manually converted weekly rate based on the EURIBOR three-month rate obtained from DataStream. SMB controls the factor of size, which is calculated by the differences between the MSCI Europe small cap return index and average large cap return index. HML controls for the book-to-market value for the firm, which is calculated as the difference between the average rate of logarithm return of MSCI Europe value stocks and growth stocks. The final term is a random error process.

Following the empirical design of Chapter 5, additional factors that control for the variation of the emissions allowances price are added into the estimation model, which enables the examination of the existence of the carbon market–financial market link. This is somewhat more advanced but broadly in line with the previous time-series literature (Oberndorfer, 2009; Knight, 2011; Mo *et al*., 2012; Veith *et al*., 2009). The two estimation models, ***Eq (5-2)*** and ***(5-3)***, can be written as follows:

Eq (5-2)

$$R_{p,t}(Sector_i) - R_{Riskfree,t} = \alpha + \beta_1 RM_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \beta_5 EUA_t + \varepsilon_t$$

Eq (5-3)

$$R_{p,t}(Sector_i) - R_{Riskfree,t} = \alpha + \beta_1 RM_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \beta_5 EUA_t + \beta_6 EUA_{t-1} + \varepsilon_t$$

EUA is the logged return of the EUA spot settlement price quoted from European Energy Exchange, which offers the longest possible dataset starting in late March 2005, while EUA_{t-1} is the lagged observation of EUA return, in this case being the observation of the previous week. Three sets of regression analyses are conducted in this chapter in order to obtain a clear picture of how EU ETS-related effects on share price performances differ among sectors during different time periods. First, the performances of sector-based portfolios are estimated using the basic four-factor model for the estimation period of 2001–2004, which coincided with the EU ETS proposed and negotiating period. This ex ante analysis is intended to reveal how the stock market investors valued the prospects of the upcoming emissions regulation. Second, using all three estimation models, the performance of all seven sector-based portfolios is studied for the full EU ETS sample period and the two sub-sample periods, respectively. Third, the performance of the over- and under-emitting portfolios in the three large sectors is investigated during the full period and the two sub-sample periods. These portfolios with different allowances holding positions are estimated under the same models for the sample period that covers the total EU ETS trading period from 2005 to 2010, given the best data availability.

5.4 Results and discussion

This section presents and discusses the results of the regressions conducted with each of the specified models and methods described in Section 6.3, which reveal two major aspects of interest. The results first show whether the sectors that are subject to the same regulatory framework experience different levels of impact on their value reflected in the stock market. This responds to the first research question by showing the performance of each sector-based portfolio indicated by the estimated constants. Furthermore, the results of second set of analysis illustrate whether the ETS-regulated firms' stock price performance within each of the major sector is differentiated by its allowances holding position.

5.4.1 EU ETS effect on stock prices - sector-level

To start with, Table 6.4 provides a summary of each portfolio's performance. The differentiation of the performance can be observed at a statistically significant level, as in the four estimation periods tested the sector-based portfolios display contrary performances in their returns. The suggested differentiation of the ETS effect is supported by two aspects from the results obtained, with different levels of effects and interactions between portfolio performance and allowances market observed across sectors. At the end of this section, the full regression results for each sector-based portfolio (ETS, Non-ETS. and long–short) using the standard Carhart four-factor model ***Eq (56-1)*** for the Pre-ETS and continuous ETS estimation periods are presented in Tables 56.6–56.9. Tables 56.10 and 56.11 present the results for the ETS portfolios for the full sample period (2005–2011) with additional EUA price factors while Tables 56.12 and 56.13 show the results from the estimation period spanning the Pre-ETS and ETS period (2001–2011).

Six out of the seven sector-based ETS portfolios see significant underperformance against the market benchmark during the Pre-ETS period (2001–2004) except for the Consumer Discretionary sector, which by contrast sees outperformance against the benchmark. The underperformance of the portfolio indicates that these sectors are valued negatively by the stock market, with investors perceiving that future environmental liabilities could pose adverse effects on the sector's performance. This finding is interesting and in line with Kahn and Knittel (2003), who find the US SO_2 regulation has had a significantly negative

Table 5.4 Summary of the estimated alpha of the sector-based portfolios

Portfolio	**2001–2004 (1)**	**2005–2011 (2)**	**2005–2007 (3)**	**2008–2011 (4)**	**2001–2011 (5)**
Energy^{ETS}	-0.009***	-0.001	0.001	-0.002	-0.002
Materials^{ETS}	-0.002*	0.003***	0.004**	0.001	0.002**
Industrials^{ETS}	-0.003*	0.004***	0.004	0.002**	0.002***
Consumer Discretionary^{ETS}	0.010**	0.007***	0.001	0.007***	0.007***
Consumer Staples^{ETS}	-0.014***	-0.009***	-0.013***	-0.007***	-0.011***
Health Care^{ETS}	-0.006**	-0.006***	-0.005**	-0.004***	-0.006***
Utilities^{ETS}	-0.012***	-0.006***	-0.008***	-0.006***	-0.008***
Energy$^{Non\text{-}ETS}$	0.012**	0.019***	0.011***	0.017***	0.017***
Materials$^{Non\text{-}ETS}$	0.000	0.012***	0.014***	0.010***	0.010***
Industrials$^{Non\text{-}ETS}$	0.008***	0.005***	0.008***	0.003***	0.005***
Consumer Discretionary$^{Non\text{-}ETS}$	0.009***	0.002***	0.000	0.003**	0.004***
Consumer Staples$^{Non\text{-}ETS}$	-0.011***	-0.005***	-0.008***	-0.004***	-0.008***
Health Care$^{Non\text{-}ETS}$	0.003	-0.005***	-0.005**	-0.004***	-0.004***
Utilities$^{Non\text{-}ETS}$	-0.013***	-0.008***	-0.005***	-0.007***	-0.009***
Energy$^{Long\text{-}Short}$	0.021***	0.019***	0.010***	0.019***	0.019***
Materials$^{Long\text{-}Short}$	0.002	0.009***	0.010***	0.009***	0.008***
Industrials$^{Long\text{-}Short}$	0.010***	0.001	0.005*	0.001	0.003***
Consumer Discretionary$^{Long\text{-}Short}$	-0.001	-0.005**	-0.0004	-0.004**	-0.003**
Consumer Staples$^{Long\text{-}Short}$	0.003*	0.003***	0.006***	0.003**	0.003***
Health Care$^{Long\text{-}Short}$	0.008**	0.001	0.002	-0.0001	0.003**
Utilities$^{Long\text{-}Short}$	-0.0004	-0.002*	0.003	-0.001	-0.001

This table provides a summary of the portfolio performance of the ETS, Non-ETS-exposed sector-based portfolios, and the long–short portfolio of each sector in a different estimation period. The long–short portfolio reflects the investment strategy of buying the Non-ETS portfolio and short selling the ETS portfolio. The performance is measured by the alpha of the estimation model ***Eq (5~~6~~-1)***, which represents the abnormal return of the portfolio which is not explained by market, size, book-to-market, and momentum facotrs. Column (1) lists the sector portfolio estimated. Columns (2)–(5) show the estimated alphas of the respective sector-based portfolio for the Pre-ETS, the full sample period, Phase 1, and Phase 2. ***, **, * represent 1%, 5%, 10% statistical significance level, respectively.

impact on coal mining firms' share prices. Similar results and concluding remarks can also be seen in Chapple *et al.* (2013), who find that a market value penalty applies for the firms which are potentially subject to future environmental liabilities.

Table 5.5 Summary of estimated coefficients of the allowances price-related factors

	2005–2011		**2005–2007**		**2008–2011**	
	EUA	**EUA(-1)**	**EUA**	**EUA(-1)**	**EUA**	**EUA(-1)**
Energy^{ETS}	~ 0	~ 0	~ 0	~ 0	~ 0	~ 0
Materials^{ETS}	~ 0	~ 0	~ 0	⊖⊖⊖	~ 0	+++
Industrials^{ETS}	⊖⊖	~ 0	~ 0	-	⊖⊖⊖	~ 0
Consumer Discretionary^{ETS}	⊖⊖⊖	⊖⊖⊖	~ 0	~ 0	⊖⊖⊖	⊖⊖⊖
Consumer Staples^{ETS}	⊖⊖⊖	~ 0	~ 0	+++	⊖⊖⊖	⊖⊖⊖
Health Care^{ETS}	⊖⊖	⊖⊖⊖	~ 0	~ 0	⊖⊖⊖	+++
Utilities^{ETS}	~ 0	~ 0	+++	~ 0	⊖⊖⊖	~ 0

This table provides a summary of the estimated coefficients of the allowances price factor, which indicates the exposure of the sector to the risk associated with the allowances price variation. The first column lists the sector portfolio estimated. The second to the fifth columns show the estimated alphas of respective sector-based portfolio for the Pre-ETS, the full sample period, Phase 1 and Phase 2. ⊖ indicates a negative estimated coefficient and the stock return and the allowances return move in the opposite direction while + indicates a positive estimated coefficient and the stock return and the allowances return move in the same direction. ⊖ or + represents the 10%, ⊖⊖ or ++ represents 5%, and ⊖⊖⊖ or +++ represents 1% significance levels and ~ 0 is not statistically significant.

The results of testing the Non-ETS-exposed portfolios add interesting insights and at first glance seem to contradict what the research questions of this chapter suggest. First, the results for the Pre-EU ETS period (2001–2004) show that the Non-ETS portfolios overall appear better off except for the Utilities. The firms were presumably prone to speculation regarding the extent to which they would be affected by the EU ETS when the emissions cap was imposed. The Utilities sector is naturally the largest emitter and expected to face potentially the highest ETS-related costs when the trading scheme was in place. Thus, the results are not beyond expectations as the performance of the ETS and Non-ETS portfolios demonstrate a certain degree of difference.

The estimation results for the EU ETS operating period (2005–2011) reveal a quite different story as the differences in the ETS and Non-ETS portfolio performance seem to have lessened but remain observable. Two ETS portfolios (Materials and Industrials) rebound from the underperforming to outperforming status, three sectors retain their underperforming status, and the energy sector seems indifferent to the market benchmark. The performance of the Non-ETS portfolios remains nearly the same with the exceptions of Materials, which shows outperformance from an insignificant alpha, and Health Care, which shows underperformance. As indicated by the summarised results, sectors are priced rather differently, with Energy, Materials, and Industrials outperforming, and the Non-ETS portfolios seeing a better performance than the ETS firms during the continuous estimation period covering Phase 1 and 2 of EU ETS. In stark contrast, Consumer Staples, Health Care, and Utilities experience underperformance and, surprisingly, the Non-ETS Utilities Portfolio suffers more underperformance than the ETS Utilities portfolio.

The changes in estimated portfolio performance for the Pre-ETS estimation period and the Phase 1 period are particularly interesting, as four out of seven sectors with ETS-exposed firms, namely Energy, Materials, Industrials, and Consumer Discretionary, see a substantial re-evaluation of their stock price by the market. It appears that stock market investors did not consider the ETS regulation costly for these sectors during the first trading period. The Materials sector, the largest sector in terms of companies included, was even expected to make gains during the first trading period. Three sectors remain underperforming the market benchmark, which indicates that the market considers that ETS regulation still shows considerable impacts on them, which could be caused by an increase in abatement costs or a reduction in operational earnings (Chapple *et al.*, 2013). On the other hand, the Non-ETS portfolios do not see drastic changes in their performance transiting into the EU ETS period except for the Health Care sector, which sees a significant underperformance. This finding suggests that the impact from the EU ETS on the non-exposed firms is minimal, which can reasonably be expected.

As the results from the two sets of regressions for the ETS and Non-ETS portfolios do seem slightly puzzling and inconclusive, a third set of regressions was run to examine the long–short portfolio of each sector, constructed by taking the long position of the Non-ETS portfolio and short selling the ETS portfolio. This test further disentangles whether the EU

ETS is essentially a deciding factor for pricing the firms in the respective sector. The results show that the ETS and Non-ETS-exposed firms in the Energy, Materials, and Consumer Staples sectors perform significantly differently during the EU ETS trading periods. However, the ETS and Non-ETS firms in the Utilities, Health Care, and Consumer Discretionary sectors are considered indifferently by stock market investors during the same periods. This is particularly interesting as a similar investigation has only been made in Hughes (2000) in the US electric utility industry context, but not in the EU ETS context so far. The underperformance identified in the ETS-exposed firms in the Utilities and Health Care sectors is a reasonable outcome, which is in line with the assumption of concern over future environmental liability. However, the Non-ETS-exposed firms in the same sectors also experience a significant underperformance, which is a counterintuitive finding, and can only be explained by either the lack of market information regarding the ETS, or other sector-specific unidentified factors that drive the market to down-value these sectors. Tables 5.14–5.18 present all the estimation results for the long-short portfolio of each sector in different sample periods.

The differences in the performances among ETS portfolios during the operating period of the EU ETS are evident, as three sectors, including Materials, Industrials, and Consumer Discretionary, appear to outperform the benchmark while Consumer Staples, Health Care, and Utilities underperform. The results remain unchanged under different model specifications, and thus could provide a positive answer to the first research question, that an EU ETS effect on stock market performance can be differentiated at sector level for the exposed firms. The estimations are also done for two separate sample periods, which cover the first and part of the second trading phases of the EU ETS, respectively. This helps to see whether EU ETS effects on stock market performance vary across two separate trading periods. Tables 5.19–5.27 present the full estimation results for each sector-based portfolio, both ETS and Non ETS-exposed, for two separate sample periods (2005–2007 and 2008–2011).

The portfolio performance outcomes change slightly as the ETS transits from the first to the second trading period, with Industrials and Consumer Discretionary sectors showing outperformance against the benchmark. The Consumer Staples, Health-cCare, and Utilities remained the most affected sectors in the second trading period from the investors' perspectives. The persistent underperformance of the Utilities sector found in this analysis appears to contradict the rates of passing-through the CO_2 emissions trading-related costs by electricity firms proposed and examined in some studies, such as Sijm *et al*. (2006b) and Hourcade *et al*. (2007), who suggest that the Utility sector is even likely to gain from the trading scheme for the free allowances received and essentially being able to pass through the costs incurred due to the ETS. Nevertheless, the results in this analysis do not completely eliminate the existence of the cost pass-through as the CO_2 cost pass-through is also likely to be asymmetric (Zachmann and von Hirschhausen, 2008). The results are meant to purely suggest from empirically tested findings that the stock market has constantly valued the ETS-regulated firms in the Utilities sector negatively, and one of the possible causes could be the emissions status and the allowances holding position, one aspect specified in the second proposed research question in this chapter.

To sum up, the EU ETS still appeared costly at the sectoral level from financial market investors' perspectives as they suffered significant underperformance in their equity prices during the Pre-ETS period (2001–2004) when the emissions trading legislation was proposed and negotiated. On the other hand, three Non-ETS portfolios (Energy, Industrials, and Consumer Discretionary) show an outperformance during the same period; two (Materials and Health Care) have no significantly abnormal returns but the Utilities and Consumer Staples do also experience an underperformance. The results from the long–short portfolios' estimation suggest that EU ETS is the differentiating factor in terms of pricing the firms in certain sectors, in particular Energy, Materials, and Consumer Staples. On the contrary, the long–short portfolio estimation suggests that ETS participation does not lead to a substantially different valuation for firms in the Utilities, Health Care, and Consumer Discretionary sectors.

The finding of significant underperformance in the Pre-ETS period is in line with Hughes (2000) and Chapple *et el*. (2013), who find that future environmental liabilities could be value-destructive for firm value. Furthermore, the results provide a certain degree of positive answer to the first research question proposed, that the EU ETS effect on share prices can be differentiated at sector level, as distinct differences in the performance of the respective sector-based portfolios can be observed in the full and separate sub-sample periods, and between the ETS and Non-ETS portfolios. The sectoral differentiation of the

ETS regulation effects appears consistent with Hourcade *et al*. (2007), who suggest that differentiated effects come from the inherent exposure of the sector to emissions restriction. However, based on the tests of the Non ETS-exposed portfolios, the stock market might not able to fully integrate EU ETS-related information into its pricing process.

Another aspect revealed by the estimation results is the interaction between the stock market and the European carbon market, which measures how sensitive the ETS-exposed firms are to the variation in allowances prices. Overall, the interaction between the stock returns and the allowances price returns varies not only across sectors but also across different trading periods. Most of the sectors react negatively to the allowances price variation, which appears consistent with the original intention of the emissions trading regulation, which is to internalise the costs of CO_2 emissions, as the rise in allowances prices would increase the costs of firms, provided the firms needed to purchase additional emissions allowances for compliance. Table 5.5 provides an overview of the estimated coefficients of the allowances price factor in different estimation periods for seven ETS portfolios tested, and the extended regression results can be seen in Tables 5.19–5.25.

One very interesting finding is the positive coefficient estimated for the Utilities sector among the mostly negative, though insignificant, coefficients. This is somehow counterintuitive though it appears in line with Oberndorfer (2009), who also finds that the stock returns of EU ETS-regulated electricity companies are positively related to the changes in allowances prices during 2005–2007. One possible explanation is the large amount and high proportion of free allowances received by the electricity firms within the trading scheme, with investors perceiving that the holding of allowances could be value-relevant. This aspect is further explored and empirically tested in the second set of analysis, which is presented in Section 5.4.3.

The trading period differentiation applies to the investigation of the link between the stock market and the carbon market. The results show that the stock market–carbon market link was strengthened substantially in the second trading period of the EU ETS (2008–2011) compared with Phase 1 (2005–2007), with stock returns in five out of seven sectors showing sensitivity to allowances price returns. It appears a reasonable progress with the maturity of the carbon market, which is indicative of a more active market relative to that in Phase 1 (Bredin and Muckley, 2011; Mo *et al*., 2012); the information associated with carbon prices becomes more incorporated into the decision making process of stock market investors. The change in the sensitivity to allowances prices from Phase 1 to Phase 2 is also seen in Mo *et al*. (2012), who find the relation of the stock returns and allowance price changes moving from positive to negative from Phase 1 to Phase 2. They attribute this change to the adjustment of the allowances allocation policy in the second phase, during which allocations became more stringent.

Both aspects of interest in this chapter –portfolio performance and the estimated coefficients of the allowances price factor – provide supporting evidence for the proposed differentiation of the EU ETS effect at sectoral level. Despite the existence of the conceptual development of the sectoral differentiation by Hourcade *et al*. (2007) and the numerical cost impact analyses (Reinaud, 2004; Lund, 2007), it is not yet clear what empirically could be the factors associated with this differentiated effect on stock market performance, as indicated in the results above. The second research question in this chapter proposes that the emissions status of the ETS-regulated firms could be the potential deciding factor in driving this sectoral differentiation of the EU ETS' effect on stock market performance. The results of the empirical analysis of the emission status effect are presented in the following sections.

Table 5.6 Extended regression results of *Portfolio(sector$_i$)^{ETS}* for the sample period of Pre-EU ETS years (2001–2004)

Dependent variable	**R_p(Energy)^{ETS}**	**R_p(Materials)^{ETS}**	**R_p(Industrials)^{ETS}**	**R_p(Consumer Discretionary)^{ETS}**	**R_p(Consumer Staples)^{ETS}**	**R_p(Health Care)^{ETS}**	**R_p(Utilities)^{ETS}**
Sample period	12/1/2001 31/12/2004						
Constant	-0.009 (-5.94)***	-0.002 (-1.91)*	-0.003 (-1.78)*	0.010 (2.35)**	-0.014 (-7.01)***	-0.006 (-2.08)**	-0.012 (-6.23)***
R_M	0.711 (20.54)***	0.899 (36.46)***	0.881 (25.34)***	1.199 (13.13)***	0.639 (15.12)***	0.844 (14.14)***	0.660 (16.22)***
SMB	0.148 (2.13)**	0.639 (17.88)***	0.528 (7.82)***	0.482 (4.20)***	0.024 (0.35)	-0.430 (-4.47)***	0.222 (4.08)***
HML	0.166 (1.52)	0.302 (4.07)***	0.230 (1.82)*	0.324 (1.31)	-0.034 (-0.34)	-0.177 (-1.03)	0.141 (1.82)*
MOM	0.224 (2.43)**	0.019 (0.40)	0.012 (0.12)	0.233 (0.97)	0.729 (7.49)***	0.551 (3.96)***	0.355 (5.04)***
Observations	208	208	208	208	208	208	208
Adjusted R^2	0.71	0.87	0.66	0.64	0.62	0.67	0.74
P-value (F-stat.)	0 (126.4)	0 (360.9)	0 (100.1)	0 (93.42)	0 (85.67)	0 (106.2)	0 (148.9)

This table reports full regression results of estimating sector-based ***Portfolio(sectori)^{ETS}*** performance using the Carhart model ***Eq (56-1)*** under OLS with a Newey–West estimator. R_M is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of the risk-free rate; SMB and HML control for the investors incline towards the size and book-to-market value of firms, respectively; MOM controls for the momentum effect. the second to eighth columns show the estimated coefficients (*t*-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care, and Utilities companies-based portfolios, respectively. ***, **, * represent 1%, 5%, 10% statistical significance level, respectively

Table 5.7 Extended regression results of *Portfolio(sector$_i$)$^{Non-ETS}$* for the sample period of Pre-EU ETS years (2001–2004)

Dependent variable	**R_p(Energy)$^{Non-ETS}$**	**R_p(Materials)$^{Non-ETS}$**	**R_p(Industrials)$^{Non-ETS}$**	**R_p(Consumer Discretionary)$^{Non-ETS}$**	**R_p(Consumer Staples)$^{Non-ETS}$**	**R_p(Health Care)$^{Non-ETS}$**	**R_p(Utilities)$^{Non-ETS}$**
Sample period	12/1/2001 31/12/2004						
Constant	0.012 (2.17)**	-3.6E-05 (-0.02)	0.008 (6.68)***	0.009 (4.70)***	-0.011 (-5.71)***	0.003 (1.06)	-0.013 (-4.47)***
R_M	1.321 (9.12)***	0.921 (24.56)***	1.155 (49.01)***	1.164 (25.50)***	0.697 (17.40)***	1.043 (16.89)***	0.670 (10.36)***
SMB	0.898 (4.58)***	0.559 (9.44)***	0.664 (16.66)***	0.549 (10.56)***	0.009 (0.17)	0.507 (4.85)***	0.140 (2.06)**
HML	0.968 (3.72)***	0.063 (0.56)	0.151 (1.72)*	-0.078 (-0.63)	0.172 (2.09)**	0.116 (0.94)	0.145 (1.21)
MOM	0.343 (1.32)	0.213 (2.35)**	0.027 (0.42)	-0.063 (-0.83)	0.659 (9.21)***	0.300 (2.74)***	0.082 (0.70)
Observations	208	208	208	208	208	208	208
Adjusted R^2	0.57	0.73	0.93	0.89	0.74	0.74	0.63
P-value (F-stat.)	0 (70.84)	0 (143.97)	0 (703.82)	0 (433.43)	0 (149.57)	0 (145.83)	0 (90.32)

This table reports full regression results of estimating sector-based ***Portfolio(Sector$_i$)$^{Non-ETS}$*** performance using Carhart model ***Eq (56-1)*** under OLS with Newey-West estimator. R_M is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. the second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.8 Extended regression results of *Portfolio(sector$_i$)^{ETS}* for the continuous sample period 2005–2011

Dependent variable	***R_p(Energy)^{ETS}***	***R_p(Materials)^{ETS}***	***R_p(Industrials)^{ETS}***	***R_p(Consumer Discretionary)^{ETS}***	***R_p(Consumer Staples)^{ETS}***	***R_p(Health Care)^{ETS}***	***R_p(Utilities)^{ETS}***
Sample period	31/12/2004 30/12/2011						
Constant	-0.001 (-0.45)	0.003 (2.78)***	0.004 (4.02)***	0.007 (3.72)***	-0.009 (-6.20)***	-0.006 (-4.64)***	-0.006 (-4.85)***
R_M	0.969 (26.9)***	1.065 (46.79)***	1.065 (51.77)***	1.206 (25.90)***	0.727 (20.93)***	0.814 (30.74)***	0.806 (22.74)***
SMB	0.316 (4.09)***	0.756 (9.66)***	0.794 (10.25)***	0.705 (5.47)***	0.046 (0.47)	-0.657 (-5.25)***	0.060 (0.91)
HML	0.213 (2.13)**	0.142 (1.50)	-0.006 (-0.06)	0.217 (0.78)	-0.170 (-1.27)	-0.304 (-2.13)**	0.150 (1.77)*
MOM	0.449 (4.51)***	0.086 (1.25)	-0.098 (-1.35)	-0.231 (-1.05)	0.090 (0.61)	0.305 (1.96)*	0.251 (3.26)***
Observations	355	355	355	355	355	355	355
Adjusted R^2	0.84	0.94	0.90	0.79	0.69	0.73	0.86
P-value (F-stats.)	0 (461.9)	0 (1496)	0 (827.2)	0 (342.3)	0 (202.7)	0 (247.2)	0 (578.3)

This table reports full regression results of estimating sector-based ***Portfolio(sectori)^{ETS}*** using Carhart four-factor model ***Eq (56-1)*** under OLS with Newey-West estimator for the estimation period of 2005 to 2011. RM is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. The second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.9 Extended regression results of *Portfolio(sector$_i$)*$^{Non\text{-}ETS}$ for the continuous sample period 2005–2011

Dependent variable	*R_p(Energy)$^{Non\text{-}ETS}$*	*R_p(Materials)$^{Non\text{-}ETS}$*	*R_p(Industrials)$^{Non\text{-}ETS}$*	*R_p(Consumer Discretionary)$^{Non\text{-}ETS}$*	*R_p(Consumer Staples)$^{Non\text{-}ETS}$*	*R_p(Health Care)$^{Non\text{-}ETS}$*	*R_p(Utilities)$^{Non\text{-}ETS}$*
Sample period	31/12/2004 06/01/2012						
Constant	0.019 (4.89)***	0.012 (4.65)***	0.005 (4.37)***	0.002 (2.10)**	-0.005 (-4.73)***	-0.005 (-4.17)***	-0.008 (-5.72)***
R_M	1.441 (13.75)***	1.296 (20.40)***	1.108 (45.77)***	1.052 (37.91)***	0.823 (26.53)***	0.839 (30.84)***	0.749 (21.90)***
SMB	0.834 (3.43)***	0.654 (3.44)***	0.643 (8.26)***	0.693 (7.86)***	0.064 (1.10)	0.140 (1.90)*	-0.121 (-1.31)
HML	0.244 (0.91)	-0.295 (-1.42)	-0.083 (-0.91)	0.113 (0.89)	-0.293 (-3.06)***	-0.143 (-1.21)	-0.076 (-0.60)
MOM	0.616 (2.12)**	0.296 (1.35)	-0.008 (-0.10)	-0.089 (-0.59)	0.127 (1.10)	0.193 (1.50)	0.386 (3.37)***
Observations	367	367	367	367	367	367	367
Adjusted R^2	0.72	0.79	0.95	0.89	0.85	0.79	0.77
P-value (F-stats.)	0 (239.4)	0 (349.56)	0 (1600.23)	0 (724.27)	0 (510.03)	0 (350.64)	0 (308.61)

This table reports full regression results of estimating sector-based ***Portfolio(Sectori)***$^{Non\text{-}ETS}$ using Carhart 4-factor model ***Eq (56-1)*** under OLS with Newey-West estimator for the estimation period of 2005 to 2011. RM is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. The second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.10 Extended regression results of *Portfolio(sector$_i$)^{ETS}* for the continuous sample period 2005–2011 with allowances price control

Dependent variable	***R_p(Energy)^{ETS}***	***R_p(Materials)^{ETS}***	***R_p(Industrials)^{ETS}***	***R_p(Consumer Discretionary)^{ETS}***	***R_p(Consumer Staples)^{ETS}***	***R_p(Health Care)^{ETS}***	***R_p(Utilities)^{ETS}***
Sample period	18/3/2005 30/12/2011						
Constant	-0.001 (-0.67)	0.003 (2.68)***	0.003 (3.80)***	0.007 (3.72)***	-0.009 (-6.14)***	-0.006 (-4.76)***	-0.006 (-4.85)***
R_M	0.968 (26.9)***	1.066 (47.04)***	1.067 (51.60)***	1.209 (25.79)***	0.730 (20.96)***	0.815 (30.48)***	0.806 (22.54)***
SMB	0.315 (4.02)***	0.754 (9.59)***	0.791 (10.16)***	0.712 (5.47)***	0.050 (0.50)	-0.653 (-5.17)***	0.059 (0.88)
HML	0.205 (2.03)**	0.127 (1.33)	-0.026 (-0.28)	0.197 (0.69)	-0.194 (-1.39)	-0.305 (-2.08)**	0.136 (1.58)
MOM	0.441 (4.33)***	0.073 (1.05)	-0.116 (-1.60)	-0.252 (-1.11)	0.066 (0.44)	0.305 (1.91)*	0.241 (3.05)***
EUA	0.001 (0.64)	0.001 (0.82)	-0.002 (-2.55)**	-0.004 (-4.68)***	-0.005 (-4.23)***	-0.002 (-1.93)*	-0.001 (-0.45)
Observations	355	355	355	355	355	355	355
Adjusted R^2	0.84	0.94	0.91	0.79	0.69	0.73	0.86
P-value (F-stats.)	0 (1496)	0 (1172)	0 (675.8)	0 (267.3)	0 (159.1)	0 (192.3)	0 (451.2)

This table reports full regression results of estimating sector-based ***Portfolio(sectori)^{ETS}*** using Carhart 4-factor based model with added EUA price factor ***Eq (56-2)*** under OLS with Newey-West estimator for the sample period of 2005 to 2011. RM is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors' incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. The second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.11 Extended regression results of *Portfolio(sector$_i$)^{ETS}* for the continuous sample period 2005–2011 with allowances price controls

Dependent variable	*R_p(Energy)^{ETS}*	*R_p(Materials)^{ETS}*	*R_p(Industrials)^{ETS}*	*R_p(Consumer Discretionary)^{ETS}*	*R_p(Consumer Staples)^{ETS}*	*R_p(Health Care)^{ETS}*	*R_p(Utilities)^{ETS}*
Sample period	25/3/2005 30/12/2011						
Constant	-0.001 (-0.63)	0.003 (2.72)***	0.003 (3.80)***	0.007 (3.78)***	-0.009 (-6.14)***	-0.006 (-4.76)***	-0.006 (-4.83)***
R_M	0.968 (26.8)***	1.065 (46.91)***	1.067 (51.57)***	1.208 (25.91)***	0.731 (20.91)***	0.814 (30.30)***	0.806 (22.48)***
SMB	0.316 (4.01)***	0.755 (9.56)***	0.790 (10.10)***	0.709 (5.43)***	0.049 (0.49)	-0.651 (-5.15)***	0.059 (0.88)
HML	0.210 (2.06)**	0.130 (1.35)	-0.024 (-0.26)	0.213 (0.74)	-0.194 (-1.39)	-0.308 (-2.09)**	0.138 (1.60)
MOM	0.445 (4.38)***	0.076 (1.09)	-0.116 (-1.59)	-0.243 (-1.07)	0.065 (0.43)	0.305 (1.90)*	0.243 (3.06)***
EUA	0.001 (0.64)	0.001 (0.80)	-0.002 (-2.55)***	-0.004 (-4.06)***	-0.005 (-4.34)***	-0.003 (-1.98)**	-0.001 (-0.44)
EUA(-1)	0.001 (0.64)	0.001 (0.44)	-0.002 (-1.53)	-0.007 (-4.89)***	-0.001 (-0.23)	0.003 (2.49)**	-0.000 (-0.38)
Observations	354	354	354	354	354	354	354
Adjusted R^2	0.84	0.94	0.91	0.79	0.69	0.73	0.86
P-value (F-stats.)	0 (308.7)	0 (980.9)	0 (561.7)	0 (225.6)	0 (132)	0 (160.3)	0 (374.3)

This table reports full regression results of estimating sector-based ***Portfolio(sectori)^{ETS}*** using Carhart 4-factor model with EUA price factor added ***Eq (56-3)*** under OLS with Newey-West estimator for the sample period of 2005 to 2011. RM is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. The second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.12 Extended regression results of *Portfolio*(*sector*$_i$)^{ETS} for the sample period 2001–2011

Dependent variable	$R_p(Energy)^{ETS}$	$R_p(Materials)^{ETS}$	$R_p(Industrials)^{ETS}$	$R_p(Consumer\ Discretionary)^{ETS}$	$R_p(Consumer\ Staples)^{ETS}$	$R_p(Health\ Care)^{ETS}$	$R_p(Utilities)^{ETS}$
Sample period	12/01/2001 06/01/2012						
Constant	-0.002 (-1.62)	0.002 (2.29)**	0.002 (2.59)***	0.007 (4.58)***	-0.011 (-9.41)***	-0.006 (-5.47)***	-0.008 (-6.40)***
R_M	0.911 (29.45)***	1.020 (54.14)***	1.014 (50.86)***	1.187 (31.24)***	0.679 (25.39)***	0.804 (31.63)***	0.757 (23.20)***
SMB	0.285 (5.72)***	0.739 (15.45)***	0.718 (11.74)***	0.625 (6.81)***	0.077 (1.25)	-0.55 (-6.69)***	0.17 (3.84)***
HML	0.257 (4.21)***	0.260 (4.08)***	0.165 (2.41)**	0.377 (2.38)**	0.115 (1.47)	-0.166 (-1.48)	0.298 (4.56)***
MOM	0.420 (5.99)***	0.127 (2.82)***	0.027 (0.46)	-0.026 (-0.18)	0.412 (4.29)***	0.4 (4.18)***	0.353 (6.47)***
Observations	574	574	574	574	574	574	574
Adjusted R^2	0.81	0.93	0.84	0.75	0.66	0.70	0.84
P-value (F-stat)	0 (595.26)	0 (1811.4)	0 (776.93)	0 (431.53)	0 (280.83)	0 (356.18)	0 (725.38)

This table reports full regression results of estimating sector-based ***Portfolio(sectori)***^{ETS} performance using Carhart model ***Eq (56-1)*** under OLS with Newey-West estimator. RM is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. the second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.13 Extended regression results of *Portfolio(sector$_i$)*$^{Non\text{-}ETS}$ for the full sample period 2001–2011

Dependent variable	***R_p(Energy)***$^{Non\text{-}ETS}$	***R_p(Materials)***$^{Non\text{-}ETS}$	***R_p(Industrials)***$^{Non\text{-}ETS}$	***R_p(Consumer Discretionary)***$^{Non\text{-}ETS}$	***R_p(Consumer Staples)***$^{Non\text{-}ETS}$	***R_p(Health Care)***$^{Non\text{-}ETS}$	***R_p(Utilities)***$^{Non\text{-}ETS}$
Sample period	12/1/2001 06/01/2012						
Constant	0.017 (5.94)***	0.010 (4.87)***	0.005 (6.14)***	0.004 (4.19)***	-0.008 (-7.25)***	-0.004 (-3.94)***	-0.009 (-7.12)***
R_M	1.398 (19.37)***	1.185 (25.18)***	1.109 (58.72)***	1.089 (43.26)***	0.758 (28.01)***	0.870 (37.16)***	0.725 (24.45)***
SMB	0.889 (5.92)***	0.694 (6.33)***	0.648 (14.35)***	0.603 (10.69)***	0.089 (2.35)**	0.275 (4.23)***	0.008 (0.12)
HML	0.488 (2.46)**	0.026 (0.20)	-0.002 (-0.03)	-0.028 (-0.33)	0.097 (1.40)	-0.065 (-0.77)	-0.004 (-0.06)
MOM	0.639 (3.61)***	0.428 (3.57)***	0.025 (0.45)	-0.150* (-1.69)	0.458 (6.10)***	0.231 (2.78)***	0.328 (4.10)***
Observations	574	574	574	574	574	574	574
Adjusted R^2	0.69	0.77	0.94	0.89	0.81	0.77	0.73
P-value (F-stat)	0 (319.41)	0 (488.74)	0 (2319.97)	0 (1128.01)	0 (617.63)	0(472.4)	0 (394.85)

This table reports full regression results of estimating sector-based ***Portfolio(Sector$_i$)***$^{Non\text{-}ETS}$ performance using Carhart model ***Eq (56-1)*** under OLS with Newey-West estimator. R_M is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. the second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.14 Extended regression results of *Portfolio(sector$_i$)$^{Long-Short}$* for the sample period 2001–2004

Dependent variable	***R_p(Energy)$^{Long-Short}$***	***R_p(Materials)$^{Long-Short}$***	***R_p(Industrials)$^{Long-Short}$***	***R_p(Consumer Discretionary)$^{Long-Short}$***	***R_p(Consumer Staples)$^{Long-Short}$***	***R_p(Health Care)$^{Long-Short}$***	***R_p(Utilities)$^{Long-Short}$***
Sample period	12/01/2001 31/12/2004						
Constant	0.021 (3.94)***	0.002 (1.34)	0.010 (4.86)***	-0.001 (-0.34)	0.003 (1.93)*	0.008 (2.46)**	-0.000 (-0.28)
R_M	0.610 (4.70)***	0.022 (0.59)	0.274 (6.12)***	-0.034 (-0.54)	0.058 (1.85)*	0.199 (2.57)**	0.010 (0.27)
SMB	0.750 (4.55)***	-0.080 (-1.29)	0.136 (1.71)*	0.067 (0.60)	-0.015 (-0.27)	0.937 (7.15)***	-0.083 (-1.08)
HML	0.802 (3.01)***	-0.239 (-2.44)**	-0.079 (-0.61)	-0.402 (-1.87)*	0.205 (2.10)**	0.293 (1.61)	0.005 (0.05)
MOM	0.060 (0.46)	0.097 (2.28)**	0.007 (0.14)	-0.148 (-1.18)	-0.035 (-0.70)	-0.126 (-1.67)*	-0.136 (-2.83)***
Observations	208	208	208	208	208	208	208
Adjusted R^2	0.26	0.03	0.14	0.04	0.03	0.27	0.10
P-value (F-stat)	0 (18.91)	0.012 (2.45)	0 (9.14)	0.002 (3.10)	0.090 (2.68)	0 (20.36)	0 (6.62)

This table reports full regression results of estimating sector-based ***Portfolio(sectori)$^{Long-Short}$*** performance using Carhart model ***Eq (5~~6~~-1)*** under OLS with Newey-West estimator. RM is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. the second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.15 Extended regression results of *Portfolio(sector$_i$)* $^{Long\text{-}Short}$ for the full sample period 2005–2011

Dependent variable	R_p(Energy) $^{Long\text{-}Short}$	R_p(Materials) $^{Long\text{-}Short}$	R_p(Industrials) $^{Long\text{-}Short}$	R_p(Consumer Discretionary) $^{Long\text{-}Short}$	R_p(Consumer Staples) $^{Long\text{-}Short}$	R_p(Health Care) $^{Long\text{-}Short}$	R_p(Utilities) $^{Long\text{-}Short}$
Sample period	31/12/2004 30/12/2011						
Constant	0.019 (6.26)***	0.010 (4.55)***	0.001 (0.85)	-0.005 (-2.57)**	0.003 (3.15)***	0.001 (0.76)	-0.002 (-1.68)*
R_M	0.471 (5.74)***	0.228 (4.48)***	0.042 (1.69)*	-0.154 (-3.40)***	0.096 (3.51)***	0.024 (0.98)	-0.057 (-2.51)**
SMB	0.517 (2.70)***	-0.103 (-0.79)	-0.152 (-2.38)**	-0.012 (-0.10)	0.018 (0.27)	0.797 (8.16)***	-0.180 (-2.92)***
HML	0.037 (0.17)	-0.424 (-2.83)***	-0.076 (-0.72)	-0.102 (-0.46)	-0.124 (-1.26)	0.162 (1.37)	-0.229 (-2.39)**
MOM	0.084 (0.74)	0.106 (1.13)	0.045 (0.99)	0.072 (0.73)	0.019 (0.45)	-0.056 (-1.17)	0.067 (1.21)
Observations	366	366	366	366	366	366	366
Adjusted R^2	0.27	0.14	0.02	0.07	0.04	0.26	0.13
P-value (F-stat)	0 (34.29)	0 (15.93)	0.054 (3.25)	0 (8.44)	0.005 (4.88)	0 (32.92)	0 (15.08)

This table reports full regression results of estimating sector-based ***Portfolio(Sector$_i$)***$^{Long\text{-}Short}$ performance using Carhart model ***Eq (56-1)*** under OLS with Newey-West estimator. R_M is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. the second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.16 Extended regression results of *Portfolio(sector$_i$)* $^{Long\text{-}Short}$ for the sample period 2005–2007

Dependent variable	***R_p(Energy)*** $^{Long\text{-}Short}$	***R_p(Materials)*** $^{Long\text{-}Short}$	***R_p(Industrials)*** $^{Long\text{-}Short}$	***R_p(Consumer Discretionary)*** $^{Long\text{-}Short}$	***R_p(Consumer Staples)*** $^{Long\text{-}Short}$	***R_p(Health Care)*** $^{Long\text{-}Short}$	***R_p(Utilities)*** $^{Long\text{-}Short}$
Sample period	18/3/2005 28/12/2007						
Constant	0.010 (2.94)***	0.010 (3.87)***	0.005 (1.70)*	-0.000 (-0.12)	0.006 (2.93)***	0.002 (0.74)	0.003 (1.62)
R_M	0.173 (2.36)**	0.217 (3.45)***	0.164 (2.71)***	-0.024 (-0.30)	0.128 (2.82)***	0.009 (0.16)	0.085 (1.90)*
SMB	0.371 (1.95)*	-0.159 (-1.50)	-0.149 (-1.70)*	0.153 (0.99)	-0.153 (-1.72)*	0.398 (2.22)**	-0.076 (-0.78)
HML	0.305 (0.87)	-0.397 (-1.44)	-0.354 (-1.66)*	-0.022 (-0.09)	-0.083 (-0.40)	0.259 (0.90)	-0.175 (-0.94)
MOM	0.699 (5.98)***	0.413 (4.72)***	0.086 (1.25)	0.052 (0.53)	0.078 (1.19)	0.190 (1.90)*	-0.106 (-1.26)
Observations	146	146	146	146	146	146	146
Adjusted R^2	0.38	0.33	0.08	-0.002	0.04	0.14	0.02
P-value (F-stat)	0 (19.0)	0 (15.0)	0.001 (3.64)	0.14 (0.94)	0.015 (2.23)	0 (5.59)	0.22 (1.47)

This table reports full regression results of estimating sector-based ***Portfolio(sectori)*** $^{Long\text{-}Short}$ performance using Carhart model ***Eq (56-1)*** under OLS with Newey-West estimator. R_M is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. the second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.17 Extended regression results of *Portfolio(sector$_i$)* $^{Long\text{-}Short}$ for the full sample period 2008–2011

Dependent variable	***R$_p$(Energy)*** $^{Long\text{-}Short}$	***R$_p$(Materials)*** $^{Long\text{-}Short}$	***R$_p$(Industrials)*** $^{Long\text{-}Short}$	***R$_p$(Consumer Discretionary)*** $^{Long\text{-}Short}$	***R$_p$(Consumer Staples)*** $^{Long\text{-}Short}$	***R$_p$(Health Care)*** $^{Long\text{-}Short}$	***R$_p$(Utilities)*** $^{Long\text{-}Short}$
Sample period	04/1/2008 30/12/2011						
Constant	0.019 (6.08)***	0.009 (3.91)***	0.001 (0.75)	-0.004 (-2.06)**	0.003 (2.27)**	-0.000 (-0.10)	-0.001 (-1.17)
R_M	0.528 (5.81)***	0.224 (3.95)***	0.005 (0.19)	-0.192 (-3.38)***	0.096 (2.70)***	0.043 (1.48)	-0.086 (-3.29)***
SMB	0.457 (1.93)*	-0.157 (-0.92)	-0.175 (-2.09)**	-0.084 (-0.54)	0.082 (0.91)	0.899 (8.18)***	-0.184 (-2.59)**
HML	-0.203 (-0.79)	-0.498 (-2.59)**	0.004 (0.03)	-0.057 (-0.21)	-0.110 (-0.89)	0.076 (0.57)	-0.153 (-1.40)
MOM	-0.078 (-0.61)	0.023 (0.20)	0.037 (0.66)	0.073 (0.63)	0.020 (0.38)	-0.123 (-2.71)***	0.112 (1.76)*
Observation	209	209	209	209	209	209	209
Adjusted R^2	0.30	0.11	0.01	0.09	0.04	0.35	0.22
P-value (F-stat)	0 (18.68)	0 (6.37)	0.014 (1.56)	0 (5.33)	0.001 (2.66)	0 (23.02)	0 (12.85)

This table reports full regression results of estimating sector-based ***Portfolio(Sector$_i$)***$^{Long\text{-}Short}$ performance using Carhart model ***Eq (56-1)*** under OLS with Newey-West estimator. R_M is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. the second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance level respectively.

Table 5.18 Extended regression results of *Portfolio(sector$_i$)* $^{Long\text{-}Short}$ **for the full sample period 2001–2011**

Dependent variable	***R_p(Energy)*** *Long-Short*	***R_p(Materials)*** *Long-Short*	***R_p(Industrials)*** *Long-Short*	***R_p(Consumer Discretionary)*** *Long-Short*	***R_p(Consumer Staples)*** *Long-Short*	***R_p(Health Care)*** *Long-Short*	***R_p(Utilities)*** *Long-Short*
Sample period	12/1/2001 30/12/2011						
Constant	0.019 (7.78)***	0.008 (5.03)***	0.003 (2.75)***	-0.003 (-2.17)**	0.003 (3.82)***	0.003 (2.15)**	-0.001 (-1.32)
R_M	0.485 (8.16)***	0.164 (4.60)***	0.096 (3.69)***	-0.096 (-3.07)***	0.080 (3.93)***	0.066 (2.33)**	-0.032 (-1.65)*
SMB	0.602 (4.79)***	-0.046 (-0.61)	-0.067 (-1.21)	-0.020 (-0.23)	0.013 (0.29)	0.823 (10.7)***	-0.161 (-3.08)***
HML	0.236 (1.29)	-0.230 (-2.71)***	-0.175 (-2.38)**	-0.413 (-3.71)***	-0.020 (-0.34)	0.097 (1.07)	-0.303 (-5.16)***
MOM	0.109 (1.36)	0.150 (3.03)***	-0.000 (-0.01)	-0.061 (-0.97)	0.023 (0.76)	-0.101 (-2.54)**	-0.013 (-0.35)
Observations	573	573	573	573	573	573	573
Adjusted R^2	0.26	0.10	0.05	0.05	0.03	0.26	0.08
P-value (F-stat)	0 (50.51)	0 (17.33)	0 (8.17)	0 (8.89)	0.003 (5.42)	0 (50.67)	0 (14.1)

This table reports full regression results of estimating sector-based ***Portfolio(Sector$_i$)***$^{Long\text{-}Short}$ performance using Carhart model ***Eq (5~~6~~-1)*** under OLS with Newey-West estimator. R_M is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. the second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance level respectively.

Table 5.19 Regression results of *Portfolio(Energy)*^{ETS} for sub-sample periods Phase 1 and Phase 2

Dependent variable	$R_p(Energy)^{ETS}$					
Model Specification	*Eq (5~~6~~-1)*	*Eq (5~~6~~-2)*	*Eq (5~~6~~-3)*	*Eq (5-1)~~Eq (6-1)~~*	*Eq (5-2)~~Eq (6-2)~~*	*Eq (5-3)~~Eq (6-3)~~*
Sample period	07/01/2005 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	27/12/2007 30/12/2011	27/12/2007 30/12/2012	27/12/2007 30/12/2013
Constant	0.001 (0.38)	0.000 (0.05)	0.000 (0.09)	-0.002 (-1.29)	-0.002 (-1.28)	-0.002 (-1.28)
R_M	1.003 (15.44)***	0.985 (14.53)***	0.981 (14.77)***	0.957 (23.27)***	0.957 (23.24)***	0.957 (23.22)***
SMB	0.247 (2.34)**	0.259 (2.28)**	0.250 (2.10)**	0.300 (2.91)***	0.300 (2.88)***	0.301 (2.88)***
HML	-0.181 (-0.63)	-0.185 (-0.61)	-0.152 (-0.50)	0.239 (1.98)**	0.239 (1.97)*	0.237 (1.95)*
MOM	0.689 (3.54)***	0.663 (3.07)***	0.700 (3.20)***	0.372 (2.92)***	0.372 (2.91)***	0.371 (2.90)***
EUA		0.006 (0.95)	0.006 (0.89)		-0.000 (-0.23)	-0.000 (-0.24)
EUA(-1)			0.003 (0.34)			0.001 (1.20)
Observations	157	146	145	210	210	210
Adjusted R^2	0.64	0.64	0.65	0.89	0.89	0.89
P-value (F-stats.)	0 (71.44)	0 (53.37)	0 (45.15)	0 (425.5)	0 (338.7)	0 (281)

The table reports coefficients (*t*-stats) from the regression results of ***Portfolio(Energy)***^{ETS} under OLS with a Newey–West estimator in two separate sub-sample periods, 2005–2007 and 2008–2011. R_M is the risk premium measured by the sector index logged return in excess of the risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is the logged weekly return of EEX EUA spot while EUA(-1) represents the allowances price return of the previous observation. The second to fourth columns show the estimated coefficients (*t*-stat) for the sample period 2005–2007. The fifth to seventh columns show the estimated coefficients (*t*-stat) for the sample period 2008–2011. ***, **, * represent 1%, 5%, 10% statistical significance levels, respectively.

Table 5.20 Regression results of *Portfolio(Materials)*^{ETS} for sub-sample periods Phase 1 and Phase 2

Dependent variable	$R_p(Materials)^{ETS}$					
Model Specification	*Eq (5-1)*~~*Eq (6-1)*~~	*Eq (5-2)*~~*Eq (6-2)*~~	*Eq (5-3)*~~*Eq (6-3)*~~	*Eq (5-1)*~~*Eq (6-1)*~~	*Eq (5-2)*~~*Eq (6-2)*~~	*Eq (5-3)*~~*Eq (6-3)*~~
Sample period	31/12/2004 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	28/12/2007 30/12/2011	28/12/2007 30/12/2011	28/12/2007 30/12/2011
Constant	0.004 (2.37)**	0.004 (2.02)**	0.004 (2.29)**	0.001 (1.38)	0.001 (1.35)	0.001 (1.30)
R_M	1.050 (26.21)***	1.049 (25.49)***	1.058 (26.51)***	1.078 (39.20)***	1.078 (39.31)***	1.079 (38.98)***
SMB	0.505 (10.03)***	0.511 (9.64)***	0.531 (10.28)***	0.816 (9.01)***	0.813 (8.87)***	0.817 (8.94)***
HML	0.143 (1.06)	0.078 (0.57)	0.089 (0.63)	0.095 (0.98)	0.096 (0.98)	0.086 (0.89)
MOM	0.436 (5.29)***	0.398 (4.56)***	0.376 (4.01)***	0.004 (0.06)	0.006 (0.08)	0.0003 (0.00)
EUA		-0.001 (-0.33)	-2E-05 (-0.01)		0.001 (1.28)	0.001 (1.24)
EUA(-1)			-0.007 (-2.63)**			0.003 (7.33)***
Observations	157	146	145	210	210	210
Adjusted R^2	0.90	0.89	0.90	0.96	0.96	0.96
P-value (F-stats.)	0 (338)	0 (243.7)	0 (218.2)	0 (1120)	0 (892.9)	0 (753.2)

The table reports coefficients (t-stats) from the regression results of ***Portfolio(Materials)***^{ETS} under OLS with Newey-West estimator in two separate sub-sample periods, 2005 to 2007 and 2008 to 2011. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance price return of the previous observation. The second to fourth columns show the estimated coefficients (t-stat) for the sample period 2005 to 2007. The fifth to seventh columns show the estimated coefficients (t-stat) for the sample period 2008 to 2011. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.21 Regression results of *Portfolio(Industrials)^{ETS}* for sub-sample periods Phase 1 and Phase 2

Dependent variable	***R_p(Industrials)^{ETS}***					
Model Specification	*Eq (5-1)*~~*Eq (6-1)*~~	*Eq (5-2)*~~*Eq (6-2)*~~	*Eq (5-3)*~~*Eq (6-3)*~~	*Eq (5-1)*~~*Eq (6-1)*~~	*Eq (5-2)*~~*Eq (6-2)*~~	*Eq (5-3)*~~*Eq (6-3)*~~
Sample period	31/12/2004 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	28/12/2007 30/12/2011	28/12/2007 30/12/2011	28/12/2007 30/12/2011
Constant	0.004 (1.64)	0.003 (1.07)	0.003 (1.15)	0.002 (2.44)**	0.003 (2.51)**	0.003 (2.50)**
R_M	1.010 (18.18)***	0.992 (17.56)***	1.003 (18.10)***	1.095 (43.47)***	1.096 (43.49)***	1.096 (43.24)***
SMB	0.664 (7.14)***	0.642 (7.21)***	0.665 (7.09)***	0.830 (8.72)***	0.836 (8.73)***	0.836 (8.68)***
HML	0.117 (0.66)	0.053 (0.28)	0.041 (0.22)	-0.088 (-0.86)	-0.089 (-0.87)	-0.090 (-0.87)
MOM	0.093 (0.73)	0.083 (0.60)	0.040 (0.28)	-0.154 (-2.10)**	-0.158 (-2.16)**	-0.159 (-2.15)**
EUA		-0.001 (-0.27)	-0.000 (-0.09)		-0.002 (-4.01)***	-0.002 (-3.96)***
EUA(-1)			-0.008 (-1.79)*			0.000 (0.17)
Observations	157	146	145	210	210	210
Adjusted R^2	0.78	0.78	0.79	0.93	0.93	0.93
P-value (F-stats.)	0 (135)	0 (106)	0 (89.19)	0 (669.1)	0 (535.4)	0 (444)

The table reports coefficients (t-stats) from the regression results of ***Portfolio(Industrials)^{ETS}*** under OLS with Newey-West estimator in two separate sub-sample periods, 2005 to 2007 and 2008 to 2011. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance price return of the previous observation. The second to fourth columns show the estimated coefficients (t-stat) for the sample period 2005 to 2007. The fifth to seventh columns show the estimated coefficients (t-stat) for the sample period 2008 to 2011. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.22 Regression results of *Portfolio(Consumer Discretionary)*^{ETS} for sub-sample periods Phase 1 and Phase 2

Dependent variable	***R_p(Consumer Discretionary)***^{ETS}					
Model specification	*Eq (5-1)*~~*Eq (6-1)*~~	*Eq (5-2)*~~*Eq (6-2)*~~	*Eq (5-3)*~~*Eq (6-3)*~~	*Eq (5-1)*~~*Eq (6-1)*~~	*Eq (5-2)*~~*Eq (6-2)*~~	*Eq (5-3)*~~*Eq (6-3)*~~
Sample period	31/12/2004 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	28/12/2007 30/12/2011	28/12/2007 30/12/2011	28/12/2007 30/12/2011
Constant	0.001 (0.32)	0.000 (0.04)	0.000 (0.09)	0.007 (3.34)***	0.007 (3.44)***	0.007 (3.53)***
R_M	1.028 (15.05)***	1.020 (14.56)***	1.019 (14.14)***	1.258 (20.99)***	1.260 (21.04)***	1.256 (21.13)***
SMB	0.327 (1.95)*	0.313 (1.79)*	0.309 (1.75)*	0.880 (5.82)***	0.892 (5.89)***	0.883 (5.77)***
HML	0.340 (1.48)	0.214 (0.87)	0.241 (0.97)	0.197 (0.63)	0.195 (0.63)	0.217 (0.69)
MOM	-0.171 (-0.98)	-0.220 (-1.15)	-0.194 (-1.01)	-0.172 (-0.67)	-0.180 (-0.69)	-0.167 (-0.65)
EUA		-0.005 (-1.00)	-0.004 (-0.94)		-0.004 (-4.56)***	-0.004 (-4.42)***
EUA(-1)			0.001 (0.22)			-0.007 (-4.03)***
Observations	157	146	145	210	210	210
Adjusted R^2	0.65	0.64	0.64	0.81	0.81	0.81
P-value (F-stats.)	0 (71.92)	0 (51.74)	0 (43.45)	0 (226)	0 (180.9)	0 (152.5)

The table reports coefficients (t-stats) from the regression results of ***Portfolio(Consumer Discretionary)***^{ETS} under OLS with Newey-West estimator in two separate sub-sample periods, 2005 to 2007 and 2008 to 2011. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance price return of the previous observation. The second to fourth columns show the estimated coefficients (t-stat) for the sample period 2005 to 2007. The fifth to seventh columns show the estimated coefficients (t-stat) for the sample period 2008 to 2011. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.23 Regression results of *Portfolio(Consumer Staples)^{ETS}* for sub-sample periods Phase 1 and Phase 2

Dependent variable	***R_p(Consumer Staples)^{ETS}***					
Model specification	Eq (5-1)~~Eq (6-1)~~	Eq (5-2)~~Eq (6-2)~~	Eq (5-3)~~Eq (6-3)~~	Eq (5-1)~~Eq (6-1)~~	Eq (5-2)~~Eq (6-2)~~	Eq (5-3)~~Eq (6-3)~~
Sample period	31/12/2004 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	04/01/2008 30/12/2011	04/01/2008 30/12/2012	04/01/2008 30/12/2013
Constant	-0.013 (-7.75)***	-0.014 (-8.05)***	-0.014 (-8.48)***	-0.007 (-4.37)***	-0.007 (-4.28)***	-0.007 (-4.22)***
R_M	0.666 (17.54)***	0.657 (17.17)***	0.642 (17.01)***	0.731 (16.32)***	0.734 (16.42)***	0.732 (16.25)***
SMB	0.351 (3.51)***	0.343 (3.35)***	0.312 (3.18)***	-0.026 (-0.21)	-0.009 (-0.07)	-0.013 (-0.10)
HML	-0.018 (-0.09)	-0.120 (-0.61)	-0.117 (-0.61)	-0.161 (-1.01)	-0.164 (-1.03)	-0.153 (-0.96)
MOM	-0.296 (-1.96)*	-0.371 (-2.36)**	-0.323 (-2.11)**	0.186 (1.06)	0.175 (0.99)	0.181 (1.03)
EUA		0.001 (0.39)	0.000 (0.05)		-0.006 (-8.13)***	-0.006 (-8.08)***
EUA(-1)			0.010 (2.30)**			-0.003 (-4.86)***
Observations	157	146	145	210	210	210
Adjusted R^2	0.58	0.56	0.57	0.71	0.71	0.71
P-value (F-stats.)	0 (53.95)	0 (37.83)	0 (33.15)	0 (126.8)	0 (103.5)	0 (86.56)

The table reports coefficients (t-stats) from the regression results of ***Portfolio(Consumer Staples)^{ETS}*** under OLS with Newey-West estimator in two separate sub-sample periods, 2005 to 2007 and 2008 to 2011. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance price return of the previous observation. The second to fourth columns show the estimated coefficients (t-stat) for the sample period 2005 to 2007. The fifth to seventh columns show the estimated coefficients (t-stat) for the sample period 2008 to 2011. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.24 Regression results of *Portfolio(Health Care)^{ETS}* for sub-sample periods Phase 1 and Phase 2

Dependent variable	***R_p(Health Care)^{ETS}***					
Model specification	~~Eq (6-1)~~ ***Eq (5-1)***	~~Eq (6-2)~~ ***Eq (5-2)***	~~Eq (6-3)~~ ***Eq (5-3)***	~~Eq (6-1)~~ ***Eq (5-1)***	~~Eq (6-2)~~ ***Eq (5-2)***	~~Eq (6-3)~~ ***Eq (5-3)***
Sample period	31/12/2004 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	04/01/2008 30/12/2011	04/01/2008 30/12/2012	04/01/2008 30/12/2013
Constant	-0.005 (-2.43)**	-0.007 (-3.05)***	-0.007 (-3.02)***	-0.004 (-2.88)***	-0.004 (-2.79)***	-0.004 (-2.81)***
R_M	0.889 (21.34)***	0.869 (21.16)***	0.873 (21.47)***	0.786 (22.22)***	0.787 (22.14)***	0.788 (22.09)***
SMB	-0.111 (-0.72)	-0.111 (-0.70)	-0.104 (-0.67)	-0.773 (-5.59)***	-0.763 (-5.53)***	-0.761 (-5.48)***
HML	-0.730 (-3.33)***	-0.842 (-3.82)***	-0.844 (-3.81)***	-0.127 (-0.92)	-0.128 (-0.92)	-0.133 (-0.95)
MOM	-0.689 (-3.96)***	-0.748 (-4.05)***	-0.760 (-4.18)***	0.548 (3.25)***	0.541 (3.20)***	0.538 (3.16)***
EUA		0.001 (0.22)	0.001 (0.29)		-0.003 (-2.46)**	-0.003 (-2.47)**
EUA(-1)			-0.002 (-0.47)			0.001 (2.15)**
Observation	157	146	145	210	210	210
Adjusted R^2	0.64	0.63	0.63	0.77	0.77	0.77
P-value (F-stats.)	0 (70.66)	0 (50.4)	0 (41.5)	0 (173.8)	0 (139.4)	0 (115.8)

The table reports coefficients (t-stats) from the regression results of ***Portfolio(Health Care)^{ETS}*** under OLS with Newey-West estimator in two separate sub-sample periods, 2005 to 2007 and 2008 to 2011. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance price return of the previous observation. The second to fourth columns show the estimated coefficients (t-stat) for the sample period 2005 to 2007. The fifth to seventh columns show the estimated coefficients (t-stat) for the sample period 2008 to 2011. ***, **, * represent 1%, 5%, 10% statistical significance level respectively

Table 5.25 Regression results of *Portfolio(Utilities)*^{ETS} for sub-sample periods Phase 1 and Phase 2

Dependent variable	***R_p(Utilities)^{ETS}***					
Model specification	Eq (5-1)Eq (6-1)	Eq (5-2)Eq (6-2)	Eq (5-3)Eq (6-3)	Eq (5-1)Eq (6-1)	Eq (5-2)Eq (6-2)	Eq (5-3)Eq (6-3)
Sample period	31/12/2004 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	04/01/2008 30/12/2011	04/01/2008 30/12/2012	04/01/2008 30/12/2013
Constant	-0.008 (-4.45)***	-0.008 (-4.95)***	-0.008 (-4.88)***	-0.006 (-4.74)***	-0.006 (-4.66)***	-0.006 (-4.64)***
R_M	0.757 (19.82)***	0.738 (20.60)***	0.737 (20.53)***	0.813 (19.73)***	0.814 (19.70)***	0.814 (19.62)***
SMB	0.114 (1.36)	0.116 (1.42)	0.113 (1.40)	0.005 (0.06)	0.013 (0.14)	0.012 (0.13)
HML	0.123 (0.76)	0.120 (0.70)	0.130 (0.76)	0.095 (0.96)	0.094 (0.95)	0.095 (0.95)
MOM	0.479 (3.81)***	0.475 (3.51)***	0.487 (3.50)***	0.169 (1.78)	0.164 (1.71)	0.164 (1.71)
EUA		0.010 (3.75)***	0.010 (3.78)***		-0.002 (-3.83)***	-0.002 (-3.84)***
EUA(-1)			0.001 (0.32)			-0.000 (-0.34)
Observation	157	146	145	210	210	210
Adjusted R^2	0.77	0.78	0.78	0.88	0.88	0.88
P-value (F-statistics)	0 (130.8)	0 (102.6)	0 (85.13)	0 (386.2)	0 (309.9)	0 (257.1)

The table reports coefficients (t-stats) from the regression results of ***Portfolio(Utilities)***^{ETS} under OLS with Newey-West estimator in two separate sub-sample periods, 2005 to 2007 and 2008 to 2011. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of the previous observation. The second to fourth columns show the estimated coefficients (t-stat) for the sample period 2005 to 2007. The fifth to seventh columns show the estimated coefficients (t-stat) for the sample period 2008 to 2011. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.26 Extended regression results of *Portfolio(sector$_i$)*$^{Non\text{-}ETS}$ for sub-sample period Phase 1

Dependent variable	**R_p(Energy)$^{Non\text{-}ETS}$**	**R_p(Materials)$^{Non\text{-}ETS}$**	**R_p(Industrials)$^{Non\text{-}ETS}$**	**R_p(Consumer Discretionary)$^{Non\text{-}ETS}$**	**R_p(Consumer Staples)$^{Non\text{-}ETS}$**	**R_p(Health Care)$^{Non\text{-}ETS}$**	**R_p(Utilities)$^{Non\text{-}ETS}$**
Sample period	31/12/2004 28/12/2007						
Constant	0.011 (2.73)***	0.014 (4.91)***	0.008 (6.58)***	-0.000 (-0.30)	-0.008 (-4.74)***	-0.005 (-2.49)**	-0.005 (-2.75)***
R_M	1.175 (12.26)***	1.265 (18.75)***	1.155 (45.60)***	0.996 (31.25)***	0.789 (18.61)***	0.856 (17.07)***	0.832 (17.28)***
SMB	0.620 (3.31)***	0.33 (2.90)***	0.493 (10.86)***	0.459 (6.28)***	0.182 (2.20)**	0.274 (2.91)***	0.021 (0.20)
HML	-0.089 (-0.20)	-0.345 (-1.42)	-0.259 (-2.35)**	0.193 (1.57)	-0.154 (-0.79)	-0.386 (-1.81)*	-0.081 (-0.41)
MOM	1.945 (7.12)***	1.184 (6.32)***	0.258 (4.14)***	-0.099 (-1.17)	-0.174 (-1.31)	-0.181 (-1.02)	0.292 (1.51)
Observations	157	157	157	157	157	157	157
Adjusted R^2	0.69	0.82	0.95	0.91	0.77	0.72	0.66
P-value (F-statistic)	0 (87.95)	0 (181.17)	0 (667.59)	0 (383.05)	0 (133.07)	0 (99.32)	0 (75.43)

This table reports full regression results of estimating sector-based ***Portfolio(Sector$_i$)***$^{Non\text{-}ETS}$ using Carhart 4-factor based model ***Eq (6-1)*** under OLS with Newey-West estimator for the sample period of 2005 to 2007. R_M is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of risk-free rate; SMB and HML controls for the investors' incline towards size and book-to-market value of firms respectively; MOM controls for the momentum effect. The second to eighth columns show the estimated coefficients (t-stats) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care and Utilities companies-based portfolio, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.27 Extended regression results of *Portfolio(sector$_i$)$^{Non-ETS}$* for sub- sample period Phase 2

Dependent variable	**R_p(Energy)$^{Non-ETS}$**	**R_p(Materials)$^{Non-ETS}$**	**R_p(Industrials)$^{Non-ETS}$**	**R_p(Consumer Discretionary)$^{Non-ETS}$**	**R_p(Consumer Staples)$^{Non-ETS}$**	**R_p(Health Care)$^{Non-ETS}$**	**R_p(Utilities)$^{Non-ETS}$**
Sample period	28/12/2007 6/1/2012						
Constant	0.017 (4.63)***	0.010 (3.78)***	0.003 (3.08)***	0.003 (2.30)**	-0.004 (-3.25)***	-0.004 (-2.72)***	-0.007 (-4.73)***
R_M	1.484 (13.16)***	1.307 (18.21)***	1.100 (39.79)***	1.067 (29.77)***	0.825 (21.61)***	0.828 (22.23)***	0.724 (15.97)***
SMB	0.756 (2.50)**	0.669 (2.78)***	0.662 (6.40)***	0.803 (7.34)***	0.061 (0.88)	0.128 (1.41)	-0.177 (-1.50)
HML	0.032 (0.10)	-0.419 (-1.77)*	-0.086 (-0.87)	0.138 (0.91)	-0.265 (-2.48)**	-0.050 (-0.39)	-0.051 (-0.33)
MOM	0.217 (0.63)	0.042 (0.17)	-0.085 (-0.86)	-0.030 (-0.16)	0.223 (1.63)	0.301 (2.02)**	0.391 (2.90)***
Observations	211	211	211	211	211	211	211
Adjusted R^2	0.75	0.80	0.95	0.89	0.86	0.80	0.80
P-value (F-statisitcs)	0 (161)	0 (206.65)	0 (961.63)	0 (404.74)	0 (323.13)	0 (213.99)	0 (204.9)

This table reports full regression results of estimating sector-based ***Portfolio(Sectori)$^{Non-ETS}$*** using the Carhart four-factor model under OLS with a Newey–West estimator for the sample period 2008–2011. R_M is the risk premium measured by the logged return of the market benchmark (MSCI Europe index) in excess of the risk-free rate; SMB and HML control for the investors incline towards size and book-to-market value of firms, respectively; MOM controls for the momentum effect. The second to eighth columns show the estimated coefficients (*t*-statistics) of Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care, and Utilities companies-based portfolios, respectively. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

5.4.2 Emissions-to-cap status analysis of the main sectors

This section presents the result of a basic comparative and statistical analysis of sectoral emissions status and stock prices performance measured by the respective portfolio, which is intended to form the first step in empirically examining the second proposed research question and enhancing the connection between the first and the second research questions. This extends the analysis conducted previously that focused solely on whether ETS effects on financial performances differed across individual sectors, and provides straightforward observations with statistical evidence regarding the association of the allowances holding position with the stock market performance at sector level.

Table 5.28 reveals two major aspects. The first is the actual sectoral emissions-to-cap (E-C) status with numerical data, and the second concerns the statistical perspective of the sectoral E-C ratio being significantly different from an 'on par' allowances holding position. At first glance, the Energy sector appeared to have a constant long position in allowances during Phase 1, with emissions below the cap by an average of 1.85% . The Materials sector had emissions below the cap by an average of 13.5%, and the Utilities sector had emissions above the cap by an average of 10.8%. The E-C ratios and the portfolio performance measured by the estimated alphas of the Materials and Utilities sectors appeared consistent with the value relevance of the allowances tested and proven in the US SO_2 market context by Johnston *et al*. (2008), as the stock market valued the Materials sector with the positive allowances holdings positively and the Utilities sector with the negative allowances holdings negatively during Phase 1.

However, the stock market appeared indifferent in valuing the Energy sector, which also had a positive allowances holding position in Phase 1. A one-sample *t*-test helps to explain this finding, as shown in Table 5.28. The Energy sector had a different emissions-to-cap status in Phase 1 and Phase 2 as indicated by the figures, however, the two-tailed one-sample *t*-test applied could not reject the hypothesis that the observed E-C ratio is different from zero at commonly accepted statistical significance levels. Turning attention to the Utilities sector, which is short of allowances in both trading periods, produces a more convincing outcome. The *t*-test shows that the E-C ratios of the Utilities sectors are significantly different from zero in both estimation periods, which indicates that the level of over-emitting is considerably high and could not be omitted. The persistent underperformance identified in the sector-based portfolio performance seems to respond coherently, as the market seems to penalise Utilities firms for emitting over their designated cap. The result of the Materials sector for Phase 1 indicates that the significant outperformance of the stock return is accompanied by the statistically verified under-emitting, which enhances the supporting evidence for the value-relevance of the sectoral emissions status.

Table 5.28 Emissions-to-cap status of the main sectors

	Energy Sector			**Materials Sector**			**Utilities Sector**		
Year (1)	**E-C Ratio (2)**	**T-Test (3)**	**Alpha (4)**	**E-C Ratio (5)**	**T-Test (6)**	**Alpha (7)**	**E-C Ratio (8)**	**T-Test (9)**	**Alpha (10)**
2005	-3.22%			-15.94%			8.56%		
2006	-1.23%			-13.19%			11.18 %		
2007	-1.11%			-11.33%			12.59 %		
Phase 1		-2.21	~ 0		-8.22**	+++		7.45**	⊖⊖⊖
2008	10.83 %			-14.49%			36.76 %		
2009	3.58%			-35.71%			24.43 %		
2010	0.88%			-27.71%			21.40 %		
Phase 2		1.40	~ 0		-3.43*	~ 0		4.79**	⊖⊖⊖

This table reports the emissions status of the three main sectors, Energy, Materials, and Utilities, analysed. The emissions status is determined by the E-C ratio, which is the emissions-to-cap ratio calculated by the difference between the verified emissions and the cap (Verified Emissions minus Cap) in relation to its cap. Column (1) lists the year of the E-C ratio recorded, columns (2)–(4) show the E-C ratio, *t*-test, and estimated alpha from the previous analysis for the Energy sector, columns (5)–(7) and (8)–(10) show the same information for the Materials and Utilities sectors. The *t*-test conducted is a two-tail, one-sample *t*-test which shows whether the E-C ratio is different from zero from a statistical point of view. ***, ** and * represents 1%, 5%, and 10% statistical significance levels, respectively.

This brief statistical analysis provides supporting evidence for the assumption linked to the second research question by confirming that emissions status appears relevant in explaining the sectoral differentiation of the EU ETS effect on stock market performance.

More precisely, this analysis shows that stock market investors consider that emissions status on aggregate at the sector level is a relevant factor in the valuation process. The value relevance of the sectoral emissions status works in the expected direction as the market seems to reward the under-emitting Materials sector and to penalise the over-emitting Utilities sector. Following this inspiring finding, the analysis is taken a step further by examining whether the value-relevance of the emissions status also applies at the firm level within the three main sectors in the EU ETS; the results are presented in Section 6.4.3.

5.4.3 EU ETS effects on stock prices: emissions status effect within main sectors

This section starts by presenting the summary of estimation results for the portfolio performance of the respective emissions status-based portfolios. The estimated alpha of the portfolio performance responds to the question asking whether firms within a specific sector would experience different levels of impact on their stock price performance depending on their emissions status. Table 5.29 provides a summary of the performance of respective portfolios in different estimation periods. In short, the differentiation of portfolio performance due to allowances holding position at the firm level could not be detected in nearly 90% of the examinations conducted.

Tables 5.31–5.33 present the full regression results of emissions status-based portfolios within the Energy, Materials, and Utilities sectors in the full sample period 2005–2010 with different model specifications. The performance estimation results of the regression conducted for the portfolios consisting of firms with different emissions status in the main sectors appear identical to the results of the sector portfolio performance estimation. Energy sector firms experience no abnormal returns regardless of their emissions status. Materials sector firms see a significant outperformance against the benchmark in the full sample period in both portfolios, which consist of over-emitting and under-emitting firms respectively, while Utilities sector firms experience the opposite, regardless of their emissions status. This finding appears to work against the positive value-relevance of allowances holding suggested in Johnston *et al*. (2008), as the under-emitting firms, which are supposed to be valued positively compared with the over-emitting firms, are in fact valued in the same manner by the stock market.

Table 5.29 Summary of estimation results of the *Portfolio(sector$_i$)$^{emission\ status}$* performance

Portfolio **(1)**	2005–2010 **(2)**	2005–2007 **(3)**	2008–2010 **(4)**
Energy (Over-Cap)	~ 0	~ 0	~ 0
Energy (Under-Cap)	~ 0	~ 0	~ 0
Materials (Over-Cap)	++	+++	++
Materials (Under-Cap)	+++	+++	~ 0
Utilities (Over-Cap)	⊖⊖⊖	⊖⊖⊖	⊖⊖⊖
Utilities (Under-Cap)	⊖⊖⊖	⊖⊖⊖	⊖⊖⊖

This table provides an overview of the portfolio performance of emissions status-based portfolios in different estimation periods. The performance is measured by the alpha of the estimation model, which represents the abnormal return of the portfolio that is not explained by the standard Fama–French risk factors. Column (1) lists the portfolio estimated. (Over-cap) contains firms with a positive E-C ratio while (Under-cap) has firms with a negative E-C ratio. Columns (2)-(4) show the estimated alphas of respective sector-based portfolio for the Pre-ETS, the full sample period, Phase1, and Phase2. ⊖ indicates a negative estimated coefficient and a underperformance while + indicates a positive estimated coefficient and an outperformance of the portfolio. ⊖ or + represents the 10%, ⊖⊖ or ++ represents 5%, and ⊖⊖⊖ or +++ represents 1% significance levels and ~ 0 is not at statistically significant.

Tables 5.34–5.39 provide full regression results for the emissions status-based portfolio performance estimation in separate sub-sample periods. The same situation persists for the separate sub-sample periods of the first and second trading periods of the EU ETS, which implies that the stock market has not yet been able to value firm-level emissions status specifically. This could be attributed to the general lack of reliable and easily accessible market information regarding accurate firm-level carbon emissions, and the actual positions of allowances holding, as such information is not made available by the EUTL, which records only installation-level data. A similar issue is also raised in Bushnell *et al.* (2013).

The outcomes of the emissions status effect differentiation estimation shares one major finding with the results of the investigation of the permit holding's asset value in Bushnell *et al.* (2013), who find that dirtier firms suffer milder underperformance than relatively cleaner firms in the sector that is overall short in allowances. The results shown in Tables 6.36 and 6.39 reveal that Utilities firms which are short in allowances experience a lower level of underperformance (–0.5% weekly rate in both estimation periods) than the firms with a net long position of allowance holding (–1.2% in the Phase 1 and –0.7% in the Phase 2 estimation periods).

Table 5.30 summarises the estimated coefficients of the allowances price factor to provide an overview of the responsiveness of emissions status-based portfolios to allowances price returns. During the longer-term estimation period which spans both trading periods of the EU ETS, the allowances price return does not seem relevant during the valuation process as none of the portfolio is responsive to the factor, as shown in Tables 5.32 to 5.33. This can be interpreted as indicating that the price signal of the EU allowances has not been strong from investors' perspectives during the 2005–2010 period. Mixed results are seen during the separate sub-sample periods of 2005–2007 and 2008–2010, as few cases of sensitivity to allowances price returns can be detected. The emission status-based portfolios in the Energy and Utilities sectors follow nearly identical patterns of allowances price exposure in the sector-based portfolios in both estimation periods. The change of allowances price effects across different trading periods are identified strongly in the Utilities sector, which appears consistent with the findings in Mo *et al*. (2012), with the portfolio returns responding positively to allowances price changes in 2005–2007 and negatively during the second trading period.

An increase in allowances prices, which is expected to increase the compliance costs for over-emitting firms, would theoretically be associated with a drop in the share price performance, which can only be seen in one case, the Utilities sector, during the 2008–2010 period. The insignificant coefficients of allowances value found in most estimations could be reasonably interpreted by the fact that the allowances price is consistently below the level of pronounced impact on the overall earnings of affected firms (Veith *et al*., 2009). Similar issues concerning the level of allowances prices during most of the trading periods of EU ETS being too low to create any significant cost impact are also raised in Rogge *et al*. (2011) and Egenhofer *et al*. (2011), as well as in government communications such as EC (2012) and the UK House of Commons' standard note by Ares (2013).

Table 5.30 Summary of estimated coefficients of the allowances price factor for *Portfolio(sector$_i$)$^{emission\ status}$*

Portfolio	2005-2010		2005-2007		2008-2010	
(1)	EUA (2)	EUA(-1) (3)	EUA (4)	EUA(-1) (5)	EUA (6)	EUA(-1) (7)
Energy$^{(Over\text{-}Cap)}$	~ 0	~ 0	~ 0	~ 0	~ 0	~ 0
Energy$^{(Under\text{-}Cap)}$	~ 0	~ 0	~ 0	~ 0	⊖⊖	~ 0
Materials$^{(Over\text{-}Cap)}$	~ 0	~ 0	⊖	~ 0	~ 0	~ 0
Materials$^{(Under\text{-}Cap)}$	~ 0	~ 0	~ 0	⊖⊖⊖	+	+++
Utilities$^{(Over\text{-}Cap)}$	~ 0	~ 0	+++	~ 0	⊖⊖⊖	~ 0
Utilities$^{(Under\text{-}Cap)}$	~ 0	~ 0	+	~ 0	⊖⊖⊖	~ 0

This table provides a summary of the estimated coefficients for the allowances price factor, which indicate the exposure of the sector to the risk associated with allowances price variation. Column (1) lists the portfolio estimated. (Over-cap) contains firms with the positive E-C ratio while (Under-cap) has firms with the negative E-C ratio. Columns (2) to (7) show the estimated coefficients of allowance price factors for respective emission status-based portfolios for the full sample period, Phase 1, and Phase 2. ⊖ indicates a negative estimated coefficient and the stock return and the allowances return move in the opposite direction while + indicates a positive estimated coefficient and stock return and the allowances return move in the same direction. ⊖ or + represents the 10%, ⊖⊖ or ++ represents 5%, and ⊖⊖⊖ or +++ represents 1% significance levels and ~ 0 is not statistically significant.

The results of the positive coefficients of both allowances price factors imply that the value-relevance of allowances, as suggested and empirically tested in the US SO_2 market context by Johnston *et al.* (2008), can be observed in the EU ETS context for two out of three Under-Cap portfolios in the Materials sector in Phase 2 and the Utilities sector in Phase 1. However, the case of the Utilities sector is not convincing as the stock returns of the over-emitting Utility firms also respond positively to the allowances price change in Phase 1.

Based on the empirical findings presented and discussed in Sections 5.4.1–5.4.3, the conclusion can be drawn from two main aspects, which answer the two research questions raised in this chapter. It is indicated by the sector-based portfolio performance estimation and the sectoral emissions status analysis that the EU ETS effect on stock price performances is differentiated at the sectoral level. The second set of analysis, which focuses on examining the emissions status of firms within the main sector, reveals that the emissions status effect on share prices appears to be differentiated at only the sectoral level, but not at the firm level. This can be interpreted as suggesting that stock market investors consider the emissions status and the net allowances holding positions of the sector relevant, and value stocks accordingly. However, investors have not yet been able to value specifically the net position at the firm level. This finding seems to share Bushnell *et al*.'s (2013) opinion, which points out that the lack of easily accessible firm-level allowances holdings and trading information with regard to the EU ETS might have caused difficulties in evaluating firms' precise net allowances position holdings and consequently difficulties in valuing the firms' share prices.

While the overall positions of most sectors regulated by the EU ETS, and the overall trading scheme in aggregate, have been long in allowances, this does not apply to the utilities sector. The Utilities sector, which comprises mainly power generators, is constantly short in allowances throughout the entire ETS trading period. The compliance costs for certain sectors, such as materials and industrials, could be as low as nil due to the over-allocation/over-supply of allowances in Phase 1 particularly, which cannot be seen in the utilities sector (Kettner *et al*., 2011; Ellerman and Buchner, 2008). However, the costs of purchasing extra allowances for emissions cap compliance still seem inconsequential for utilities firms from the long-term perspective, as they are able to access low-cost allowances provided by other participants in the scheme.

One estimated outcome throughout Chapter 4 and 5 that is somehow less intuitive and worth mentioning is the significantly positive coefficient of the SMB factor, which implies that the portfolios tested in this chapter demonstrate the feature of small-cap risk premium in terms of stock returns. As one might expect the firms covered by the trading scheme tend to be the larger firms, although it is not necessarily the case that this is also true of the sample dataset used in this thesis. The sample dataset contains 153 firms from seven sectors while the benchmark universe contains ten sectors. The Financials, Information Technology and Telecommunication are currently not directly exposed to the EU's trading scheme, and thus are not included in the sample dataset. According to the Financial Times and PwC[53] these three sectors in fact account for a considerable proportion of the companies of large market capitalisation globally (35%) and in Europe (36.8%).

53 Pwc (2015) Global Top 100 Companies by market capitalization; Financial Times Europe Top 500 (2014)

Furthermore, the healthcare and consumer goods sectors also account for a considerable number of large-cap companies, while their exposure to EU ETS is very limited as these two sectors accounts for less than 15% of the sample composition. Hence, the nature of the sample dataset is reasonably reflected by the positive SMB coefficient as the actual components of the portfolios tested in both chapters are likely on the small-cap side in relation to the benchmark.

In addition, the decision of constructing the portfolios with an equal weight to each component is intended to more closely represent the equal exposure to the same emission trading scheme, as the main purpose of this thesis has always been to understand the potential impacts of the EU ETS on the share prices of exposed firms. The value-weighted strategy has been considered but was not carried out due to the possibility that the portfolio performance can then be heavily influenced by the market capitalisation rather than the exposure to EU ETS. Nevertheless, it is recognised that the empirical analysis in both Chapter 4~~5~~ and 5~~6~~ could be examined by applying alternative portfolio construction methods.

Table 5.31 Extended regression results of *Portfolio(Sector$_i$)*$^{emission\ status}$ for the sample period 2005–2010

Dependent variable	***R_p(Energy)***$^{over\text{-}cap}$	***R_p(Energy)***$^{under\text{-}cap}$	***R_p(Materials)***$^{over\text{-}cap}$	***R_p(Materials)***$^{under\text{-}cap}$	***R_p(Utilities)***$^{over\text{-}cap}$	***R_p(Utilities)***$^{under\text{-}cap}$
Sample period	07/01/2005 24/12/2010					
Constant	-0.002 (-1.18)	0.001 (0.87)	0.007 (2.47)**	0.003 (3.16)***	-0.005 (-2.99)***	-0.009 (-5.26)***
R_M	0.911 (19.45)***	1.027 (23.91)***	1.135 (17.49)***	1.061 (53.04)***	0.849 (22.07)***	0.745 (18.34)***
SMB	0.384 (3.80)***	0.405 (5.13)***	0.652 (3.44)***	0.736 (9.37)***	-0.024 (-0.32)	0.163 (1.88)*
HML	0.347 (2.40)**	0.091 (0.80)	-0.115 (-0.59)	0.242 (2.52)**	0.016 (0.15)	0.077 (0.85)
MOM	0.628 (3.86)***	0.468 (4.01)***	-0.075 (-0.32)	0.165 (2.28)**	0.327 (2.81)***	0.294 (3.41)***
Observations	312	312	312	312	312	312
Adj. R^2	0.75	0.84	0.78	0.94	0.84	0.79
P-value (F-stats.)	0 (238.2)	0 (410.3)	0 (280.2)	0 (1235)	0 (406)	0 (292.5)

This table reports full regression results of estimating emission status-based ***Portfolio(Sectori)***$^{emission\ status}$ within three major sectors using ***Eq (56-1)*** under OLS with Newey-West estimator for the sample period of 2005 to 2010. RM is the risk premium measured by MSCI Europe sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively. MOM controls for the momentum effect. The second and third columns report coefficients (t-stat) of over-emitting and under-emitting energy firms; the fourth and fifth columns report coefficients (t-stat) of over-emitting and under-emitting materials firms, and the sixth and seventh columns report coefficients (t-stat) of over-emitting and under-emitting utilities firms. ***, **, * represent 1%, 5%, 10% statistical significance level, respectively.

Table 5.32 Extended regression results of *Portfolio(Sector$_i$)$^{emission\ status}$* for the sample period 2005–2010

Dependent variable	$R_p(Energy)^{over\text{-}cap}$	$R_p(Energy)^{under\text{-}cap}$	$R_p(Materials)^{over\text{-}cap}$	$R_p(Materials)^{under\text{-}cap}$	$R_p(Utilities)^{over\text{-}cap}$	$R_p(Utilities)^{under\text{-}cap}$
Sample period	18/03/2005 24/12/2010					
Constant	-0.003 (-1.45)	0.001 (0.59)	0.007 (2.41)**	0.003 (3.05)***	-0.005 (-3.01)***	-0.009 (-5.25)***
R_M	0.908 (19.36)***	1.025 (23.81)***	1.136 (17.38)***	1.061 (53.55)***	0.849 (21.75)***	0.746 (18.27)***
SMB	0.379 (3.70)***	0.405 (5.12)***	0.656 (3.42)***	0.734 (9.31)***	-0.023 (-0.31)	0.163 (1.85)*
HML	0.349 (2.36)**	0.092 (0.80)	-0.128 (-0.64)	0.228 (2.36)**	0.001 (0.01)	0.062 (0.67)
MOM	0.634 (3.78)***	0.468 (3.92)***	-0.087 (-0.36)	0.151 (2.07)**	0.317 (2.64)***	0.285 (3.19)***
EUA	0.002 (1.48)	0.000 (0.09)	-0.001 (-1.40)	0.001 (1.55)	-0.001 (-0.84)	-0.002 (-1.10)
Observations	302	302	302	302	302	302
Adj. R^2	0.76	0.84	0.78	0.94	0.84	0.79
P-value (F-stats.)	0 (191.2)	0 (327.5)	0 (215.6)	0 (968.9)	0 (318.3)	0 (228.5)

This table reports full regression results of estimating emission status-based ***Portfolio(Sectori)$^{emission\ status}$*** within three major sectors analysed using ***Eq (56-2)*** under OLS with Newey-West estimator for the sample period of 2005 to 2010. R_M is the risk premium measured by MSCI Europe sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively, and MOM controls for the momentum effect. EUA is logged weekly return of EUA spot from European Energy Exchange(EEX). The second and third columns report coefficients (t-stat) of over-emitting and under-emitting energy firms; the fourth and fifth columns report coefficients (t-stat) of over-emitting and under-emitting materials firms, and the sixth and seventh columns report coefficients (t-stat) of over-emitting and under-emitting utilities firms. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.33 Extended regression results of *Portfolio(Sector$_i$)$^{emission\ status}$* for the sample period 2005–2010

Dependent variable	***R_p(Energy)$^{over\text{-}cap}$***	***R_p(Energy)$^{under\text{-}cap}$***	***R_p(Materials)$^{over\text{-}cap}$***	***R_p(Materials)$^{under\text{-}cap}$***	***R_p(Utilities)$^{over\text{-}cap}$***	***R_p(Utilities)$^{under\text{-}cap}$***
Sample period	25/03/2005 24/12/2010					
Const.	-0.003 (-1.44)	0.001 (0.62)	0.007 (2.42)**	0.003 (3.09)***	-0.005 (-3.04)***	-0.009 (-5.18)***
R_S	0.908 (19.29)***	1.024 (23.69)***	1.135 (17.34)***	1.061 (53.32)***	0.850 (21.78)***	0.745 (18.12)***
SMB	0.380 (3.69)***	0.405 (5.10)***	0.656 (3.41)***	0.734 (9.26)***	-0.024 (-0.31)	0.164 (1.86)
HML	0.350 (2.35)**	0.096 (0.83)	-0.123 (-0.61)	0.230 (2.38)**	-0.003 (-0.02)	0.069 (0.75)
MOM	0.635 (3.78)***	0.472 (3.94)***	-0.083 (-0.34)	0.154 (2.11)**	0.313 (2.60)***	0.293 (3.32)***
EUA	0.002 (1.46)	0.000 (0.10)	-0.001 (-1.38)	0.001 (1.50)	-0.001 (-0.85)	-0.002 (-1.12)
EUA(-1)	0.000 (0.23)	0.000 (0.35)	-0.000 (-0.35)	0.000 (0.18)	-0.000 (-0.21)	0.001 (0.69)
Observations	301	301	301	301	301	301
Adj. R^2	0.76	0.84	0.78	0.94	0.84	0.79
P-value (F-stats.)	0 (158.3)	0 (272.3)	0 (178.8)	0 (807.8)	0 (264.8)	0 (193.1)

This table reports full regression results of estimating emission status-based ***Portfolio(Sectori)$^{emission\ status}$*** within three major sectors analysed using ***Eq (56-3)*** under OLS with Newey-West estimator for the sample period of 2005 to 2010. R_M is the risk premium measured by MSCI Europe sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms respectively. MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of the previous observation. The second and third columns report coefficients (t-stat) of over-emitting and under-emitting energy firms; the fourth and fifth columns report coefficients (t-stat) of over-emitting and under-emitting materials firms, and the sixth and seventh columns report coefficients (t-stat) of over-emitting and under-emitting utilities firms. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.34 Extended regression results of *Portfolio(Energy)$^{emission\ status}$* for the sample period 2005–2007

Dependent variable	$R_p(Energy)^{over\text{-}cap}$			$R_p(Energy)^{under\text{-}cap}$		
	Eq (5-1)	***Eq (5-2)***	***Eq (5-3)***	***Eq (5-1)***	***Eq (5-2)***	***Eq (5-3)***
Sample period	07/01/2005 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	07/01/2005 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007
Constant	-0.002 (-0.56)	-0.004 (-0.93)	-0.004 (-0.92)	0.003 (0.90)	0.002 (0.42)	0.002 (0.44)
R_M	0.891 (10.68)***	0.863 (10.03)***	0.859 (9.39)***	1.044 (14.91)***	1.014 (14.51)***	1.006 (14.76)***
SMB	0.358 (2.93)***	0.352 (2.77)***	0.345 (2.67)***	0.314 (2.82)***	0.313 (2.65)***	0.296 (2.38)**
HML	-0.012 (-0.04)	0.011 (0.03)	0.018 (0.05)	-0.216 (-0.71)	-0.141 (-0.44)	-0.112 (-0.35)
MOM	0.679 (3.32)***	0.706 (3.03)***	0.722 (3.09)***	0.739 (3.57)***	0.781 (3.44)***	0.826 (3.54)***
EUA		0.008 (1.17)	0.007 (1.00)		0.008 (1.17)	0.007 (1.05)
EUA(-1)			0.002 (0.21)			0.005 (0.73)
Observation	156	146	145	156	146	145
Adjusted R^2	0.50	0.51	0.50	0.65	0.65	0.66
P-value	0 (40.12)	0 (30.55)	0 (25.13)	0 (73.7)	0 (55.68)	0 (46.71)

The table reports the full regression results for emission status-based energy firms' portfolios under OLS with Newey-West estimator for the sample period of 2005 to 2007. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of previous observation . The second to fourth columns report the coefficients (t-stat) for Portfolio (over-cap energy) which consists of firms with allowance shortage in the energy sector, and the fifth to seventh columns report the coefficients (t-stat) for Portfolio (under-cap energy) which consists of firms with allowance surplus in the energy sector. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively

Table 5.35 Extended regression results of *Portfolio(Materials)*$^{emission\ status}$ for the sub-sample period 2005–2007

Dependent variable	$R_p(Materials)^{over\text{-}cap}$			$R_p(Materials)^{under\text{-}cap}$		
	Eq (5-1)	***Eq (5-2)***	***Eq (5-3)***	***Eq (5-1)***	***Eq (5-2)***	***Eq (5-3)***
Sample period	07/01/2005 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	07/01/2005 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007
Constant	0.006 (2.65)***	0.005 (2.28)**	0.006 (2.37)**	0.003 (1.86)*	0.003 (1.61)	0.003 (1.85)*
R_S	1.113 (20.45)***	1.103 (20.26)***	1.107 (20.34)***	1.035 (24.70)***	1.034 (24.00)***	1.047 (24.98)***
SMB	0.630 (7.61)***	0.631 (6.87)***	0.638 (6.80)***	0.458 (7.55)***	0.466 (7.44)***	0.493 (8.37)***
HML	0.194 (0.98)	0.146 (0.75)	0.161 (0.81)	0.145 (0.99)	0.092 (0.61)	0.095 (0.62)
MOM	0.151 (1.29)	0.157 (1.22)	0.156 (1.18)	0.527 (5.33)***	0.484 (4.69)***	0.446 (4.12)***
EUA		-0.006 (-1.91)*	-0.006 (-1.73)*		0.001 (0.19)	0.002 (0.58)
EUA(-1)			-0.003 (-0.92)			-0.009 (-2.90)***
Observations	156	146	145	156	146	145
Adjusted R^2	0.85	0.84	0.84	0.87	0.87	0.87
P-value (F-stats.)	0 (212)	0 (155)	0 (131.1)	0 (256.9)	0 (186.1)	0 (165.3)

The table reports the full regression results for emission status-based materials firms' portfolios under OLS with Newey-West estimator for the sample period of 2005 to 2007. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of previous observation . The second to fourth columns report the coefficients (t-stat) for Portfolio (over-cap materials) which consists of firms with allowance shortage in the materials sector, and the fifth to seventh columns report the coefficients (t-stat) for Portfolio (under-cap materials) which consists of firms with allowance surplus in the materials sector. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.36 Extended regression results of *Portfolio(Utilities)$^{emission\ status}$* for the sub-sample period 2005–2007

Dependent variable	$R_p(Utilities)^{over\text{-}cap}$			$R_p(Utilities)^{under\text{-}cap}$		
	Eq (5-1)	***Eq (5-2)***	***Eq (5-3)***	***Eq (5-1)***	***Eq (5-2)***	***Eq (5-3)***
Sample period	07/01/2005 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007	07/01/2005 28/12/2007	18/03/2005 28/12/2007	25/03/2005 28/12/2007
Constant	-0.006 (-3.49)***	-0.007 (-4.15)***	-0.007 (-4.26)***	-0.012 (-4.71)***	-0.012 (-4.74)***	-0.012 (-4.67)***
R_S	0.784 (18.06)***	0.761 (18.81)***	0.758 (18.72)***	0.683 (14.23)***	0.667 (14.06)***	0.658 (13.42)***
SMB	-0.036 (-0.37)	-0.038 (-0.41)	-0.043 (-0.46)	0.402 (4.59)***	0.400 (4.76)***	0.380 (4.60)***
HML	0.140 (0.74)	0.165 (0.80)	0.155 (0.74)	0.107 (0.58)	0.084 (0.46)	0.126 (0.70)
MOM	0.628 (3.89)***	0.648 (3.76)***	0.649 (3.64)***	0.094 (0.80)	0.072 (0.58)	0.132 (1.01)
EUA		0.010 (3.74)***	0.010 (3.48)***		0.009 (1.82)*	0.009 (1.77)*
EUA(-1)			0.002 (0.63)			0.006 (1.54)
Observation	156	146	145	156	146	145
Adjusted R^2	0.73	0.74	0.74	0.61	0.60	0.62
P-value (F-stats.)	0 (104.4)	0 (83.39)	0 (69.08)	0 (60.58)	0 (45.15)	0 (40.4)

The table reports the full regression results for emission status-based utilities firms' portfolios under OLS with Newey-West estimator for the sample period of 2005 to 2007. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of previous observation . The second to fourth columns report the coefficients (t-stat) for Portfolio (over-cap utilities) which consists of firms with allowance shortage in the utilities sector, and the fifth to seventh columns report the coefficients (t-stat) for Portfolio (under-cap utilities) which consists of firms with allowance surplus in the utilities sector. ***, **, * represent 1%, 5%, 10% statistical significance level respectively.

Table 5.37 Extended regression results of *Portfolio(Energy)*$^{emission\ status}$ for the sub-sample period 2008–2010

Dependent variable	$R_p(Energy)^{over\text{-}cap}$			$R_p(Energy)^{under\text{-}cap}$		
	Eq (5-1)	***Eq (5-2)***	***Eq (5-3)***	***Eq (5-1)***	***Eq (5-2)***	***Eq (5-3)***
Sample period	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010
Constant	-0.003 (-1.63)	-0.003 (-1.65)	-0.003 (-1.64)	-0.000 (-0.16)	-0.000 (-0.12)	-0.000 (-0.13)
R_M	0.911 (17.14)***	0.911 (17.13)***	0.911 (17.09)***	1.022 (20.10)***	1.022 (20.02)***	1.023 (19.92)***
SMB	0.385 (2.81)***	0.382 (2.75)***	0.383 (2.74)***	0.399 (4.06)***	0.402 (4.07)***	0.403 (4.04)***
HML	0.381 (2.09)**	0.382 (2.08)**	0.381 (2.06)**	0.085 (0.61)	0.084 (0.60)	0.083 (0.59)
MOM	0.597 (2.73)***	0.599 (2.73)***	0.598 (2.71)***	0.351 (2.44)**	0.349 (2.42)**	0.348 (2.40)**
EUA		0.001 (1.18)	0.001 (1.17)		-0.001 (-1.97)*	-0.001 (-1.97)*
EUA(-1)			0.000 (0.41)			0.000 (0.34)
Observations	156	156	156	156	156	156
Adjusted R^2	0.84	0.84	0.84	0.91	0.91	0.91
P-value (F-stats.)	0 (203.8)	0 (162.1)	0 (134.2)	0 (378.1)	0 (300.9)	0 (249.1)

The table reports the full regression results for emission status-based energy firms' portfolios under OLS with Newey-West estimator for the sample period of 2008 to 2010. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of previous observation . The second to fourth columns report the coefficients (t-stat) for Portfolio (over-cap energy) which consists of firms with allowance shortage in the energy sector, and the fifth to seventh columns report the coefficients (t-stat) for Portfolio (under-cap energy) which consists of firms with allowance surplus in the energy sector. ***, **, * represent 1%, 5%, 10% statistical significance level respectively.

Table 5.38 Extended regression results of *Portfolio(Materials)$^{emission\ status}$* for the sub-sample period 2008–2010

Dependent variable	$R_p(Materials)^{over\text{-}cap}$			$R_p(Materials)^{under\text{-}cap}$		
	Eq (5-1)	*Eq (5-2)*	*Eq (5-3)*	*Eq (5-1)*	*Eq (5-2)*	*Eq (5-3)*
Sample period	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010
Constant	0.007 (2.08)**	0.007 (2.09)**	0.007 (2.06)**	0.002 (1.58)	0.002 (1.51)	0.001 (1.48)
R_M	1.147 (14.77)***	1.147 (14.76)***	1.147 (14.75)***	1.075 (46.20)***	1.075 (46.30)***	1.077 (45.56)
SMB	0.641 (2.41)**	0.642 (2.39)**	0.643 (2.38)**	0.822 (9.71)***	0.817 (9.54)***	0.827 (9.84)
HML	-0.219 (-0.97)	-0.219 (-0.97)	-0.221 (-0.97)	0.196 (1.94)*	0.197 (1.95)*	0.185 (1.83)
MOM	-0.167 (-0.55)	-0.168 (-0.55)	-0.169 (-0.55)	0.055 (0.77)	0.058 (0.80)	0.049 (0.68)
EUA		-0.000 (-0.37)	-0.0004 (-0.37)		0.001 (1.79)*	0.001 (1.77)*
EUA(-1)			0.0004 (0.44)			0.003 (8.21)***
Observations	156	156	156	156	156	156
Adjusted R^2	0.77	0.76	0.76	0.96	0.96	0.96
P-value (F-stats.)	0 (126.8)	0 (100.8)	0 (83.44)	0 (995.1)	0 (795.5)	0 (673.8)

The table reports the full regression results for emission status-based materials firms' portfolios under OLS with Newey-West estimator for the sample period of 2008 to 2010. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of previous observation . The second to fourth columns report the coefficients (t-stat) for Portfolio (over-cap materials) which consists of firms with allowance shortage in the materials sector, and the fifth to seventh columns report the coefficients (t-stat) for Portfolio (under-cap materials) which consists of firms with allowance surplus in the materials sector. ***, **, * represent 1%, 5%, 10% statistical significance levels respectively.

Table 5.39 Extended regression results of *Portfolio(Utilities)*$^{emission\ status}$ for the sub-sample period 2008–2010

Dependent variable	$R_p(Utilities)^{over\text{-}cap}$			$R_p(Utilities)^{under\text{-}cap}$		
Model Specification	*Eq (5-1)*	*Eq (5-2)*	*Eq (5-3)*	*Eq (5-1)*	*Eq (5-2)*	*Eq (5-3)*
Sample period	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010	04/01/2008 24/12/2010
Constant	-0.005 (-2.96)***	-0.005 (-2.86)***	-0.005 (-2.85)***	-0.008 (-4.45)***	-0.008 (-4.36)***	-0.007 (-4.33)***
R_M	0.869 (20.42)***	0.870 (20.36)***	0.870 (20.28)***	0.756 (15.70)***	0.758 (15.68)***	0.758 (15.62)***
SMB	-0.051 (-0.46)	-0.042 (-0.37)	-0.042 (-0.37)	0.077 (0.69)	0.087 (0.76)	0.087 (0.75)
HML	-0.096 (-0.71)	-0.098 (-0.72)	-0.099 (-0.72)	0.062 (0.60)	0.060 (0.58)	0.061 (0.59)
MOM	0.194 (1.34)	0.188 (1.29)	0.188 (1.28)	0.341 (3.08)***	0.335 (2.98)***	0.335 (2.98)***
EUA		-0.003 (-5.30)***	-0.003 (-5.28)***		-0.003 (-6.23)***	-0.003 (-6.17)***
EUA(-1)			9E-05 (0.10)			-0.000 (-0.32)
Observations	156	156	156	156	156	156
Adjusted R^2	0.87	0.87	0.87	0.83	0.83	0.83
P-value (F-stats.)	0 (251.3)	0 (202.1)	0 (167.3)	0 (192.2)	0 (154.9)	0 (128.2)

The table reports the full regression results for emission status-based utilities firms' portfolios under OLS with Newey-West estimator for the sample period of 2008 to 2010. R_M is the risk premium measured by sector index logged return in excess of risk-free rate; SMB and HML controls for the investors incline towards size and book-to-market value of firms; MOM controls for the momentum effect. EUA is logged weekly return of EEX EUA spot while EUA(-1) represents the allowance return of previous observation . The second to fourth columns report the coefficients (t-stat) for Portfolio (over-cap utilities) which consists of firms with allowance shortage in the utilities sector, and the fifth to seventh columns report the coefficients (t-stat) for Portfolio (under-cap utilities) which consists of firms with allowance surplus in the utilities sector. ***, **, * represent 1%, 5%, 10% statistical significance level respectively.

5.5 Conclusion

This chapter responds to two research questions. First, it explores whether the EU ETS has an impact on share prices and the extent to which this impact can be differentiated at the sectoral level. This is done by comparing the performances of sector-based portfolios consisting of ETS and Non-ETS-exposed firms, respectively, with the standard and extended market models. Second, the effect of the emissions status on the share prices of ETS-regulated firms is further examined at the sectoral level and firm level within the Energy, Materials, and Utilities sectors, respectively. The three main sectors are identified based on their shares of allowances allocation in the entire trading scheme and their inclusion in the number of companies. This is intended to find out whether stock market investors consider the emissions status relevant in the valuation process. The result of this test signals how much the emission-related information is taken into consideration by stock market investors during the valuation process.

The analyses comprise three parts. The first part uses regressions with multi-factor market models to evaluate the performance of sector-based portfolios, which are constructed by ETS-regulated firms and Non-ETS firms that operate in the same sector. The second part contains the comparative and statistical analysis of the sectoral emissions status and stock price performance measured by the respective portfolios. The third and final part takes the investigation of the emissions status effect differentiation a step further by utilising the same econometric method and forming portfolios that consist of firms with the same emissions status within each sector.

The results of the first set of analyses reveal that six out of seven sector-based portfolios with ETS-exposed firms significantly underperformed the market benchmark during the Pre-ETS period of 2001–2004. Among these six sectors, the Energy sector has been valued indifferently by the stock market since the official launch of the EU ETS in 2005. During the continuous EU ETS trading period, the Utilities, Health Care, and Consumer Staples sectors consistently experience underperformance while the Materials, Industrials, and Consumer Discretionary sectors see an outperformance against the market benchmark. This indicates that the impact of the EU ETS on stock prices does differ across sectors among ETS-exposed firms. On the other hand, the Non ETS-exposed portfolios show less sensitivity toward the transition from the Pre-ETS period into the ETS period.

Interestingly, the performance of the three major sectors (Energy, Materials, and Utilities) is found to be closely related to sectoral emissions status, with the significantly over-emitting sector Utilities underperforming and the significantly under-emitting sector Materials outperforming the market benchmark. Moreover, the performance estimation results of the regression done for the portfolios consisting of firms with different emissions status in the main sectors appear fairly similar to the results of the sector-based portfolio performance estimation. Energy sector firms experience no abnormal returns regardless of their emissions status. Materials sector firms see a significant outperformance against the benchmark in the full sample period in both portfolios, which consist of over-emitting and under-emitting firms, respectively, while Utilities sector firms experience consistent underperformance regardless of emissions status.

Three main conclusions can be drawn from these findings. The first confirms that the stock return performance of ETS-regulated firms can be differentiated at sectoral level to a certain degree, as different levels of abnormal portfolio returns are observed. Second, it appears that performance can also be differentiated by emissions status at sectoral level as the under-emitting sector sees a reward in share value while the over-emitting sector experiences a value penalty. The third aspect concerns the finding that the stock return performances differentiated by emissions status cannot be seen at the firm level within sectors. These results are interpreted as implying that investors considering the net allowances holdings positions of the sector relevant for the valuation of stocks. However, stock market investors have not yet been able to specifically value the net allowances holdings positions of firms, as indicated by the portfolio performance estimations of the emission status-based portfolios within sectors. In contrast, it seems relatively viable for investors to gain information or a general sense of emissions status at the aggregate level, such as at the sectoral level. In terms of policy implications, this chapter highlights the relevance of any government or NGO initiatives aiming to ensure the reliability and accessibility of firm-level carbon emissions data. Equivalently, this chapter signals a need for business processes that ensure the reliability of reported carbon data – for instance, through independent audits or verifications – so that the shareholder value of the firms can be more precisely reflected.

6 Determinants of firm-level emissions performance ratio in EU's emission trading

6.1 Introduction

The research focus of this chapter lies in firm-level emissions across different countries and industrial sectors within the EU ETS context. More specifically, the interest lies in identifying the factors that are associated with the emissions level of each firm during the period 2005–2010. Firm emissions regulated by the EU ETS are relevant for the European Union's efforts to achieve their emissions reduction target, as they account for more than 45% of the total greenhouse gas (GHG) emissions in the entire European Union. Understanding what contributes to GHG emissions at the corporate level can thus provide useful insights into a potentially more effective emissions reduction. Furthermore, this chapter is also planned with the purpose of further enhancing the practicability of the empirical methods applied in the previous two chapters by providing a suitable proxy for the emission status with a series of tested factors.

Empirically-based studies that focus on this particular subject are still relatively limited, which is presumably due to the lack of availability of relevant and reliable firm-level emissions data. This lack of factual data might be related to the fact that regulations concerning standardised emissions reporting are far from complete. As documented in the Data Chapter, the majority of currently existing carbon emissions reporting/disclosure schemes are on a voluntary basis. Furthermore, the reporting and verification standards are not unified, which results in an inconsistency in the data quality gathered by voluntary schemes (Cho and Patten, 2007; Liesen *et al*., 2013; Matsumura *et al.*, 2013).

Existing studies have limited their empirical examinations of the emissions determinants of firms to a single country (Cole *et al*., 2005, 2012) or a single industrial sector (Apergis *et al.*, 2013; Gray and Shadbegian, 2007; Shadbegian and Gray, 2003). To the best of the author's knowledge, no empirical analysis has so far explicitly identified firm-level emissions determinants within a multi-nation, multi-sector context, and under a compulsory emissions cap. The analysis in this chapter is the first attempt to identify the drivers of firm-level emissions under the EU's emissions trading scheme (ETS), within which the regulated firms have obligations to manage their emissions levels under the given cap.

The reason for focusing on the EU ETS is mainly to address the data unavailability drawbacks mentioned above. The mandatory scheme provides a consistent legislative background and requirements for verifying and reporting carbon emissions for each company. Furthermore, the emissions produced by each firm can be benchmarked against its respective allocated allowances, which provide a more accurately scaled dependent variable and indicates the performance of each company in maintaining its emissions compliance levels under the same regulatory scheme (EC, 2003b). The focus of this analysis is to empirically investigate and explain firm-level emissions performance within a mandatory scheme, the EU ETS. It is expected that the results will provide insights into how firm-level emission behaviour might be influenced by a mandatory emissions restriction scheme.

The research question can be posed as follows: which factors systematically explain the carbon emissions performance, measured by the verified emission-to-cap ratio, at firm level within the EU ETS? The research question is explored from two perspectives: first, what are the main determinants of the firm's emissions compliance performance? Second, the firms subject to the EU ETS in the first two trading periods generally operate in emissions intensive sectors,[54] such as the utilities, materials, and energy sectors. Among these emissions intensive firms, how far is the firm's emissions performance ratio related to the sector in which it operates? Furthermore, will any factor have a greater influence on the firm's performance ratio in specific sectors? The analysis in this chapter aims to extend previous research by exploring the determinants of emissions compliance performance within a relatively new regulatory context, while the study by Cole *et al*. (2012), which also focused on firm-level emissions, examined the emissions of firms that are not subject to mandatory emissions restriction. This chapter is also expected to benefit from the improved quality of firm-level emissions data, as the data reported within the EU ETS is now subject to standardised procedures and required verifications (EC, 2007b). A set of potential determinants of firm-level emissions performance are tested using a panel dataset, composed of an exclusive company database of EU ETS, the world's largest mandatory ETS. The analysis in this chapter is the first attempt to date to utilise EU ETS-

54 The EU ETS targets bigger emitters, in particular during the first and second trading period. The threshold for inclusion in the ETS is defined in Directive 2003/87/EC (EC, 2003a).

regulated firm-level data to empirically examine the association of emissions performance with firm characteristics.

The investigation into the proposed research question aims to make a contribution to the current literature in four major aspects. First, the investigation examines factors that have previously been tested in other geographic locations in the EU ETS context, to reveal whether determinants of firm emission intensity apply in different geographic settings. Second, unlike previous studies, the investigation concentrates on firms within a mandatory environmental regulation regime. The results of the investigation are expected to reveal whether firms that are subject to explicit environmental regulation react differently in their emissions behaviour since results from previous research, such as the study by Cole *et al*. (2012), indicate that self-constructed regulation proxies do not show a significant impact on firm-level emissions intensity. Third, the investigation explores the potential sectoral differentiation of emissions determinants, as the dataset employed in the empirical analysis consists of firms that operate across seven industrial sectors. Fourth, the investigation empirically tests the effects of early preparation by EU member states for the implementation of the EU ETS, as well as the effects of technology adoption by firms. This is also the first attempt to include such factors.

In addition to the contribution to academic literature, this chapter is also expected to complement the previous two chapters by demonstrating how to incorporate emission status data *ex-ante* into the investment decision-making process and adding practicability to the thesis. The hypothetical portfolios with specific emission status in the two previous chapters are constructed *ex-post* as emission data is only accessible after it had been recorded and published, and hence the analysis and results from the previous two chapters provide empirical evidence with regard to how ETS-exposed firms having specific emission status performed historically. This chapter is designed to create a model that can explains the determinants of a firm’s emissions performance ratio with explanatory factors that can be used to estimate the firm’s future or contemporary emission status, provided the explanatory factors are either known and can also be properly estimated. As the proposed explanatory factors are mostly firm-specific operational and accounting measures, they can be more easily obtained than emissions data. The application of the estimation process enables the use of emission status information before the actual data are published and accessible, as the proximate emission performance ratio of a specific firm can be obtained by inputting the firm's operational data into the estimation model used in this chapter.

This chapter is structured as follows. Section 6.2 presents a review of two streams of literature that inspired the empirical investigation and provided the estimation framework empirically tested in this chapter. Section 6.3 first describes the dataset used in the analysis, from which the research methods and model specifications follow. The last part of Section 6.3 details the model and regression specification used in the analysis. Section 6.4 presents the results of the empirical analysis and discusses the implications of the main findings; Section 6.5 concludes.

6.2 Literature review

Two streams of literature motivated and helped to build the main framework of the empirical estimation model in this chapter, and are reviewed in this section in the following order. At first, inspiration was drawn from studies that focus on empirically examining the determinants of emissions, as this stream of literature explores a similar subject, either GHG or carbon emissions, to that in this chapter. Although the main research subject in this chapter is firm-level emissions, studies that investigate emissions in aggregate, such as industry- or country-level emissions, are also reviewed, for two reasons. First, aggregate-level emissions provide a foundation for the estimation model that drills down to the firm-level emissions, as the aggregate-level data are ultimately inclusive of disaggregate-level data. For instance, overall industrial-level emissions consist of individual plant-/firm-level emissions. Second, studies that concentrate on firm-level emissions are relatively limited in number, presumably due to data availability. The second stream of literature investigates the factors that can influence corporate environmental performance and also provides a motivation for establishing the foundation of the empirical model for firm-level carbon emissions by associating the emissions level with indicators of corporate environmental performance.

6.2.1 Emission determinants

Cole *et al.* (2012) investigate emissions per output unit at firm level by utilising an extensive dataset that comprises emission data of 1961 manufacturing firms for 2006 with a cross-sectional regressions technique. The authors model the emissions output as a function of the supply–demand fundamentals of environmental services, which is an essential element in determining a firm's production function, as also applied in Cole *et al*. (2005) and Pargal and Wheeler (1996). The model is built upon reaching the equilibrium of utilisation of environmental services, which is reflected by the demand of the firm interacting with the supply provided by society or mandatory environmental regulations. Control variables are then identified and grouped into firm characteristics, which potentially affect the demand side, and regulatory characteristics, which represent the supply-side influences. Their results show that several firm characteristics significantly influence emissions intensity in varying degrees and directions. While the capital–labour ratio and wage rate are positively related to CO_2 emissions intensity, firm size, innovation expenditure, export share, and foreign affiliation appear to be negative functions of unit emissions intensity.

Apergis *et al*. (2013) apply an autoregressive model to examine the effect of research and development (R&D) expenditure on emissions at firm level with manufacturing sector data in three European countries where the mandatory adoption of International Financial Reporting Standards (IFRS) takes place. Their findings reveal that R&D expenditure increases emissions abatement, i.e. a reduction in total emissions, of firms during post-IFRS adoption. This study is interesting as its setting within the mandatory reporting context is similar to the empirical design of this chapter. The introduction of EU ETS, which coincides partially with their estimation sample period, also provides valuable insights for this chapter. The results demonstrate the anticipated direction of influences, though at this stage without statistical significance.

More disaggregate plant-level emissions data have also been examined. Such studies are set largely within the US context by utilising the US Environmental Protection Agency (EPA), particularly its plant-level toxic release inventory (TRI) data. Evidence is provided that local manufacturing activities are strongly linked with local pollution levels. Spillovers of cross-regional pollution are also identified (Kahn, 1999). Determinants of the environmental performance of paper mills, which is measured by pollution emissions per unit of output, have been empirically examined by Shadbegian and Gray (2003). Financial resources of plants used for abatement expenditure and productivity efficiency are significant factors that drive plants' emissions levels. An interesting finding in the study is that plants located in regions that failed to comply with ambient air quality standards that had been previously implemented,[55] thus facing higher local regulation pressure, show significantly lower emissions in the analysis. Plant- and firm-specific characteristics including size, profitability, and technology level are again confirmed as factors that drive the differences in environmental management, measured by Gray and Shadbegian (2007) for pollution emissions of manufacturing plants. They intend to explore the spatial correlations of plants' different types of pollution emissions further, and suggest that plant-specific characteristics still provide a large amount of explanatory power for the models inspected.

In addition to studying firm-level subjects, research at a more aggregate level was also reviewed for inspiration. Hamit-Haggar (2012) investigates the long-term equilibrium between GHG emissions, energy consumption, and economic growth at the industrial level in Canada. He also tests whether a causal relationship between these variables exists. The use of industry-level data is intended to reduce the conflicting results provided by aggregate-level data as done in previous country-level studies. The dataset comprises 21 industrial sectors in Canada with annual emissions from 1990 to 2007. The findings confirm a strong long-term relationship between energy consumption and GHG emissions. The empirical design and findings based on the use of industrial-level data support the relevance of the research question and the use of firm-level data proposed in this chapter.
From a similar industrial level perspective, Cole *et al*. (2005) investigate emissions intensity using UK industry-level data, which encompass six sources of emissions, including CO_2, across 22 industries from 1990 to 1998. They focus on exploring how industrial characteristics and environmental regulation has shaped industrial emissions intensity, which also forms the fundamental framework for the firm-level study by Cole *et al*. (2012). Their results reveal a positive link between energy use and physical as well as human capital intensity and emissions intensity. On the other hand, industrial emissions intensity appears to be negatively associated with the average value-added of firms, and the productivity and expenditure on technology innovation within the industry.

55 The authors use the ambient air quality standards for particulates and SO_2 in 1985.

The relationship between GHG emissions, energy consumption, and economic growth (income) at country level has been largely studied on the basis of the Environmental Kuznet Curve (EKC) hypothesis. This hypothesis proposes that the relationship between pollutant sources, which form the proxies of environmental pressure faced by countries, and economic conditions, which are usually measured by per capita income, follows an inverted U-shaped function. That is to say, the environmental pressure facing a country rises with the growth of national income up to a certain level, and decreases subsequently (Dinda, 2004; Kijima *et al.,* 2010).

A number of studies focus on exploring the causal relationships between GHG emissions, economic conditions, and energy consumption on the basis of the EKC hypothesis; however the results tend to be mixed and inconclusive, particularly under different scales of economy setting (Shafik, 1994; Coondoo and Dinda, 2002; Friedl and Getzner, 2003; Dinda and Coondoo, 2006; Ang, 2007; Soytas *et al*., 2007). Nevertheless, the logic used to explain the EKC hypothesis and its associated effects has helped to develop the theoretical framework for potential drivers of different forms of environmental performance, including emissions, through several aspects. For instance, the technology effect is one explanation for a positive link between economic growth and environmental quality after the turning point. A nation/society with more wealth can better afford the costs of technological innovation, which can replace obsolete, energy inefficient technologies, thus eventually improving overall environmental quality (Komen *et al*., 1997).

Apergis *et al*. (2010) further extend previous studies by introducing different mixtures of energy sources and present evidence that such sources can moderate the level of emissions in different ways. A similar investigation is also seen in Marrero (2010), who applies a dynamic panel data of 27 EU countries to examine the extended EKC hypothesis. The results do not support the assumption of EKC, when the energy and emissions convergence factors are taken into consideration in addition to economic growth.

Country-level studies with aggregate-level subjects shed light on the fundamental assumption about the factors associated with emissions at the aggregate country level, such as economic conditions, energy consumption, and energy mix; however these factors cannot directly differentiate among more disaggregated entities, such as industries or firms within a country. Adjustments are required to better proxy for factors potentially associated with firm-level emissions.

6.2.2 Corporate environmental performance drivers

The literature that studies the determinants of factors driving firm-level environmental performance is also reviewed, to provide a more comprehensive perspective on the environmental behaviour of firms. As suggested by Ilinitch *et al*. (1998) and Delmas and Blass (2010) conceptually, the measures of corporate environmental performance are often inclusive of emissions behaviour.

A number of studies provide empirical evidence on the linkage between firm environmental performance and firm characteristics in various performance measures and geographical contexts. An empirical study by Henriques and Sadorsky (1996) aimed to identify the factors that explicitly influenced firms' responsiveness towards environmental issues in Canadian industries. Their results revealed that industries differed in their response in engaging in the process of becoming environmentally responsive. Internal and external pressures from various groups, including shareholders, management, and customers, also showed various levels of influence. It was further shown that the firm's sales-to-assets ratio negatively affected the possibility of forming active environmental plans. Extending the Henriques and Sadorsky (1996) study by explicitly fixing the variable of research interest on the actual environmental performance, Doonan *et al*. (2005) sought to learn the determinants of the specific environmental performances of firms. The environmental performance defined in their study encompassed a series of events including emissions in a single industry. Their results remained partially consistent with previous studies indicating that external pressures, such as government and community pressures, are the main drivers of firms' environmental performance. The involvement of a higher management level, including a consideration of the firm's financial resources, also plays a significant part in moderating the environmental performances of firms. A similar subject has been studied in Japanese industries, and firm size, profitability (measured by return on assets or ROA), the debts-to-assets ratio as well as technology innovation investment are among the factors that determine organisational commitment towards overall environmental performance and specific environmental issue management, such as CO_2 emissions management (Nakamura *et al*., 2001; Cole *et al*., 2006). Using TRI data as the measure of environmental performance of S&P 500 firms, Anton *et al*. (2004) empirically tested the effects of a firm's adoption of comprehensive environmental management systems on their environmental performance, as measured by TRI. Their results suggested that the adoption of a more extensive environmental management strategy had a significant impact on reducing emissions. Firm-specific characteristics, such as the sale-to-assets ratio and technology innovation investment, also showed some degree of direct or indirect effect on firm environmental performance. Examining the related subject of the determinants of firms' decisions to adopt a proactive environmental management strategy, Clarkson *et al*. (2011) provide empirical evidence that the firm's financial resources, proxied by ROA, liquidity, and leverage (the debt–asset ratio), are crucial factors affecting its environmental performance.

Some other studies have employed a broader perspective by examining and testing empirically overall environmental, social, and governance performance drivers. While the attempt might be made to explain overall corporate social responsibility primarily by institutional factors, a set of industry and firm effects are also selected and controlled for. Empirically tested firm characteristics, such firm performance/profitability and size, show significant impacts on three dimensions of corporate social responsibility which encompass the environmental performance of firms (Ioannou and Serafeim, 2012).

Another study that focuses on corporate environmental performance is that by de Villiers *et al*. (2011), who primarily investigate the effects of corporate board characteristics on firm environmental performance. In addition to their principal test variables, which are a set of board features motivated by agency theory and resource dependence theory, the authors also employ a set of firm characteristics which are potentially linked to corporate environmental performance as control variables. Their results indicate that firm size, age, profitability measured by ROA, slack, and equipment age are significantly related to firm environmental performance. The analysis in this chapter benefits from this research design as the results provide strong empirical evidence on the factors associated with environmental performance, and thus potentially associated with the emission behaviour of firms.

To briefly summarise, the theoretical foundations of investigation planned in this chapter is informed by two streams of literature building. First, studies with empirical evidence on disaggregated emission determinants have shown that factors driving the demand–supply fundamentals of the environmental services, emissions output in our case, are significantly associated with the emissions level. Among these factors, capital intensity shows a strong influence on emissions levels at both firm and industrial level (Cole *et al.*, 2005, 2012). Furthermore, studies that empirically examined the EKC hypothesis inform us about the impact of technology effects associated with economic conditions on environmental quality. Second, the literature that empirically examines the factors that systematically explain corporate environmental performance provides support for the theoretical basis of firm characteristics-driven environmental performance. These firm characteristics are presumed to be linked with the emissions behaviour of firms, with the emissions level serving as a proxy for environmental performance (Delmas and Blass, 2010).

6.3 Data and method

This section consists of two parts: the first describes the sample dataset used for the analysis, including its source and scope. The second starts by explaining the rationale behind the proposed effects, which are expected to be related to firm-level emissions and form the framework of the estimation model. This part continues with the description of the model construction process, followed by the detailed model specification.

6.3.1 Data

The primary purpose of the analyses in this chapter is to reveal the factors that are related to the firms' emissions performance, measured by the emissions-to-allowances ratio. To construct the variable under investigation, emissions data and allowances allocated to each firm are extracted from the Carbon Market Data ETS Company Database. As described in Chapter 3, Carbon Market Data provides users with the regulated firm population within the EU ETS and annual firm-level verified emissions. It is thus the most appropriate provider of data for the research subject.

The full database provided by Carbon Market Data contains 887 firms that are regulated by the EU ETS, and include public and private companies. Due to the inaccessibility of data regarding private companies underlying several independent variables (i.e, production, use of renewable energy), the sample in this analysis contains only the 201 publicly listed firms. As the information on location of each individual installation owned by the respective firm is lacking, spatial factors could not be precisely addressed as in Cole *et al*. (2012). Firms with headquarters outside the European territory are excluded from this analysis, leaving a final sample of 140 firms of data spanning 2005–2010[56]. Firm financial data is obtained from Thomson Reuters Datastream. The sample distribution, correlation matrix, and basic descriptive statistics of the sample dataset are produced to provide the basic information and understanding of the data used in the analysis. None of the correlations between proposed independent variables exceeds 0.4, which ensures minimum interference among independent variables that could lead to erratic estimated coefficients caused by multicollinearity. Increasing ROA, and the capital–labour ratio see an ascending trend in the emissions-to-allowances ratio, which is consistent with the hypotheses proposed.

6.3.2 Method and model specification

a). Dependent variable

The main subject of investigation in this chapter is the emissions performance of each company within the EU ETS. The performance measure is constructed by calculating the verified emissions-to-allowances ratio. This approach is mainly inspired by Cole *et al*. (2012, 2005) and Pargal and Wheeler (1996), in which the dependent variables serve as the proxy for firms' pollution levels, and these studies provide an empirically tested reference to reflect upon. These studies have been the best available proxy for the analysis proposed to answer the research question in this chapter.

It is noteworthy that the dependent variable adopted in this chapter differs in distinct ways from the studies mentioned above. While the firm's production output is used as the denominator to scale the absolute emissions in Cole *et al*. (2012), it is not the most ideal scaling unit for this analysis. To construct a clean and accurate dependent variable, in the Cole *et al*. (2012) case, both figures presumably represent the same percentage of the total figure in each company, if not 100%. However, the total emissions of each firm regulated

56 The exclusion is primarily due to restrictions of data access as well as the reason explained in 3.4.1. Given Cole *et al*. (2012) excludes 85% of their full sample, the inclusion rate of analyses in this chapter is considered acceptable.

by EU ETS is not necessarily 100% of the firm's emissions, as the EU ETS Directive includes installations that pass a certain threshold, which is indicated in Annex I of the ETS Directive (EC, 2003a). The total production output of each firm, which is used to scale the emissions, is obtained from Datastream, which in most cases would be expected to represent 100% of each firm's production output.

Therefore, a new denominator to scale the absolute emissions is required in this chapter to ensure the accuracy of the dependent variable, which is essential to obtain meaningful estimation results. The objective of the entire thesis, thus including this first empirical chapter, is to observe and empirically test how much impact the mandatory emissions restriction, in this case the EU ETS, has upon the regulated firms, given their either full or partial inclusion in the EU ETS. The way to form the dependent variable in this chapter using all EU ETS data ensures that the new dependent variable is more accurately constructed using data of the same scope for each firm. This will be the first empirical evidence to date showing the factors that are relevant to the firm's performance in terms of emitting below its cap, which is imposed by the EU ETS.

b). Independent variables

Based on the theoretical background gathered from previous literature, five firm-level emissions-related effects are proposed and each effect is tested by a corresponding independent variable. The propositions are briefly summarised in Table 6.1. The set of independent variables is built largely upon the previous literature that specifically examines firm-level emissions, while a mixture of empirical evidence at the industry and national levels as well as the corporate environmental performance literature is also utilised. This is intended to better configure the specification of the estimation model to be used in explaining firm-level emissions intensity. The set of independent variables contains a series of firm characteristics which have been previously tested and linked to corporate emissions/environmental performance, and are considered the most relevant to the research question in this chapter. Each variable is defined and discussed in more detail below.

Table 6.1. Proposed firm-level emissions related effects and the corresponding variables

(1)	Proposed effect (2)	Variable and proposition (3)
1	Production Output Effect	Firm production is positively related to Verified Emissions-to-Cap Ratio
2	Capital Intensity Effect	Capital–Labour Ratio is positively related to Verified Emissions-to-Cap Ratio
3	Action Taking Effect	Renewable Energy Use (by firm) is negatively related to Verified Emissions-to-Cap Ratio
4		Early Action toward EU ETS taken by member states is negatively related to Verified Emissions-to-Cap Ratio
5	Sector Differentiation Effect	Determinants of Verified Emissions-to-Cap Ratio are Sector-specific, as indicated by the Sector Dummy
6	Sector-Specific Effect	Sector-specific interaction terms are expected to show if any of the proposed effects (1) to (4) are significant in a specific sector

This table lists the proposed effects and corresponding hypothesis of the estimation model used in examining the determinants of firm-level emission behaviour. Column (2) lists the proposed effect on emission behaviour, column (1) lists the respective hypothesis and column (3) describes the underlying hypothesis for each effect and the independent variable used in the model.

- Production

  The production effect is motivated by two observations that imply a linkage between production output and the two figures which are used to form the dependent variable in this chapter, respectively. First, following Cole *et al*. (2012, 2005), carbon emissions could be modelled as the supply of and demand for environmental services, which compose an input into a firm's production function. In other words, absolute emissions are correlated with the firms' production output. The production output of each firm is defined as the summation of each firm's total sales, finished goods, and work-in-progress figures. The figure is estimated in its natural logarithmic form to minimise the effect of extreme values.

- Capital–Labour Ratio

  The capital intensity of the production processes is likely to influence the pollution level of firms in the same direction; that is to say, more capital intensive firms, which are generally heavily dependent on machinery and equipment, tend to be more pollution intensive than labour intensive firms. Empirical evidence is provided at both the industrial and firm levels of investigation by Cole *et al*. (2005, 2012) and Cole and Elliot (2003). The capital–labour ratio is defined as capital expenditure divided by the total number of employees of each firm. To minimise the effect of extreme values, the capital–labour ratio is estimated using its natural logarithmic form.

- Renewable Energy Use

  The link between renewable energy use and emissions performance is hypothesised based on the technology effect. As obsolete machinery and equipment can be less energy efficient and more pollution intensive, newer equipment is expected to incorporate greener technologies, which should lead to better environmental performance, and will be less emissions intensive. A proposition with similar equipment/technology-specific concerns is documented in Clarkson *et al*. (2008) and also used in de Villiers *et al*. (2011). This factor is controlled using a dummy variable, with 1 representing a company that uses renewable energy in a specific year.

- Early Action

  Prior to the implementation of EU ETS, a number of EU member states had implemented or prepared to implement their own carbon emissions/climate acts (Ellerman *et al*., 2010: 19–20). For instance, a voluntary ETS was initiated and ran from 2002 in the UK. The UK DEFRA[57] and NAO[58] reports indicate that the direct participants in the UK ETS on average committed to a 13% reduction in

57 Department of Environment, Food, and Rural Affairs.

58 National Audit Office.

emissions over the lifetime of the trading scheme (DEFRA, 2006: 18–20; NAO, 2004: 13). Furthermore, participating companies gain experience and are well prepared for a mandatory scheme while the managing governmental agency also learns from the experience of running a trading scheme prior to a mandatory EU-wide trading scheme. This factor is controlled using a dummy variable, with 1 representing the member state in which the company's HQ is located, adopting early actions prior to the official implementation of the EU ETS.

- Sector[59]

  Firms that operate in different sectors are expected to face different levels of exposure regarding environmental issues, and thus different sectors will demonstrate varying levels of environmental management capability. This aspect is particularly relevant to analyses in this chapter, as the sample dataset employed consists of firms operating across sectors. The Cole *et al*. (2005) study that empirically examines the relationship between industrial pollution intensity and industrial characteristics enhances the motivation to test the sector differentiation effect. The industry dummy was also applied in Henriques and Sadorsky (1996), and is found to be significant. The sample contains seven sectors, as the inclusion of firms in the EU ETS follows the Annex I of the EU ETS Directive (EC, 2003), which is briefly documented in Appendix 2-B of Chapter 2. The intention of EU ETS for the first two phases is to regulate installations with higher thermal inputs/outputs caused from fuel and energy consumption, as this allows a relatively comparable measurement. The transportation industry is only included in the scheme from the beginning of Phase 3 (2013-), which is beyond the scope of this thesis as data had not been available.

Model Specification

The propositions raised above are tested by a random effect Generalised Least Squares (GLS) regression. The GLS random effect model is applied and proved to be appropriate

59 See Appendix 4A for reasons for sector categorisation, sector definition, and data distribution across sectors.

after conducting the Hausman Test, see Table 6.2. The random effect is specified in order to allow the sector differentiation effect by adding sector dummies.

Table 6.2 The result of the Hausman Test

	-coefficients-		(b-B)	$\sqrt{(diag(V(b)-V(B)}$
	(b) fixed	(B) random	Difference	S.E.
Production	0.08	0.02	0.06	0.03
K–L Ratio	0.07	0.07	0.00	0.02
Renewable Energy Use	-0.09	-0.07	-0.02	0.01
ROA	0.01	0.01	-0.00	0.00
Leverage	-0.25	-0.26	0.01	0.11
$Chi^2(5) = 5.94$ (P-value = 0.31)				

This table shows the result of the Hausman test for the baseline model for a fixed/random effect specification using STATA. b = consistent under Ho and H_1; obtained from the regression. B = inconsistent under H_1, efficient under Ho; obtained from the regression. Test: Ho: difference in coefficients not systematic. The result indicates that the null hypothesis that the difference in coefficients is not systematic cannot be rejected, and thus a random effect model is appropriate.

Firstly, a baseline model is constructed to test the general proposed effects (1) to (5), and can be written as:

$$Y_{it} = \alpha + \beta_1(K-L\,ratio)_{it} + \beta_2(Production)_{it} + \beta_3(Renew)_{it} + \beta_4(Action)_{it} + \sum_{j-1}^{n}\beta_j(Sector)_{it} + \sum_{K=1}^{n}\beta_k Z_{ikt} + \varepsilon_{it} \qquad \textbf{\textit{Eq (6-1)}}$$

where,

i = 1st, 2nd,......,141th firm in the sample and t = 1st, ...6th year of figures recorded (2005–2010). Y = verified emissions-to-allowances ratio of $Firm_i$. $Sector_j$ denotes the sector dummy while j indicates which sector represents. Z presents a vector of general control factors including ROA, leverage, and a year dummy, which serve as control variables for their potential to influence corporate performance. Their link with emissions-specific performance has, however, been mixed and inconclusive (Cole *et al*., 2006; Nakamura *et al*., 2001; de Villiers *et al*., 2011).

The inclusion of the independent variables in the estimation model considers the most relevant firm characteristics, as the dependent variable in the model represents the firm's emission management capability, rather than a return series of the type commonly used in asset pricing models. Previous literature (Cole *et al*., 2012, 2005; Apergis *et al.* 2013) have also mainly considered firm characteristics that are more relevant to emission or environmental performance rather than the common financial market risk factors (market capitalization, book-to-market value and momentum) used in the previous two chapters of the thesis.

Secondly, another attempt is made to further disentangle the extent to which the proposed effects differ across sectors. More specifically, this analysis intends to determine whether the proposed effects appear more prominent in certain sectors in explaining firms' emission behaviour. This approach is expected to further distinguish sector differences in firm-specific emissions intensity, by adding interaction terms on firm characteristics and sector dummies into the baseline model, with which the dataset is estimated.

The inclusion of sector-specific interaction terms aims to address the issues raised in section 4.3.1, which explains that the sample used in this analysis contains firms that operate across different sectors, as opposed to previous studies that examined emissions within a single industrial sector, such as Cole *et al*. (2012) and Shadbegian and Gray (2003). The same technique to capture the potential effects caused by two factors interacting with each other is also applied in previous studies, such as Antweiler *et al*. (2001) and Cole and Elliot (2003). These studies control for the interaction between a trade liberalisation measure and country-specific characteristics, in order to better address the problem that a weak and inconsistent relationship between emissions sources and free trade measures can sometimes be detected. Only the energy, materials, and utilities sectors are included in the sector-specific analysis as none of the other four sectors accounts for more than 1% of the allowances share in the sample dataset. Also, the three sectors included in the second set of analysis all have a company count of more than 20, which ensures at least 120 observations in each sub-sample. A detailed sample distribution across each sector is provided in Appendix 4-A. The interaction term is formed by the product of the firm characteristics effect, such as production or capital intensity, and the sector dummy. Interaction terms are made sector-specific and estimated separately. For instance, to examine whether the production effect is significantly influential for the energy sector, the regression is run by applying the energy–production interaction term. The same applies to other effects and sectors.

The estimation model using only the energy sector interaction terms can be written as ***Eq (6-2)***, and the other two models with the materials and utilities sector-specific interaction terms are written as ***Eq (6-3)*** and ***Eq (6-4)***, respectively. Following the estimation with an individual interaction terms-added model, the dataset is estimated lastly by ***Eq (6-5)***, which contains all the sector-specific interaction terms.

Eq (6-2)

$$Y_{it} = \alpha + \beta_1(Energy * K - L\,ratio)_{it} + \beta_2(Energy * production)_{it} + \beta_3(REnergy * enew)_{it} + \beta_4(Energy * Action)_{it} + \sum_{j-1}^{n} \beta_j (Sector)_{it} + \sum_{K=1}^{n} \beta_k Z_{ikt} + \varepsilon_{it}$$

Eq (6-3)

$$Y_{it} = \alpha + \beta_1(Materials * K - L\,ratio)_{it} + \beta_2(Materials * production)_{it} + \beta_3(Materials * Renew)_{it} + \beta_4(Materials * Action)_{it} + \sum_{j-1}^{n} \beta_j (Sector)_{it} + \sum_{K=1}^{n} \beta_k Z_{ikt} + \varepsilon_{it}$$

Eq (6-4)

$$Y_{it} = \alpha + \beta_1(Utilities * K - L\,ratio)_{it} + \beta_2(Utilities * production)_{it} + \beta_3(Utilities * Renew)_{it} + \beta_4(Utilities * Action)_{it} + \sum_{j-1}^{n} \beta_j (Sector)_{it} + \sum_{K=1}^{n} \beta_k Z_{ikt} + \varepsilon_{it}$$

Eq (6-5)

$$Y_{it} = \alpha + \beta_1(Energy * K - L\,ratio)_{it} + \beta_2(Energy * production)_{it} + \beta_3(REnergy * enew)_{it} + \beta_4(Energy * Action)_{it} + \beta_5(Materials * K - L\,ratio)_{it} + \beta_6(Materials * production)_{it} + \beta_7(Materials * Renew)_{it} + \beta_8(Materials * Action)_{it} + \beta_9(Utilities * K - L\,ratio)_{it} + \beta_{10}(Utilities * production)_{it} + \beta_{11}(Utilities * Renew)_{it} + \beta_{12}(Utilities * Action)_{it} + \sum_{j-1}^{n} \beta_j (Sector)_{it} + \sum_{K=1}^{n} \beta_k Z_{ikt} + \varepsilon_{it}$$

6.4 Results and discussion

6.4.1 Result of estimations using the baseline models

This section presents the basic descriptive statistics and correlation of the variables before the estimation results of the baseline models are shown and discussed. Tables 6.3 and 6.4 present the descriptive statistics and the correlation matrix. Results are summarised with regards to the hypothesis tested in Table 6.5 and the full estimation results and the discussion of practical relevance and further implications of the findings follow.

Table 6.3 Descriptive Statistics of Variables

	N	Mean	S.D.	Min.	Max.	Median
Emission–Cap Ratio	821	-0.15	0.36	-3.30	1.65	-0.11
Production	821	19.54	2.10	12.06	23.89	19.90
Capital–Labour Ratio	811	3.40	1.15	0.38	8.33	3.19
Renewable Energy Use	840	0.46	0.5	0	1	0
Early Action tw. ETS	840	0.43	0.5	0	1	0
ROA	821	6.61	6.59	-24.30	62.35	6.02
Leverage	821	0.27	0.13	0	0.64	0.27

The panel dataset contains 140 firms and covers six years of the sample period. The loss of data points is due to (i) some firms dropping out of the EU ETS in phase 2,[60] and (ii) the incomplete data of certain firms in some years.[61]

None of the correlations between proposed independent variables exceeds 0.4, which ensures minimum interference among independent variables that could lead to erratic estimated coefficients caused by multicollinearity. Increasing ROA and a capital–labour ratio sees an ascending trend in the emissions-to-allowances ratio, which is consistent with the hypotheses proposed.

60 Greencore, The Linde Group.

61 CIE Automotive in 2010, Cyprus Cement Company in 2010, Tenaris SA in 2005 and 2006, Vassiliko Cememt Works in 2010.

Table 6.4 Correlation Matrix of dependent and independent variables

	E-to-A	**Product.**	**C-L**	**Renew.**	**Early Act**	**ROA**	**Lvg.**
Emission–Cap Ratio							
Production	-0.07						
Capital–Labour Ratio	0.35*	-0.06					
Renewable Energy Use	0.02	0.36*	0.13*				
Early Action	-0.11	0.26*	0.04	0.15*			
ROA	0.10	0.06	0.05	-0.02	0.00		
Leverage	-0.16	0.03	0.00	0.15*	0.05	-0.24	

The summarised estimation results of the baseline models indicate that three out of five propositions are supported, among which the capital intensity effect and production output effect are consistent with the previous literature, including Cole *et al*. (2005, 2012) in that both factors drive the emissions of firms. Full estimation results are presented in Table 64.6. Columns (1) and (2) report results using only control variables and sector dummies to test the reliability of the model. The results suggest the sectoral differentiation effect hypothesis holds from two aspects. The added sector dummies provide considerable amount of explanatory power, with energy and utilities sectors showing significant effects on the firms' emissions levels. Column (3) reports the estimation results from testing the production output and capital intensity effect propositions. Both propositions are supported and the findings appear consistent with those in Cole *et al*. (2012), which also suggest that capital intensity is a positive function of emissions. Column (4) reports the results of testing the environmentally friendly actions effect proposition and indicates that the statistical significance is insufficient to support it. Columns (5) and (6) report the estimation with the full baseline model with all variables in place, and the results remain unchanged since capital intensity and production effects as well as the sectoral differentiation effect still show significant explanatory power while the action effect remains insignificant. The robustness of the baseline model can be verified by the results of testing all proposed effects jointly, as the directions and magnitudes of the coefficients relating to the major factors remain consistent. Overall, the baseline model demonstrates reasonably strong explanatory power, as indicated by the overall R^2 for panel datasets with a rather short sample period.

Table 6.5. Summary of hypotheses tested with baseline models

Proposition (1)	**Related Variable (2)**	**Result (3)**
1	Firm production is positively related to Verified Emissions-to-Cap Ratio	Supported*
2	Capital–Labour Ratio is positively related to Verified Emissions-to-Cap Ratio	Supported*
3	Renewable Energy Use (by firm) is negatively related to Verified Emissions-to-Cap Ratio	Coefficients at expected direction but lack statistical significance
4	Early Actions toward EU ETS taken by member states is negatively related to Verified Emissions-to-Cap Ratio	Coefficients at expected direction but lack statistical significance
5	Determinants of Verified Emissions-to-Cap Ratio are Sector specific	Supported*

This table summarises the regression results regarding respective proposed hypothesis tested. Column (1) gives the number of each hypothesis, column (2) lists the independent variable which explains the respective hypothesis and column (3) indicates the result. * coefficients with statistical significance at 1%, 5%, or 10%, respectively.

The production effect, as anticipated, forms a positive function of firms' emission performance although the significance level varies in different model specifications. This could be related to the Kahn (1999) study, which shows that manufacturing activities are a strong driving force of pollution emissions levels. Capital intensity shows the strongest influence on a firm's emission levels, as its statistical significance remain highest under different estimation model specifications. This finding adds supporting evidence of capital intensity impacting on emissions, which is found in the Japanese manufacturing sector context by Cole *et al*. (2012) as well as in the UK industrial context by Cole *et al*. (2005).

Table 6.6. Extended regression results of baseline estimation model (2005-2010)

Random-effects GLS regression, Robust control for heteroscedasticity

Dependent Variable: Verified CO^2 emissions-to-cap ratio (at firm level)

Model Specification	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Production			0.01* (1.92)		0.02*** (2.69)	0.02** (2.29)
Capita–-Labour Ratio			0.06*** (3.28)		0.06*** (3.25)	0.05*** (2.82)
Renew. Energy Use				-0.05 (-1.43)	-0.06* (-1.75)	-0.03 (-0.88)
Early Action re EU ETS				0.01 (0.31)	-0.04 (-0.92)	-0.04 (-0.84)
Energy Sector		0.32*** (3.65)	0.21** (2.25)	0.3*** (3.29)	0.16* (1.66)	0.17* (1.81)
Materials Sector		0.12 (1.51)	0.16** (2.04)	0.1 (1.19)	0.13* (1.7)	0.12 (1.57)
Utilities Sector		0.38*** (3.9)	0.35*** (3.49)	0.37*** (3.57)	0.34*** (3.36)	0.32*** (3.16)
ROA	0.004 (1.57)	0.005* (1.68)	0.006** (2.42)	0.005 (1.64)	0.005** (2.38)	0.002 (1.18)
Leverage	-0.26 (-1.53)	-0.16 (-1.02)	-0.28 (-1.61)	-0.13 (-0.85)	-0.26 (-1.49)	-0.23 (-1.41)
Other Sectors	No	Yes	Yes	Yes	Yes	Yes
Year	No	No	No	No	No	Yes
Observations	810	810	788	810	788	788
R^2 overall (within) (between)	0.03 (0.01) (0.04)	0.22 (0.01) (0.36)	0.24 (0.04) (0.38)	0.21 (0.02) (0.34)	0.24 (0.05) (0.37)	0.27 (0.10) (0.37)
P-value (Wald $Chi^{2)}$	0.06	0	0	0	0	0

The table presents estimated coefficients (z-statistics) of the baseline model. Model specification (1) tests control variables without any hypothesis, Model specification (2) tests Hypothesis 5 on sector differentiation, Model specification (3) tests Hypothesis 1 and 2 on firm characteristics, focusing on production and capital spending, Model specification (4) tests Hypothesis 3 and 4 on actions taken against emissions, Model specification (5) tests all hypotheses without year control, while Model specification (6) tests all hypotheses with year control. *** represents significance at 1%, ** at 5%, and * at 10%, respectively.

The estimated coefficients of the action effect, including renewable energy use and early action taken to prepare for a mandatory ETS, show the expected sign that reduces the emissions, which is in line with the proposition; however, they are without sufficient statistical significance. The lack of significance could be explained by the relatively short length of the estimation period, as it is reasonable to assume that the effects of these environmentally friendly actions, such as the adoption of new technology, renewable energy, as well as proactive regulations, could only be detected in the medium-to long-term (Apergis *et al*., 2013).

The sector differentiation effect can be recognised consistently under different specifications, which supports the hypothesis proposed and also appears in line with previous studies, such as de Villiers *et al*. (2011), Cho and Patten (2007), and Patten (2002), which explicitly suggest the rationale to control for industries based on their environmental sensitivities. In our case, the utilities sector is among those with the highest exposure to the mandatory emission restriction based on the analysis of allowances allocation plans and verified emissions data (Zetterberg *et al*., 2004; Betz *et al*., 2006; Grubb and Neuhoff, 2006). This high exposure is indicated by the positive and statistically significant coefficient of the utilities sector dummy.

The capital intensity effect implies that business models could significantly matter with regard to firms' sustainability and environmentally friendly concerns. Business operating activities inevitably impose substantial consequences on the environment, as indicated empirically by the positive link between production output and emissions behaviour. One solution to improve environmental performance without compromising operating activities or business models would be to effectively enhance technology innovation. Based on the current empirical data and analysis, the magnitude of action effect is not sufficient to moderate firms' emissions levels, which could imply a lack of effort by firms to invest and adopt new technology. Moreover, policy makers are also expected to generate adequate incentives for large-scale investments in technology innovation, which should ultimately aim to benefit all the parties involved, including industries, the public, and the environment. One relevant aspect would be the heterogeneity of the environmental sensitivities of different sectors, as to tailor-make sector-specific policies is likely to be more environmentally effective and cost efficient in the long term.

By comparing the results of Specifications 5 and 6, it can be noticed that time effect also increases a certain degree of explanatory power of the full model, which is another interesting aspect to be developed in the future. The regression results show significant negative coefficients in Year 2009 and Year 2010, which indicates a downward trend of the firms' emissions-to-allowances ratio. Further analyses could aim to distinguish the temporal effects of other factors from the time effect. Another research opportunity would be to estimate with the same dependent variable using refined region-specific data. As shown in the results, the statistical significance levels of the production effect vary across different specifications. One possible cause comes from the origin of the production data, which are collected through overall operating activities of firms instead of being EU region-specific. Furthermore, as mentioned on several occasions, and particularly in the data sections, limited sources of reliable GHG emissions data subject to independent and standardised verification is one of the major restrictions of conducting empirical analyses for this subject. Nevertheless, with the development of comprehensive compulsory schemes, such as the EU ETS, the quantity and quality of emissions data should see a good degree of improvement and should enable more empirical investigation in this area.

6.4.2 Results of estimation with sector-specific interaction terms added

This section reports the results of estimations that are further extended with industry-specific interaction terms added to the baseline model, which is intended to capture industry-influenced firm characteristics and their effects on emissions intensity. The results are presented in the following order: energy sector, materials sector, and utilities sector.

Energy,[62] Materials, [63]and Utilities[64] sector-specific analysis

Table 6.7 summarises the results of estimations with energy sector-specific interaction terms-added models for each effect proposed. Capital intensity appears to be related to the emission levels of firms in the energy and utilities sectors, but not to those in the materials

62 The energy sector comprises firms with oil and gas activities as their main business. A number of those included in our sample dataset are British Gas Group, British Petroleum, and ConocoPhillips.

63 The materials sector comprises firms that operate a wide range of industrial activities, such as chemicals, metal and mining, and forest and paper products. Example firms in the sample include Acerinox S.A., Ahlstrom, and ArceloMittal.

64 The utilities sector comprises firms that operate as electricity providers and distributors. The sample includes firms such as Centrica, E.ON, and EDF.

sector. The production effect remains influential for the utilities sector, while the energy sector appears to be more subject to the effect of early action. None of the suggested effects are significant in the materials sector. The full results are presented in Table 64.8 and a detailed discussion follows. Column (1) of Table 64.8 presents the result of the original baseline model, column (2) reports the results of testing if any of the suggested firm-level emissions-related effects is significant in the energy sector, and columns (3) and (4) report the results of the test in the materials and utilities sectors, respectively. Column (5) reports the result of testing all sector-specific effects jointly. The proposition suggesting that the emission-related effects are sector-specific is supported under the new specifications.

Table 6.7 Summary of the results from sector-specific interaction terms added-model

Related Variable (1)	**Result**		
	Energy (2)	**Materials (3)**	**Utilities (4)**
Firm production*sector interaction term is positively related to Verified Emissions-to-Cap Ratio	Coefficients in expected direction but lack statistical significance	Coefficients in expected direction but lack statistical significance	Supported*
Capital–Labour Ratio*sector interaction term is positively related to Verified Emissions-to-Cap Ratio	Supported*	Coefficients in expected direction but lack statistical significance	Supported*
Renewable Energy Use (by firm)*sector interaction term is negatively related to Verified Emissions-to-Cap Ratio	Coefficients in expected direction but lack statistical significance	Coefficients in expected direction but lack statistical significance	Coefficients in expected direction but lack statistical significance
Early Actions toward EU ETS*sector dummy interaction term taken by member states is negatively related to Verified Emissions-to-Cap Ratio	Supported*	Coefficients in expected direction but lack statistical significance	Coefficients in expected direction but lack statistical significance

This table summarises the regression results regarding respective proposed hypothesis tested. Column (1) describes the independent variable which tests the corresponding proposed effect and the expected outcome. Columns (2)–(4) report the result of the Energy, Materials, and Utilities sector, respectively. * represents that the estimators are of commonly acceptable statistical significance at 1%, 5%, or 10%, respectively.

The energy sector appears more sensitive to the capital intensity and early action effects, as these two energy sector-specific interaction terms show consistent statistical significance in two model specifications. On the other hand, the production and technology effects are less influential in the performance ratio within the energy sector. Firms within the energy sector are believed to be capital intensive given the nature of their operating activities, such as oil and gas drilling, equipment and services, exploration and production, which are basically the raw materials of other end-products that produce higher emissions. As the the results show, the production effect is not as significant within the energy sector. Of the other interaction terms, early action appears important and works in the expected direction, which suggests that the regulatory framework in which the firm operates can play a crucial role in affecting its emission behaviour. Surprisingly, renewable energy usage is positively related to emissions levels, though without statistical significance, in both energy and materials sectors, indicating that the technology adoption has no profound effect so far in improving the firms' emission efficiency.

One reasonable speculation is that the production effect plays a more dominant role in this case and offsets the technology adoption effect. Financially more sound firms are more likely to invest in new, environmentally friendly technology such as renewable energy, a similar concept raised in an early country-level emissions study (Komen *et al.*, 1997). A firm's financial conditions can be correlated with its operating conditions, implying that firms having sufficient financial resources to invest in technological innovation are likely to have better operating conditions, such as higher production outputs, which eventually lead to increasing emissions levels. Also, as the data collected regarding a firm's renewable energy use are binary (YES for use, NO for no usage of renewable energy) instead of the actual quantified amount of renewable energy usage, the factor could only be constructed as a dummy variable and thus the estimation results might not be as precise as estimation with quantified variables. However, this does not mean the estimations are of no value as they still provide a clear picture of the effects of the actions adopted by firms; on the contrary, the models with interaction terms-added still demonstrate robust power in explaining the variation in firm-level emissions, as indicated by both p-values and overall (between) R^2.

None of the proposed emissions-related effects appears influential at any statistical significance level in the materials sector, and the results are consistent across different estimation specifications. One possible explanation is the extensive inclusion of different firms in the sector. The materials sector contains a wide range of industrial activities, from chemicals, construction materials, metals and mining to paper and forest products, which could explain the lack of firm characteristic effects at sector level. The heterogeneous nature of firms in the sub-sample formation within each sector makes it difficult for specific firm characteristics to show any distinct effect on the entire sector. For instance, the capital intensity effect on the chemicals industry might offset the same effect on the paper and forest product industry. Similar to the energy sector, the utilities sector is also found to be subject to in particular two proposed emissions-related effects. The capital intensity effect is equally associated with the emission behaviour of firms in the utilities sector, which appears to be a reasonable outcome and in line with Cole *et al*. (2005). Furthermore, the utilities firms are also exposed to the production effect, which enhances the significance of the association of business models with firm-level emissions. As the utilities sector mainly involves the production and distribution of power/electricity, its capital intensive and production-driven business model inevitably drives up emissions and results in relatively high emissions-to-cap ratios. The renewable energy use and early action effects appear to work in the expected direction; however, the magnitude of the association lacks statistical significance. This again highlights the fact that the current states of investment in technology or regulatory inputs are not of sufficient levels to effectively improve the firms’ emission performances.

While the utilities sector constantly forms a positive input into emissions levels under the baseline models, its statistical significance disappears after the utilities sector-specific interaction terms are controlled for in two model specifications (4 and 5 in Table 64.8). This result is of particular interest; given the nature of the utilities sector’s operating activities, which mainly involve the production and distribution of power, the sector is inevitably the largest emitter[65] within the EU ETS, and thus the loss of significance of the sector dummy appears unusual. One explanation is the shift of explanatory power from the utilities sector dummy caused by certain utilities sector specific-interaction terms. An extended experimental regression is conducted in order to understand whether the

65 Details are in Chapter 3, Data section.

proposed explanation on the shift in explanatory power is supported. It is shown that the production effect within the utilities sector takes away the statistical significance of the utilities sector dummy, while the capital intensity effect demonstrates less dominance in taking over the explanatory power of the sector dummy within the utilities sector.

This finding indicates that capital intensity is in general a stronger determinant of the firm-level emission performance ratio, which again supports the conclusion drawn from the main analysis that the business model is highly related to the firm's emissions performance ratio. It should be noted that the primary purpose of this test is not to decide the optimal model. It is rather intended as a supplementary analysis to the main analysis to further explore the interaction between the explanatory factors, in particular capital intensity and production, and the sector dummy within the utilities sector, which potentially explains the shift in the explanatory power. The results and model specifications, ***Eq(6-5a)*** and ***Eq(6-5b),*** are reported in Appendix 6-B.

To briefly sum up and reflect, sector-specific models overall still provide strong robustness in explaining emissions variations, with several interesting findings observed. First, the energy sector is unique in comparison with the other two sectors in terms of its sensitivity to legislative action. Energy sector firms with their headquarters in the member states that adopted early action prior to the EU ETS see a reducing trend in emissions levels relative to their respective caps. A similar regulatory focus is empirically tested in Cole *et al.* (2005) in the UK context, and the formal regulatory pressure shows a generally significant impact on reducing pollution intensity. The materials sector contains a large degree of heterogeneity of firm characteristics, which makes it difficult to provide significant explanatory power at the sectoral level for individual firm characteristics. The utilities sector shows a certain degree of sensitivity towards the production and capital intensity effects, at the 10% and 5% significance level, respectively, under three different specifications. The results remain robust under the model specification that tests all sector-specific effects jointly.

Table 6.8. Full regression results with updated interaction terms-added models

Random-effects GLS regression, Robust control for heteroscedasticity					
Dependent Variable: Verified CO^2 emissions-to-cap ratio (at firm level)					
Model Specification	***Eq (6-1)*** **(1)**	***Eq (6-2)*** **(2)**	***Eq (6-3)*** **(3)**	***Eq (6-4)*** **(4)**	***Eq (6-5)*** **(5)**
Production	0.020** (2.29)				
Capital-Labour Ratio	0.060*** (2.82)				
Renew. Energy Use	-0.032 (-0.88)				
Early Action re. EU ETS	-0.041 (-0.84)				
Energy Sector	-0.761 (-0.95)	-0.738 (-0.94)	0.312*** (3.50)	0.312*** (3.50)	-0.761 (-0.95)
Energy * Production		0.020 (0.66)			0.020 (0.66)
Energy * C-L Ratio		0.145** (2.15)			0.149** (2.17)
Energy * Renew. Use		0.118 (1.21)			0.121 (1.23)
Energy * Early Act.		-0.320** (-2.25)			-0.327** (-2.29)
Materials Sector	0.124 (1.57)	0.125 (1.57)	-0.015 (-0.08)	0.121 (1.52)	-0.039 (-0.21)
Materials*Product.			0.004 (0.44)		0.005 (0.54)
Materials*C-L Ratio			0.022 (1.07)		0.025 (1.21)
Materials*Renew.			0.012 (0.42)		0.021 (0.70)
Materials*Early Act.			-0.020 (-0.40)		-0.025 (-0.51)

Table 6.8 (continued)

Random-effects GLS regression, Robust control for heteroscedasticity					
Dependent Variable: Verified CO^2 emissions-to-cap ratio (at firm level)					
Model Specification	***Eq (6-1)*** **(1)**	***Eq (6-2)*** **(2)**	***Eq (6-3)*** **(3)**	***Eq (6-4)*** **(4)**	***Eq (6-5)*** **(5)**
Utilities Sector	0.330*** (3.16)	0.375*** (3.88)	0.370*** (3.83)	-0.516 (-1.29)	-0.540 (-1.33)
Utilities*Production				0.041* (1.82)	0.041* (1.83)
Utilities*C-L Ratio				0.048** (2.02)	0.052** (2.08)
Utilities*Renew. Use				-0.048 (-0.66)	-0.043 (-0.59)
Utilities*Early Act.				-0.084 (-0.56)	-0.085 (-0.56)
ROA	0.002 (1.18)	0.003* (1.67)	0.002 (1.29)	0.002 (1.30)	0.003 (1.55)
Leverage	-0.235 (-1.41)	-0.202 (-1.29)	-0.176 (-1.10)	-0.176 (-1.10)	-0.232 (-1.47)
Other Sectors	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Observations	788	788	788	788	788
R^2 overall (within) (between)	0.267 (0.370) (0.105)	0.270 (0.381) (0.105)	0.250 (0.357) (0.090)	0.263 (0.377) (0.091)	0.285 (0.399) (0.110)
P-value (Wald Chi^2)	0	0	0	0	0

This table presents the estimated coefficients (z-statistics) of sector-specific interaction terms-added models. Column (1) shows the result of the original baseline model with all sector dummies and year controls. Columns (2)–(4) show results of the energy, materials, and utilities sector-specific interaction terms-added models, respectively. Column (5) shows the result of the regression with all sector interaction term controls. *** represents significance at 1%, ** at 5% , and * at 10% ,respectively.

6.5 Conclusion

This chapter has explored the determinants of firms' emissions performance ratios, given that a compulsory emission cap has been imposed. It intends to shed light on the firms' emission behaviour while they are subject to a mandatory emission restriction in the Europe. The analysis benefits from a panel dataset of a multi-national and multi-sectoral scale, which comprises the largest European-based listed firms in terms of their shares in allowances allocated and emissions verified, and covers in total six years of operation of the EU ETS. The scale of the dataset enables analysis to be conducted at both general and sector-specific level. The results from the general-level analysis show that three out of five proposed effects are supported, among which the capital intensity and production output effects are prominent. This finding implies that the business model of a firm appears prominent in determining its emissions performance and appears similar to that in Cole *et al*. (2005, 2012) where both factors drive up the emissions of firms, within or across sectors. However, Cole *et al*. (2012)'s focus appears to be the determinants of the CO_2 emissions of firms within a single sector and the effect of spatial correlation, whereas this chapter explores the relationship between the determinants and the sector in which the examined firm operates.

The sector-specific analysis adds more insights to the current empirical literature by revealing the degree of sensitivity facing different sectors. The results show that the energy sector appears more sensitive to legislative action, as the early action–energy sector interaction term is significant, and indicates a decrease in emissions levels. Production output does not seem influential in explaining emissions levels within the energy sector at any statistically accepted significance level. None of the material sector-specific factors turns out to be significant, which might be attributed to the more diversified industrial activities included in the materials sector, compared to the relatively homogeneous business activities of the energy and utilities sectors.

With extended experimental analysis that focuses on the utilities sector, a shift of explanatory power from the utilities sector dummy is revealed, caused by the utilities sector-specific effect. The extended regression results indicate that the production effect within the utilities sector takes away the statistical significance of the utilities sector dummy, while the capital intensity effect within utilities demonstrates less dominance in taking over the explanatory power of the sector dummy. The main policy implications from the analysis in this chapter include the necessity for sector-specific environmental targets and incentives to achieve the target, as different sectors inevitably experience different levels of sensitivity to certain environmental issues, such as carbon emissions.

The research method designed in this chapter also enhances the links among all three empirical chapters and provides a better practicability, as a suitable approximant of the firm-level emission status is obtained through the application of the estimation models with the known firm characteristic inputs, such as the capital-asset ratio, production output, or ROA before the actual emission data are published. The approximant of the firm-level emission status can then be utilised for any portfolio construction that requires the specific emission status information. This aspect has in particular real-practice implications for any asset manager who is interested in incorporating the firm-level emission status into their investment selection and decision process.

The empirical findings of this chapter provide the first set of evidence on the determinants of firm-level emissions behaviour within a mandatory emissions restriction setting with a multi-national and multi-sectoral coverage, as opposed to the previous studies which focused either on a single sector or country (Cole *et al*.,2012; Apergis *et al*., 2013). The results add value to the current literature on environmental management – in particular within the GHG emissions management area. Moreover, as the focus of this thesis lies on the EU ETS and its implications, the analysis in this chapter is performed in a way that best utilises firm-level emissions data in the EU ETS context, which essentially accounts for the endogenous regulatory effect within the system.

Nevertheless, given the scope of the trading scheme, and the accessibility of firm-level financial and characteristics data, the prospects to extend the analysis look good. More in-depth analyses, which could aim to disentangle the firm emission determinants within a certain industry, could be performed provided that an extensive set of data with detailed firm characteristics and verified emission data spanning a reasonable period of time could be obtained. One opportunity is to break down the sectors into industries or sub-industries on the basis of certain commonly used industry classification standards, e.g. the Global Industry Classification Standard (GICS), and perform an industry-specific analysis.

Appendix 6-A

In the original EU transaction log (EUTL) that records the installation-based data, each unit is assigned an activity based on its main operating activity (EC, 2003a). The firms in the sample dataset are categorised using the Global Industry Classification Standards (GICS)[66] for the consistency through the thesis.

Table 6-A.1. Sample dataset distribution

Sector	Main Activity	Firms	% of total*
10 Energy	Oil and gas	25	13.66%
15 Materials	Cement and lime, iron and steel, pulp and papers, chemicals	61	26.65%
20 Industrials	Glass, iron and steel	9	0.95%
25 Consumer Discretionary	Motor industry	7	0.14%
30 Consumer Staples	Food and drink	10	0.25%
35 Health Care	Pharmaceuticals, chemicals	5	0.21%
55 Utilities	Power and heat	27	58.13%

* % is the percentage of the allowances allocated to each sector in terms of the total allowances in the sample dataset.

Table 6-A.2. Variable Measure

VARIABLE	Definition	Source
Emission Level	Verified emissions per unit of EUA allocated	Carbon Market Data
Production	Total production output in €	Datastream
Capital–Labour Ratio	Capital expenditure per employee	Datastream
Renewable Energy Use	Dummy; 1= firm that uses renewable energy	Datastream
Early Action tw. ETS	Dummy; 1= member state that takes early actions prior to EU ETS	Ellerman *et al.* (2010)
ROA	Returns on assets	Datastream
Leverage	Debts-to-assets ratio	Datastream

66 GICS is jointly developed by Standard & Poor's and MSCI, and is widely used in capital market research (Bhojraj *et al.*, 2003). The full GICS methodology and structure can be found in www.msci.com/products/indices/sector/gics/.

Appendix 6-B

Table 6-B. 1. Results of extended tests with Utilities Sector-Specific estimation model

Random-effects GLS regression, Robust control for heteroscedasticity

Dependent Variable: Verified CO^2 emissions-to-cap ratio (at firm level)

Model Specification	*Eq (6-5a)*	*Eq (6-5b)*
Production	0.017^{**} (2.05)	
Capital–Labour Ratio		0.056^{***} (2.77)
Utilities*Production		0.041^{*} (1.83)
Utilities*C-L Ratio	0.051^{**} (2.03)	
Utilities*Renew. Use	-0.024 (-0.36)	-0.046 (-0.64)
Utilities*Early Act.	-0.059 (-0.42)	-0.084 (-0.56)
Energy Sector	0.335^{***} (3.79)	0.193^{**} (2.05)
Materials Sector	0.166^{**} (2.05)	0.105 (1.33)
Utilities Sector	0.255^{*} (1.75)	-0.400 (-1.02)
ROA	0.002 (1.28)	0.002 (1.19)
Leverage	-0.211 (-1.34)	-0.207 (-1.33)
Other Sectors	Yes	Yes
Year	Yes	Yes
Observations	788	788
R^2 overall **(within)** **(between)**	0.258 (0.0927) (0.370)	0.268 (0.101) (0.380)
P-value	0	0

This table reports the results from estimations made with model specification

Eq(6-5a) $Y_{it} = \alpha + \beta_1(Production)_{it} + \beta_2(Utilities * K - L\, ratio)_{it} + \beta_3(Utilities * Renew)_{it} + \beta_4(Utilities * Action)_{it} + \sum_{j-1}^{n} \beta_j(Sector)_{it} + \sum_{K=1}^{n} \beta_k Z_{ikt} + \varepsilon_{it}$ and

Eq(6-5b) $Y_{it} = \alpha + \beta_1(K - L\, ratio)_{it} + \beta_2(Utilities * Production)_{it} + \beta_3(Utilities * Renew)_{it} + \beta_4(Utilities * Action)_{it} + \sum_{j-1}^{n} \beta_j(Sector)_{it} + \sum_{K=1}^{n} \beta_k Z_{ikt} + \varepsilon_{it}$

which jointly test whether the explanatory power of the utilities sector dummy is shifted towards the sector-specific KL ratio or the sector-specific production factor. ***, **, and * represents significance at 1%, 5%, and at 10%, respectively.

7 Conclusion

7.1 Thesis overview

This thesis is particularly interested in one of the European Union's major climate policies, the European Union Emissions Trading Scheme (EU ETS), and empirically examines its implications with regard to firm-level emission behaviour and to stock market performance. The EU ETS is an interesting topic of great relevance, for a number of specific reasons. First, the scale of the EU ETS is largest in terms of its trading activities in relation to the global carbon market. Approximately 45% of total greenhouse gases (GHGs) in the European Union is regulated and for the first two trading periods (2005–2012), EU ETS covers more than half of the carbon dioxide (CO_2) emissions within the community (EC, 2009b). It is also the first multi-sector and multi-nation trading scheme. A stream of EU ETS literature had started to develop before the official launch of the trading scheme in 2005, and has seen considerable growth since. Compared with other streams of the EU ETS literature, however, studies with empirical evidence of an EU ETS-related impact on stock markets are limited, presumably due to the lack of accessibility to company-level data (Bushnell *et al.*, 2013).

This thesis empirically examines the EU ETS effect on emission behaviour, as well as on the stock market performances of exposed and non-exposed firms. The analyses and findings benefit from econometrics techniques and verified carbon emissions data that are sourced from the transaction log administered by the European Commission (EUTL). Three sets of empirical analyses are conducted, which are designed to answer the following questions posed in Chapters 4, 5 and 6, respectively. First, what factors are systematically associated with firm-level emissions within the EU ETS context? Second, what are the effects of the EU ETS on the share price performances of the exposed firms? Third, can EU ETS effects on stock price performance be differentiated at sectoral level? If 'yes', is the emissions status, a.k.a., the net allowances holdings position of firms value-relevant?

The results of the analysis for each of the questions that are conducted in the respective empirical chapter (Chapters 4–6), are summarised and concluded in the following sections.

The implications of the results are also discussed following the summarised findings of each chapter. The last section discusses the limitations of this research project, as well as future research opportunities.

7.2 Aggregate-level EU ETS effects examined from stock market perspectives

The examination on the implications of the EU ETS on the share price of exposed firms is conducted in the second set of empirical analyses, which is the core interest in this thesis. These estimations provide the first piece of empirical evidence on the EU ETS' stock market implications using firm-level real market data from multiple sectors, as opposed to previous studies that primarily focused on electricity/utility providers. Results from this set of analyses reveal the impacts of the trading scheme by examining the stock price performance of a comprehensive dataset containing a considerable proportion of all EU ETS-exposed firms. Specifically, Chapter 4 examines in detail the effect of not only the implementation, but also the planning, of the EU ETS on the stock market performance of the regulated firms.

The majority of previous empirical studies of the effect of EU ETS and its stock market relationships focus on small samples of listed firms participating in the EU ETS (Oberndorfer, 2009; Veith *et al*., 2009; Knight, 2011; Mo *et al*., 2012). The findings are rather inconclusive, as some identify the negative impacts of the ETS on firms' equity prices (Mo *et al*., 2012; Diltz, 2002) while others find no significant performance disadvantages associated with the ETS (Oberndorfer, 2009; Veith *et al*., 2009). The empirical analysis in Chapter 5 consists of two parts: the first tests the impact of the EU ETS on the stock market performance of participating firms; the second investigates whether the participating firms' emissions status (i.e., whether a firm emits CO_2 higher or lower than their allocated allowances) determines the impact of the EU ETS on the firms' stock market performance.

The results show that the portfolio constructed by all ETS-exposed firms sees an expected underperformance at the highest statistical significance level, but only in the sample period 2001–2004 during which the EU ETS was going through the proposed and negotiation process before its launch (Ellerman *et al*., 2010; EC, 2003a). Once the EU ETS was officially in place in 2005, regulated firms did not experience any subsequent negative effects on their stock market performance. These results are in line with previous studies that observe no adverse impacts on the performance of regulated firms within the EU ETS context (Oberndorfer, 2009; Veith *et al*., 2009), as the performance impact appears to arrive ex ante in terms of reduced investor expectations (Chapple *et al*., 2013; Hughes, 2000). No significantly negative contemporaneous impact of the EU ETS on stock market performance is identified in the tests conducted. However, the possibility that the effect exists but has been offset by another unidentified factor can certainly not be ruled out, though it is beyond the current scope of this chapter to examine. It still remains questionable if firms, and eventually their shareholders, are internalising sufficient costs to contribute in a significant way to the proposed climate change mitigation. The forward-looking nature of the financial markets may have forced firms to internalise sufficient costs during the Pre-ETS period (2001–2004). However, they have clearly not done so during the EU ETS itself and since meaningful climate change mitigation requires consistent effort it seems fair to argue that firms currently may not have internalised sufficient costs (EC, 2009a; Stern, 2006, 2008).

7.3 The sectoral differentiation of EU ETS effects on the stock market

The second empirical chapter (Chapter 5) attempts to reveal first whether EU ETS effects on the share prices of exposed firms are differentiated at the sectoral level. It also investigates the performance of Non-ETS-exposed firms at the sectoral level in order to better understand if the ETS is indeed a differentiating factor. The chapter further examines whether the effect on the share prices of firms within the respective sector is differentiated by the firm’s emissions status. First, the performance of sector-based portfolios, which are constructed by ETS and Non-ETS exposed firms operating in seven different sectors, is estimated with extended Carhart models. The portfolios using the long–short strategy for each sector are also tested to further verify the degree of difference in the performance of the ETS and Non-ETS-exposed firms. The analysis further focuses on estimating the performance of firms with different allowances holdings positions within sectors, which may reveal whether stock market investors consider the firms’ emissions status relevant in the equity valuation process. The sectoral performance analysis is achieved by running regressions with the Carhart model and an extended version to evaluate the performance of sector-based portfolios. The emissions status-integrated analysis contains first the comparative and statistical analysis of sectoral emissions status and the related stock prices performance measurement. This takes the investigation of the emissions status effect differentiation a step further by utilising the same econometric method and forming portfolios that consist of firms with the same emissions status within a respective sector. For example, the firms in the Energy sector are separated into over-emitting and under-emitting groups to form sector-based portfolios with emissions status specification.

Six out of seven ETS sectors are found to have significantly underperformed the market benchmark during the Pre-ETS period (2001–2004), during which the ETS regulation was proposed, negotiated, and passed. The differentiation of the performance of ETS-exposed sector portfolios and the Non-ETS sector portfolios can be clearly identified during this period, and is further verified by the estimation results of the sector-based long–short portfolios. As time progressed, the ETS-exposed Energy portfolio was valued indifferently by the stock market after the official launch of the EU ETS in 2005, while its Non ETS-exposed peer saw a constant outperformance through all the estimation periods tested. During the estimation period 2005–2011, the Utilities, Health Care, and Consumer Staples sectors experienced an underperformance while Materials, Industrials, and Consumer Discretionary sectors saw an outperformance against the market benchmark. It is interesting to observe that the performance estimation results of the regression conducted for the portfolios consisting of firms with different emissions status in the main sectors appeared fairly similar to the results of the sector-based portfolio performance estimation. No abnormal returns were detected in both portfolios formed by the Energy firms, both under-emitting and over-emitting ones. Materials sector firms saw a significant and constant outperformance against the benchmark in the full sample period in both over-emitting and under-emitting portfolios. Utilities sector firms experienced a consistent underperformance, even in the case of the under-emitting firms.

Two aspects drawn from the findings of Chapter 5 are of particular interest. The first is to identify that the stock return performance of ETS-exposed firms can be differentiated at sectoral level. More specifically, the estimation done for the ETS-exposed, Non-ETS-exposed, and long–short portfolios jointly indicate that the share prices of firms in certain sectors – namely Energy, Materials, and Consumer Staples – are more prone to the effect of the emissions trading regulation, while the abnormal returns identified in other sectors could not be fully attributed to ETS. It appears that the performance can also be differentiated by sectoral emissions status, as the under-emitting sector sees a reward in the share value while the over-emitting sector experiences a value penalty. Another aspect concerns the stock return performances differentiated by the emissions status that cannot be seen at firm level within sectors. The results are interpreted as suggesting that stock market investors consider the emissions status and the net allowances holdings positions of the sector as value-relevant. This is generally consistent with the positive value-relevance view by Johnston *et al*. (2008). However, stock market investors have not yet been able to value specifically the net positions at the firm level, as indicated by the portfolio performance estimations of the emissions status-based within-sector portfolios. This is consistent with Bushnell *et al*.'s (2013) views regarding the lack of easily accessible firm-level allowances holdings and trading information of the EU ETS. The findings in this chapter thus appear to confirm the difficulties in evaluating the firms' net position of allowances holdings by stock market investors, while it is relatively easy to gain the information or a general sense regarding emissions status at the aggregate sector level.

In summary, the most interesting finding in this chapter highlights the fact that stock market investors are able to value sectors according to their overall emissions status but unable to do so at company level with the sector. This enhances the proposition about the lack of adequate company-level emissions information raised in Chapter 5, as the results show that stock market investors are not able to distinguish over-emitting firms from under-emitting ones and value them indifferently in terms of the signs of estimated abnormal returns. This finding implies that the current level of corporate carbon reporting is insufficient in terms of value-relevance for the market. This may lead to fewer incentives for long-term investments on low-carbon technology, as explained earlier. It is thus considered very encouraging that the UK has taken the first step towards mandatory GHG emissions reporting with support from the businesses community (DEFRA, 2012).

7.4 Determinants of firm-level emissions-to-cap status

The last empirical chapter (Chapter 6) sheds light on identifying the determinants of firm-level carbon emissions behaviour within a regulated ETS context and answers the following question: what factors systematically explain the carbon emissions intensity, which is measured by emissions per production unit, at the firm level within the EU ETS? The analysis performed in this chapter provides the first empirical evidence of the determinants of firm-level emissions behaviour within a mandatory ETS at multi-national and sector scale, and hence the results are value-added to the current literature on the environmental, in particular the emissions management, area.

The analysis benefits from a panel dataset that comprises the largest European listed firms, in terms of their shares in allowances allocated and verified emissions subject to the mandatory emissions restriction. The sample dataset covers six years of operation of the EU ETS and is on a multi-sector scale. It also benefits from verified emissions data from the EU ETS covering 140 listed firms during 2005–2010 and the reliability and quality of the data being sourced directly from the EUTL administered by the European Commission. Given the properties of the dataset of research interests, a panel regression with multi-factor model, which draws inspiration from previous studies with a similar research subject, such as Cole *et al*. (2012, 2005) and Pargal and Wheeler (1996), is used in this set of analyses. In addition to the baseline model that encompasses firm characteristics and sector dummies, the interaction terms between such characteristics and dummies are added into the baseline model, to better differentiate the potential effects from sector differences on firm-specific emissions intensity (Antweiler *et al*., 2001; Cole and Elliott, 2003).

The results suggest that the capital intensity and production output effect are associated with increasing emissions, a similar finding to that seen in Cole *et al*. (2005, 2012). However, the novel and more accurately constructed emissions performance measure, which best utilises the emissions data from the mandatory scheme, has advanced the quality of the estimation outcome. With regard to the sector-specific analysis, the Energy sector appears sensitive to legislative action while the firm characteristics do not seem influential in explaining the emissions variation within the sector at any statistically accepted significance level. The Materials sector does not show particular sensitivity toward any explanatory variable while the Utilities sector-specific interaction terms for production and capital intensity are statistically significant. The sector differentiation effects again remain supported at the overall level, while the hypothesis of a sector-specific effect has no significant coefficients. A sector differentiation effect can be recognised consistently under different specifications, which supports the hypothesis proposed and also appears in line with previous studies, such as de Villiers *et al*. (2011), Cho and Patten (2007), and Patten (2002), which explicitly suggest the rationale to control for industries based on their environmental sensitivities. In Chapter 4 of this thesis, the utilities sector is among those with the highest exposure to the mandatory emissions restriction based on the allowances plan analysis and the verified emissions data (Zetterberg *et al*., 2004; Betz *et al*., 2006; Grubb and Neuhoff, 2006). This high exposure is indicated by the positive and statistically significant coefficient of the utilities sector firms.

The main policy implications from the analysis in this chapter include the necessity for sector-specific environmental targets and incentives to achieve such targets, as different sectors inevitably experience different levels of sensitivity to certain environmental issues, such as carbon emissions. The capital intensity effect implies that business models matter in terms of how a firm behaves in terms of sustainability and environmental concerns. Moreover, business operating activities inevitably impose substantial consequences on the environment, as indicated by the positive link between production output and emissions behaviour. One solution to improve the environmental performance of a firm without compromising operating activities or business models will be to effectively enhance technological innovation. As indicated by the results, the magnitude of the action effect is not sufficient to moderate firms' emissions levels at this stage, which can imply a lack of effort from firms to invest and adopt new technology. Hence, policy makers may need to generate more suitable incentives for large-scale investments in technological innovation, which should aim to benefit all parties concerned, including the industry, public, and ultimately the environment. One aspect to which extra attention should be paid would be the heterogeneity of the environmental sensitivities of different sectors, for it could be more environmentally effective and cost efficient in the long term to tailor-make sector-specific policies and particular incentives.

7.5 Limitations and future research opportunities

The analysis in this thesis has several limitations, which allow scope for future research opportunities. As the focus of this thesis lies in the EU ETS and its implications from various aspects, the empirical analysis in this chapter that examines the firm-level emissions determinants is performed in a way that best utilises the company-level emissions data in the EU ETS context. However, given the scope and history of the trading scheme and the lack of accessibility of company-level data for non-listed firms, future research may be able to extend this research once more data become available. For instance, more in-depth analyses which aim to explore firm-level emissions determinants within a certain industry could be performed provided that an extensive set of data that comprise detailed firm characteristics and verified emissions data spanning a reasonable period of time are available. One opportunity will be to further break down sectors into industries or sub-industry.

The main research challenge of this thesis, which shares similar interests to Oberndorfer (2009) Veith *et al*. (2009), and Knight (2011), is the limited number of firms qualified for the analysis. Although the dataset used in the econometrics analysis in Chapters 4, 5, and 6 is by far the largest compared with the previous studies mentioned above, it appears that the availability and amount of reliable real market data remains a shared limitation among all the EU ETS studies that attempt to empirically examine similar topics. Investigations with an extended dataset can thus be expected to add value to current research as it can provide a more complete picture of the EU ETS implications for relevant parties within both complete trading periods.

The equity valuation process is certainly a procedure subject to numerous complications and there undoubtedly will be other unidentified but relevant factors. Future research may want to investigate the effects of the volatility in the price trends of allowances, especially with relation to the information shock in the first trading period, as both could have considerable impacts or cause imprecise estimation results. The EU ETS is also currently progressing its third phase as planned, which covers an eight-year period from 2013 to 2020. The third phase has undergone several major amendments aiming to improve the system and mitigate a few shortcomings identified in previous phases. These systemic improvements in the subsequent phases of the EU ETS will be another promising topic to explore, given that significantly different levels of stringency of the reformed EU ETS are expected (EC, 2010, 2012). As more emission trading schemes emerge [67] (The WorldBank, 2011, 2012), the problem of small datasets in the literature on this particular subject can be addressed more extensively than already done in this thesis. It will be very interesting to examine whether the EU ETS effects found in this thesis differ substantially from the results of equivalent analyses performed on the third phase of the EU ETS, once data becomes available.

67 Australia, California, RGGI and other trading schemes are emerging worldwide. See TheWorldBank (2012).

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