DIRTY STOCK RETURNS IN THE ERA OF SUSTAINABILITY

A STUDY OF THE WORLD'S LARGEST CARBON MARKET

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Abstract:

Using a dataset on the stock returns of 65 German firms, this thesis empirically analyses the effect of the European Union Emissions Trading System on the biggest economy and carbon market in Europe. We conclude that the different allocation methods have resulted in large discrepancies in stock performance for the firms reporting under the ETS. More specifically, we find a statistically significant premium in stock returns for carbon emitting firms when carbon allowances are freely allocated. This is due to two economic mechanisms, namely the cash-flow effect and the carbon risk effect. When allowances are sold in auctions as opposed to being allocated for free, this premium dissipates, and clean firms outperform dirty firms. In short, this thesis contributes to the evaluation of the world's largest carbon market and its effect on the financial performance of firms reporting under the system.

Keywords:

European Union Emissions Trading System, Carbon Emission Allowances, Carbon Risk, Environmental Regulation

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1. Introduction

The European Union Emissions Trading System, hereafter ETS, was the world's first greenhouse gas emissions trading scheme of significant size and remains the biggest financial carbon market globally. The ETS serves an important role as a key weapon for the EU to combat climate change. The flagship project was established in 2005 and aims to reduce carbon emissions through economic incentives, see Table 1 for a detailed timeline of events concerning the ETS. The scheme has the ambitious goal of cutting total emission in the EU by more than 40% to 2030, compared to the levels in 2005. As of writing, the ETS covers over 11,000 installation and 2,000 megatonnes of carbon dioxide, which corresponds to almost half of all greenhouse emissions in the EU. The ETS is a cap-and-trade program which allocates carbon emission allowances, i.e. polluting rights to companies based on an annual cap. One carbon emission allowance gives the right to pollute one tonne of greenhouse gas emissions. This cap is systematically reduced over time to lower total emissions. During the initial two phases of the system, beginning in 2005 and ending in 2012, carbon emission allowances were granted to firms predominantly free of charge. However, in 2009 there was an EU law passed which established the key features of the third phase, due to start in 2013. It was in this law made public that beginning in 2013, carbon allowances would predominantly be sold in auctions. After this law was made public in 2009, carbon emitting firms were suddenly expecting to have to begin purchasing carbon allowances from 2013 and onwards. This monumental shift in how carbon allowances are allocated has led us to the following research question:

How have the different allocation methods of carbon allowances in the ETS affected stock returns of carbon emitting firms?

Since the inception of the ETS, financial markets have been curious to understand which financial consequences environmental policy of this sort would have on the performance of the affected firms. Given the size of the ETS, small changes in policy could have severe and long-lasting effects on those firms that are under regulation. For instance, a new law establishing that firms have to start paying for something that they expected to be free, or vice versa, can have significant effects on future earnings.

This is why we are interested in researching how this shift, concerning the allocation of carbon allowances, has affected the financial performance of carbon emitting firms.

We answer our research question by first replicating, and then extending the empirical analysis in Oestreich and Tsiakas (2015). The authors analysed German stock returns for a sample period beginning in November 2003 and ending in December 2012. In this paper, we analyse a sample period beginning in November 2003 and ending in June 2016, which is interesting for a number of reasons. Most importantly, the authors analysed the ETS during its initial two phases, when carbon allowances were predominantly allocated to carbon emitting firms free of charge. By extending the sample period, we also analyse the ETS during a period of time when carbon allowances are predominantly sold in auctions. By extending the sample period in Oestreich and Tsiakas (2015) we contribute to the scientific community by validating the findings in the previously mentioned paper, and also by providing novel research in a sparsely examined field, namely where environmental economics is intertwined with finance.

We follow the methodology in Oestreich and Tsiakas in order to answer our research question. Firstly, we limit our data to Germany, since it is both the largest economy and emitter of carbon emissions in Europe. Secondly, we create three stock portfolios, which are supposed to proxy the stock performance of three categories of firms, those receiving many carbon allowances, those receiving a few carbon allowances, and those receiving no carbon allowances. More specifically, we create a dirty portfolio for those firms receiving more than a million annual free carbon allowances, a medium portfolio for those firms receiving more than zero but less than a million free carbon allowances, and a clean portfolio for those firms receiving no free carbon allowances. We also create a dirty-minus-clean portfolio, which implies taking a long position in the dirty portfolio and a short position in the clean portfolio.

There are two economic mechanisms driving the results in our empirical analysis. The first mechanism is the cash flow effect, and by using the framework of Goulder, Hafstead and Dworsky (2010) we show that by allocating carbon allowances for free, carbon emitting firms can experience windfall profits as a result of the cap-and-trade system. The framework shows that the cap-and-trade system leads to increased marginal costs for carbon emitting firms. Carbon emitting firms respond to this increased marginal cost by increasing prices, decreasing output volumes, or adopting new carbon-friendly technologies. This results in large gains in producer surplus for carbon emitting firms. However, by using the same framework, we show that if carbon allowances predominantly are sold in auctions, carbon emitting firms would experience large losses in producer surplus.

The second mechanism is the carbon risk effect. Carbon emitting firms are more exposed to carbon risk than non-carbon emitting firms, which could for instance be increased prices of carbon allowances or the consequences of devastating climate change as suggested in Weitzman (2009), Litterman (2013) and Pindyck (2013). As a result of the increased exposure to carbon risk, carbon emitting firms will demand higher expected returns compared to non-carbon emitting firms.

Our most important empirical findings are the following. During the initial stages of the ETS, when carbon allowances were predominantly allocated for free, we find that dirty firms significantly outperform clean firms, which is measured by a high and significant abnormal excess return of the dirty-minus-clean portfolio. Therefore, we conclude that there was a high and significant dirty carbon premium present, for the period of time firms received free carbon allowances and expected these to be free for the foreseeable future. However, when it is made public in 2009 that firms will have to begin purchasing carbon allowances in auctions beginning in 2013, the dirty carbon premium dissipates in size and significance. Analysing a sample period that begins in 2009 and ends in 2016, we find that there emerges a high and significant clean carbon premium shortly after it is made public that firms will have to begin purchasing carbon allowances in auctions.

On a separate note, we find that there is a positive and significant carbon risk factor during the initial stages of the ETS. This explains the high expected returns that dirty firms demand, for having a high exposure to carbon risk. However, we find that over time, the size and significance of the carbon risk factor disappears. Analysing a sample period that begins in 2009 and ends in 2016, we find that the carbon risk factor becomes negative, and of little statistical significance. This could explain why after 2009, dirty firms started performing worse, and have had negative expected returns as a result of their high exposure to carbon risk.

2. Literature Review

The origins of environmental economics date back to the 1960's, when both the political interest and the first research papers concerning environmental economics widely spread (Pearce 2002). Environmental economics has over time studied several means of achieving an environmental goal. Common examples include setting minimum technological standards, introducing pollution taxes and establishing markets for tradable permits. Some of the first scientific work on markets with tradable permits was done by Dales (1968). He showed that if pollution without permits are forbidden, and the cost of polluting is lower than the price of a permit, dirty firms will tend to buy permits whereas clean firms will sell them, thus creating an equilibrium for permit prices.

The use of tradable permits has accelerated all over the world with some common examples of usage being acidic pollutants in the US, overfishing in Northern Europe and water rights in Chile. There is evidence that markets for emission rights are here to stay and according to Pearce (2002), there is reasonable consensus that tradable emission allowances must play a key role in tackling climate change.

Research lines that are pertinent to the ETS and relevant for our study include the studies by Koch and Bassen (2013), Smale et al (2006) and Oestreich and Tsiakas (2015). The first mentioned study investigated the correlation between carbon stock prices and the price of carbon allowances. This line of research was extended by an event study by Jong et al (2014), which showed the effect of environmental laws on the profits of carbon-emitting firms. Moreover, Smale et al (2006) showed, using a Cournot representation, that the introduction of the ETS generally increases expected profits for companies in energy-intensive sectors. Finally, a third line of research, focused on the development of the alpha depending on the cleanliness of a portfolio, was put forward in Oestreich and Tsiakas (2015). They investigated the presence of a carbon premium in stock returns stemming from the free carbon allowances during Phase I and II of ETS. Moreover, the authors reached the conclusion that after the key features of Phase III of the ETS are made public in March 2009, the carbon premium that carbon emitting firms previously developed, completely disappeared. The authors reached this conclusion by studying the stock performance of German firms from November 2003 to December

2012. What is interesting is that the authors reached the conclusion before Phase III even began trading, which started in January 2013. As a result, the authors predicted the dissipation regarding the carbon premium, based on a period of doubt, when the public was made aware that carbon emitting firms would have to purchase the majority of emission rights in auctions, beginning in 2013. Even though this is a fair and reasonable theoretic prediction, based on future cash flows being at risk as a result of increased spending on emission rights, one cannot be sure that these predictions will hold in reality.

This paper aims to contribute by replicating the results put forward by Oestreich and Tsiakas and also by extending the sample period to June 2016. The replication is important, in part to validate the extension of this paper, and in part because similar research on other carbon markets has yielded different results. Zhang and Gregory-Allen (2018), using the same methodology as Oestreich and Tsiakas, showed no significant carbon premium for the Shenzhen Pilot Emissions Trading Scheme in China. Moreover, extending the paper through more than three years of trading in Phase III contributes to novel research.

In short, while the ideas of academics in the field of environmental economics often have been remarkably quickly adopted, it is not seldom that the effectiveness of the implementation of the ideas remain unexplored. There is thus a great need for studies that evaluate the effectiveness of environmental economic instruments. This study does just that; and focuses on the world’s largest carbon market.

3. The European Union Emissions Trading System

The following section provides a brief description of the ETS, for more information see World Bank (2014) and European Commission (2015). The ETS is the world's largest carbon dioxide emissions trading system. The cap-and-trade program was launched in 2005 and is a cornerstone of the European Union's energy policy. It covers all EU member states as well as Iceland, Norway and Liechtenstein.

The scheme allocates polluting rights to companies based on an annual cap. This cap is systematically reduced over time so that total emissions fall. The unit used for emissions are European Union Allowances, or EUAs, where one EUA gives the polluter the right to emit one tonne of greenhouse gases. If an emitter wishes to pollute more than their initial allowance, they must purchase additional EUAs from those who used less than they received. The intuition is that the program will create incentives for firms to reduce emissions, as they can sell excess allowances for profit.

The ETS has been implemented in four phases. During the first phase, which begins in January 2005 and ends in December 2007, EUAs were predominantly given to emitters free of charge, and there was no possibility to store allowances for Phase II. In other words, allowances lost their value if left unused after Phase I. During Phase II, which begins in January 2008 and ends in December 2012, EUAs were also primarily allocated free of charge, however with the possibility to bank allowances for future phases. During these initial phases, free allowances were allocated with the grandfathering approach. This approach essentially means that EUAs were allocated based on historical greenhouse emissions. After facing criticism for unfairly punishing proactive firms, the grandfathering approach was replaced with a benchmarking approach in Phase III and onwards. The benchmarking approach allocates allowances based on production performance (measured against specific sector benchmarks) instead of historical emissions. This has created sounder incentives as it becomes increasingly difficult for inefficient installations to cover their emissions with freely allocated allowances. In Phase III, which begins in January 2013 and ends in December 2020, the majority of the EUAs are sold in auctions. Spare allowances can be either stored for future use or sold to other firms. Phase IV begins in January 2021 and is expected to end in

December 2030, with the goal being that by the end of this period, total emission levels will have been cut by 40% from 2005 levels.

EUAs are given to individual factories, and not on a firm level. In March every year installations receive annual allowances. For all emissions emitted by a company, they must surrender the corresponding amounts of allowances by the end of April the following year or else the company faces a fine. The emission level for each separate EU country are also made public in the end of April each year. There are several trading platforms for trading EUAs, with the biggest being the European Climate Exchange (ECX) in London. The ETS covers more than 11,000 installations which together stand for about 45% of total greenhouse emissions in the EU.

The development for Carbon Emissions Futures has been volatile since 2008, this has raised questions about the stability of the system (see Figure 4). For example, in the beginning of the year of 2012, the price was consistently under €10 compared to almost €30 per tonne in 2008. The large surplus of allowances that at times have been present, often coinciding with general economic downturns, have driven prices to very low levels. Criticism has thus been raised whether prices have at times been too low to provide proper incentives for firms to reduce emissions. However, measures such as banking of allowances have been introduced to mitigate volatility. There have also been calls made to introduce price floors. This has, as time of writing, not been put in place. However, one must keep in mind that the volatility levels in energy commodities markets are relatively high compared to other types of markets. Thus, the volatility seen in the ETS, albeit high in absolute numbers, is quite in line with comparable energy commodities markets. Moreover, the EU has introduced the Market Stability Reserve, MSR, to combat oversupply of allowances. In effect, the MSR is a central bank for carbon allowances that will remove surplus inventory. The role of MSR is to create a mechanism to regulate supply, in order to maintain the balance of the ETS which had until the introduction of MSR been struggling with fixed supply but variable demand. The introduction of the MSR led to a spike in prices, subsequently stabilizing at these higher levels, around €25 per tonne.

4. Cash Flows, Expected Returns and the ETS

4.1. The Effect on Cash Flows

The underlying component to this effect is the marginal cost of production, which increases with the introduction of the cap-and-trade system, compared to having no carbon regulation at all. The market value of the amount of carbon allowances required in order to produce one unit of output is equal to the increase in the marginal cost of production. This is the case regardless if the carbon allowances were allocated freely or purchased in the market. This essentially means that a firm using a carbon allowance can choose between either purchasing that unit or forfeiting one unit from the surplus carbon allowances it could have subsequently sold.

For the illustration and economic mechanisms taking place as a result of the introduction of a cap-and-trade system in line with the analysis in Goulder, Hafstead and Dworsky (2010), see Figure 1. In this figure we see the supply curve shifting up as a result of the increased marginal cost. There is a two-fold explanation to the increased marginal cost, namely due to having to purchase or forfeit excess carbon allowances, illustrated by *r* in the figure, and due to increased costs of switching to less carbon-intensive fuels, illustrated by *c*. In other words, it shows the effect of the free allocation of carbon allowances on the profits of a perfectly competitive industry, where the initial equilibrium is given by *b*. When the cap-and-trade program is in place, the new equilibrium is given by *a*, with increased consumer price, exceeding the previous price by $c + r$, and decreased producer output.

The introduction of a cap-and-trade program could potentially generate windfall profits to firms affected by the system. In a scenario where there is free allocation of carbon allowances, area A would illustrate gain in producer surplus. If the newly generated gain in producer surplus is greater than the loss in producer surplus, illustrated by area B, we will find that firms receiving free carbon allowances realize greater profits as a result of the imposed system. However, in a scenario where carbon allowances are sold in auction, area A would represent government revenue, resulting in a net loss of producer surplus for carbon emitting firms.

On a final note, even though it is expected that there would be a positive cash flow effect on carbon emitting firms as a result of the cap-and-trade program, there are many uncertainties surrounding this project, and therefore also the outcome. For instance, the fact that the ETS was a pilot project, information asymmetries, volatility in the price of carbon allowances, and so on. Therefore, our first hypothesis reads as follows:

H1: During the initial two phases of the ETS, when firms predominantly receive carbon allowances free of charge, carbon emitting firms will experience higher cash flows and therefore higher average returns. Thus, there will emerge a dirty carbon premium in stock returns. However, during the third phase of the ETS, when carbon allowances are predominantly sold in auction, the dirty carbon premium will dissipate.

4.2. The Effect on Expected Returns

Besides the cash flow effect, there is an additional more subtle effect that has to do with the increased risk that carbon emitting firms run, for having a high exposure to carbon risk. Carbon risk is primarily described as the risk of future cash flows being affected by increased prices of carbon allowances. Prices of carbon allowances have experienced considerable volatility since its inception. In addition, policy changes, such as passing legislation implying a different method for allocating allowances, or the creation of the MSR, have significant effects on the future expectations of cash flows. Finally, catastrophic climate change as described in Weitzman (2009), Litterman (2013) and Pindyck (2013), would imply an increase in prices of carbon allowances for carbon emitting firms. Again, proving the inherent risk of having a high exposure to carbon risk.

For the mentioned reasons, there is a general risk aversion toward investing in carbon emitting firms. Therefore, there has to be a risk premium in carbon emitting firms, implying that carbon emitting firms should yield higher expected returns than non-carbon emitting firms. Therefore, our second hypothesis reads as follows:

H2: Carbon emitting firms are subject to carbon risk and will therefore require higher expected returns than non-carbon emitting firms, denoted by a dirty carbon premium. This dirty carbon premium will in part be explained by a positive and significant price of a carbon risk factor. When the dirty carbon premium dissipates, so will the size and significance of the price of a carbon risk factor.

5. Data Description

5.1. Sample Period

The complete sample period we analysed in this paper begins in November 2003 and ends in June 2016. November 2003 coincides with the passing of an EU law that establishes the two initial phases of the ETS. It is therefore made public in 2003 that the ETS will begin in 2005, and that firms will predominantly be receiving free carbon allowances for the foreseeable future. The sample period ends in June 2016, which considers more than three years of trading during Phase III of the ETS, which begins in January 2013. An additional reason for choosing June 2016 as the end date of the sample period concerns the availability of data needed in order to analyse our research question. In particular, data regarding Fama-French (1993) size and value factors, as well as the Carhart (1997) momentum factor, especially constructed for the German economy ends in June 2016. The mentioned data is provided by the Business and Economics Faculty at Humboldt-Universität Zu Berlin and explained in detail in Brückner et al. (2015).

In our analysis, we take three shorter sample periods into consideration. The first two sample periods coincide with the periods analysed in Oestreich and Tsiakas (2015). The first sample period begins in November 2003 and ends in March 2009, and thus ends with the passing of an EU law that establishes Phase III of the ETS. It is through the passing of this law that it is made public that beginning in 2013, firms will have to purchase the majority of carbon allowances in auction, as opposed to receiving them for free. As a result, this sample period only takes into consideration the period of time during which firms receive carbon allowances for free and expect these to be free for the foreseeable future. Through this first sample period, we analyse the stock performance of firms during a period of time when firms were not expecting to have to purchase carbon allowances.

The second sample period begins in November 2003 and ends in December 2012, and therefore ends with the expiration of the second phase of the ETS. Even though firms continue to receive carbon allowances for free until 2013, this sample period is particularly interesting to analyse. This period of time captures the stock performance of firms in a time of uncertainty and confusion concerning what will happen when they have to start purchasing carbon allowances in auctions. What is almost certain is that starting in 2013, carbon emitting firms will have to start purchasing carbon allowances, resulting in increased costs, and decreased future cash flows. The notion that future cash flows are at risk is immediately reflected in the current stock price. Therefore, it is highly relevant to analyse this sample period.

It is through the two previously mentioned sample periods, ending in 2009 and 2012, that Oestreich and Tsiakas (2015) analyse and make conclusions concerning the ETS' effect and ramifications on firms trading on the Frankfurt Stock Exchange. However, the end date of their sample period does not consider the period of time during which firms actually have to purchase carbon allowances in auctions. They base their conclusions on the period of uncertainty from 2009 to 2012. Therefore, extending the sample period through 2016 makes an interesting extension, considering more than three years of trading during Phase III of the ETS, as well as there being sufficient data in order to produce relevant results. Through this extended sample period, we are able to measure and validate the results in Oestreich and Tsiakas (2015), and research how the stock performance of carbon emitting firms has developed since the third phase of the ETS began trading.

Finally, we decided to include a third, shorter sample period in our analysis, which begins in April 2009 and ends in June 2016. What makes this period interesting is that it starts a month after the passing of the law establishing the third phase of the ETS and ends with the end-date of our extended sample period. This sample period neglects the period of time when firms receive carbon allowances for free and expect to receive these for free. What is new about this sample period is that the financial distress of having to purchase carbon allowances is reflected in the stock price of firms throughout the entire period of time.

5.2. Stock Returns

In order to apply the same methodology as in Oestreich and Tsiakas (2015), we collected monthly stock returns from firms trading on the Frankfurt Stock Exchange, from the last day of each month. In particular, we analyse stock returns of those 80 firms which are either included in the DAX or MDAX stock indexes. The DAX is a blue-chip stock market index, which includes 30 major firms trading on the Frankfurt Stock Exchange, while the MDAX includes 60 mid-cap firms (excluding tech-sector firms) trading on the Frankfurt Stock Exchange. However, at the time of writing for Oestreich and Tsiakas (2015), the MDAX only consisted of 50 firms. Firms included in either of the two indexes encompass 95% or more of Germany's stock market cap; see Table 2 for the complete descriptive statistics concerning firms under analysis, their respective industry classification, and market cap. The high stock market cap of our sample indicates large diversity concerning industry, which proves to be a good representation of the overall economy in Germany.

Oestreich and Tsiakas (2015) proceed to exclude all firms for which they do not find monthly return data concerning their complete sample period from 2003 to 2012. As a result, they exclude 15 firms, leaving them with the remaining 65 firms. As for our extension of the paper we apply the same methodology as the authors. Only one firm, Douglas Holding, that was included in the original paper was delisted from the Frankfurt Stock Exchange during Phase III of the ETS, prior to June 2016. As a result, we had to carry out a portfolio rebalancing before January 2013, resulting in the exclusion of the previously named firm from our analysis.

We continue by calculating monthly stock returns in accordance with the authors methodology. Therefore, we calculate monthly stock returns through the following logarithmic formula:

$$r_{j,t+1} = \ln(P_{j,t+1}) - \ln(P_{j,t}),$$

where $P_{j,t}$ is the adjusted price (accounting for dividend reinvestment and stock splits) of stock j at time t. Data concerning stock prices, as well as market capitalization has been downloaded from *Datastream*.

In accordance with Oestreich and Tsiakas (2015), we proxy the return of the market portfolio by using the DAX index return. However, as for the risk-free rate, the proxy used by the authors is not available for our extended sample period, which is why we proxy the risk-free rate by using the German ten-year government bond, which is in line with standard practice. Finally, the Fama-French (1993) size and value factors, and the Carhart (1997) momentum factor for the German economy has been provided by the Business and Economics Faculty at Humboldt-Universität Zu Berlin and explained in detail in Brückner et al. (2015). This set of size, value, and momentum factors differs from that employed in Oestreich and Tsiakas (2015), which ends in 2012, and can therefore not be applied in our extension of the sample period.

5.3. Carbon Emission Allowances

We have gathered data concerning each firm's freely allocated carbon allowances by analysing archives and results published in the German Emissions Trading Authority (DEHSt). Each year, the DEHSt issues a publication of the results of the free allocation of emission allowances to incumbent installations. We are then able to manually match the free allocation of emission allowances to a particular installation, with the firm it belongs to. Finally, we aggregate the free allocation of emission allowances issued to each firm. See Table 2 for descriptive statistics concerning freely allocated carbon allowances to each firm (annual average), for the three separate phases of the ETS.

During the initial two phases of the ETS, 24 firms received free carbon allowances. There are large discrepancies in regard to the amount of free carbon allowances allocated to each firm, some receiving only a couple of thousand allowances each year, while others receive tens of millions. Furthermore, in the transition to the third phase of the ETS, we find a substantial decrease in the number of carbon allowances allocated freely. During Phase III, only 20 firms receive free carbon allowances, and the amount of annually allocated allowances decreases dramatically compared to the two initial phases. The trend is generally that there is a small decrease in the amount of annually freely allocated allowances from Phase I to Phase II, and then a substantial decrease from Phase II to Phase III. The decrease in freely allocated carbon allowances to the third phase is however not a surprise. As mentioned previously, the passing of an EU law in 2009 established that beginning in 2013, the majority of carbon allowances would be sold in auction.

6. Empirical Analysis

6.1. A Portfolio Approach

Following the methodology applied in Oestreich and Tsiakas (2015), we address our research question by creating three portfolios: “dirty”, “medium”, and “clean”. The dirty portfolio consists of those firms that have received on average more than one million free carbon allowances annually. The medium portfolio consists of those firms that received on average more than zero free carbon allowances, but less than one million annually. Finally, the clean portfolio consists of those firms that have not received any free carbon allowances. We furthermore analyse a “dirty-minus-clean” portfolio, DMC, which is a zero-investment portfolio implying taking a long position in an equally weighted dirty portfolio and a short position in an equally weighted clean portfolio.

During the initial two phases of the ETS, 8 firms were regarded as dirty, thus receiving annually more than a million free carbon allowances, 16 firms were regarded as medium, and 41 firms regarded as clean, not receiving any free carbon allowances. However, as for the third phase, and our sample period extension, some changes were made in the categorization of firms. Starting in 2013, 5 firms were regarded as dirty, 15 firms were regarded as medium, and 43 firms regarded as clean. The number of firms in our analysis decreased by one due to the delisting of Douglas Holding from the Frankfurt Stock Exchange during our extended sample period. Due to the delisting of one firm, as well as the re-categorization of several other firms, we had to perform a portfolio rebalancing after 2012.

6.2. Portfolio Returns

We find similar results to those in Oestreich and Tsiakas (2015) concerning the portfolio returns, see Table 3 for detailed results in regard to the annualized mean return of the dirty, medium, clean, and DMC portfolios for the different sample periods. We find that the DMC portfolio has an annualized mean return of 16.4% for the first sample period, which begins in 2003 and ends in 2009. This result implies that for the first sample period, when dirty firms receive the majority of carbon allowances for free and expect these to be free for the foreseeable future, the dirty portfolio outperform the clean portfolio on the stock market. For the next sample period, which begins in 2003 and ends in 2012, we find that the annualized mean return of the DMC portfolio is 2.9%, implying that the dirty portfolio still outperforms the clean one, but not by as much as in the previous sample period. For the extended sample period, which begins in 2003 and ends in 2016, we find that the DMC portfolio has an annualized mean return of -1.6%, implying that the clean portfolio outperforms the dirty portfolio, albeit by a small degree. Finally, we find that for our final sample period, which begins in 2009 and ends in 2016, the DMC portfolio has an annualized mean return of -14.9%.

The result concerning the final sample period from 2009 to 2016 is interesting since it suggests that after March 2009, when firms are made aware that they will have to start purchasing carbon allowances in 2013, the clean portfolio by far outperforms the dirty portfolio. These levels are equivalent to those in the first sample period, when the DMC portfolio had an annualized mean return of 16.4%. From the moment that the DMC portfolio peaked during the first sample period, the annualized mean return of the DMC portfolio decreased by 31.3% to June 2016. The annualized mean return of the portfolio decreased by close to a third based on the notion that firms expected carbon allowances to be free in the foreseeable future but found out they would have to start paying for these.

6.3. Factor Models

In order to establish the abnormal excess return of a portfolio, denoted by alpha (α), which is the main point of analysis in the next section of the paper, we use three factor models, in line with the procedure in Oestreich and Tsiakas (2015). In order to establish the alpha of each portfolio for a given sample period we perform time-series regressions. The constant that is yielded through each regression is the alpha of the portfolio. Our first regression is derived from the Capital Asset Pricing Model (CAPM), and is calculated by:

$$r_{j,t} - r_{f,t} = \alpha_j + \beta_j\left(r_{M,t} - r_{f,t}\right) + \varepsilon_{j,t},$$

$r_{j,t} - r_{f,t}$ being the monthly excess return of portfolio *j* at time *t*, and $r_{M,t} - r_{f,t}$ being the monthly excess return to the market portfolio at time *t*, and $\varepsilon_{j,t}$ being the normal error.

Our second regression is derived from the Fama and French (1993) three-factor model, which from now on we term FF3, and is calculated by:

$$r_{j,t} - r_{f,t} = \alpha_j + \beta_{j1}(r_{M,t} - r_{f,t}) + \beta_{j2}SMB_t + \beta_{j3}HML_t + \varepsilon_{j,t},$$

SMB_t being the monthly excess return of the "small-minus-big" size premium that smaller market cap firms have over large market cap firms. Fama and French (1993) deem this the "small firm effect" since they found in their study that small market cap firms significantly outperform large market cap firms, which is why they have included this factor in their stock pricing model. HML_t refers to the monthly excess premium of the "high-minus-low" value premium that firms with high book-to-market ratios have over firms with low book-to-market ratios. The authors found that value stocks significantly outperform growth stocks, resulting in the inclusion of this factor in their stock pricing model.

Our third regression is derived from the Carhart (1997) four-factor model, which from now on we term FF4, and is calculated by:

$$r_{j,t} - r_{f,t} = \alpha_j + \beta_{j1}(r_{M,t} - r_{f,t}) + \beta_{j2}SMB_t + \beta_{j3}HML_t + \beta_{j4}MOM_t + \varepsilon_{j,t},$$

MOM_t being the monthly return of the momentum factor, capturing the tendency of stocks to move in the same direction as they did in the previous period.

6.4. The Carbon Premium

The carbon premium is defined as the abnormal excess return, i.e. alpha, of the DMC portfolio; see Table 4 of the appendix for the regression results. For the first sample period, which begins in 2003 and ends in 2009, we find that the annualized carbon premium of the DMC portfolio can be as high as 16.2% relative to the CAPM, and highly significant relative to all but one factor model. Therefore, during the first sample period, there is a high and significant dirty carbon premium. This empirical finding suggests that during the period of time when firms receive carbon allowances for free, and expect these to be free in the future, dirty firms significantly outperform clean firms. Our findings are in line with those of Oestreich and Tsiakas (2015).

However, looking at the second sample period, which begins in 2003 and ends in 2012, we find that the annualized carbon premium of the DMC portfolio only is as high as 2.5% relative to the CAPM, as well as not being of statistical significance. This empirical finding suggests that once firms are made aware in 2009 that they will have to begin purchasing carbon allowances, dirty firms seize to significantly outperform clean firms.

As for our extended sample period, which begins in 2003 and ends in 2016, we find that the annualized carbon premium of the DMC portfolio becomes negative, even as low as -5.6% relative to the FF4, and again, of no statistical significance. Therefore, considering a period of time when firms have to purchase carbon allowances, we find that clean firms outperform dirty firms over this extended sample period, albeit the results are not of statistical significance.

As for our final sample period, between 2009 and 2016, we find that the annualized carbon premium of the DMC portfolio is between -17.2% and -18.2% relative to the FF3 and FF4 respectively, and that they according to all factor models are highly statistically significant. These results are interesting since they suggest that starting in April 2009, there is a high and significant clean carbon premium, in contrast to the previous dirty carbon premium. During this period of time, clean firms significantly outperform dirty firms.

These findings provide empirical support for our first hypothesis. Namely, that when carbon allowances are allocated freely, dirty firms will experience higher cash flows and therefore higher expected returns, which is manifested by a high and significant dirty carbon premium. However, once firms realize in 2009 that they will have to begin to purchase carbon allowances, the size and significance of the dirty carbon premium dissipates. This empirical finding sheds light on the impact that changes in environmental policy can have on the stock performance of firms reporting under the ETS. The framework provided by Goulder, Hafstead and Dworsky (2010) explains in part how a cap-and-trade system can result in large gains in producer surplus for dirty firms, when carbon allowances are freely allocated. However, the same framework also shows that once carbon allowances are sold in auctions, the previous gain in producer surplus realized by dirty firms, now becomes revenue for governments issuing the carbon allowances. As a result, by auctioning carbon allowances, dirty firms begin to realize large deficits in producer surplus. Hence, explaining why after 2009, dirty firms are significantly outperformed by clean firms.

On a final note, we find in line with Oestreich and Tsiakas (2015) that the dirty carbon premium was a "one-off event" which took place between 2003 and 2009. However, by extending our sample period we find that beginning in 2009, there emerges a clean carbon premium, which remains of size and significance until 2016.

6.5. The Price of Carbon Risk

We estimate the price of carbon risk through cross-sectional regressions on the stock returns of our sample firms. We are especially interested in analysing a dirty-minus-clean factor, DMC, which is used to proxy the price of carbon risk. As previously mentioned, the DMC factor is the expected return of a zero-investment portfolio that has a long position in an equally weighted dirty portfolio, and a short position in an equally weighted clean portfolio. The cross-sectional regressions are in line with the Fama and MacBeth (1973) two-step procedure. The first step is to estimate betas concerning the DMC factor, CAPM, FF3 and FF4 for each firm through time-series regressions. Hence, we find through this first step each firm's sensitivity concerning each factor for a given sample period. The second step is to perform cross-sectional regressions on each firm's stock returns based on their respective betas. The cross-sectional regression yields the price of each factor; see Table 5 for the results of the cross-sectional regressions.

Our results are in line with Oestreich and Tsiakas (2015). During the initial sample period, which begins in 2003 and ends in 2009, we find that the price of risk of the DMC factor can be as high as above one, and highly significant relative to all the factor models. However, for the second sample period, which begins in 2003 and ends in 2012, we find that the price of risk of the DMC factor decreases, although still being positive, and highly statistically significant. This finding is essential in understanding our previous empirical findings. The higher the price of risk of the DMC factor, the higher the expected return of the DMC portfolio. As a result, during the first sample period, when firms receive free carbon allowances, and expect these to be free in the future, the price of risk of the DMC factor is high, thus leading to high DMC portfolio returns, and the emergence of a high and significant dirty carbon premium. However, during the second sample period, when firms have been made aware that they will have to purchase carbon allowances in the future, the price of risk of the DMC factor decreases, resulting in decreased DMC portfolio returns, and the dissipation of the dirty carbon premium.

As for our extension of the empirical analysis we find the following results. During the extended sample period which begins in 2003 and ends in 2016, we find that the price of risk of the DMC factor continues to decrease, although still being positive, and of high statistical significance. For our final sample period, which begins in 2009 and ends in 2016, we find that the price of risk of the DMC factor is negative, although of little statistical significance.

These finding are important in order to validate the economic mechanism suggested in Oestreich and Tsiakas (2015), as to why the return of the DMC portfolio decreases over time, and eventually becomes negative looking at a sample period that begins after 2009. Our main empirical finding in this section of the paper is that for the initial sample period, when firms receive free carbon allowances, and expect these to be free in the future, the price of risk of the DMC factor is high, leading to high DMC portfolio returns, and the emergence of a high and significant dirty carbon premium. As time goes by, and firms are made aware that they will have to start paying for carbon allowances, the price of risk of the DMC factor decreases, resulting in lower DMC portfolio returns, and the dissipation of the dirty carbon premium. Finally, the price of risk of the DMC factor becomes negative, taking into consideration a period of time when firms are aware that they will have to start paying for carbon allowances, and this knowledge is reflected in the stock price of firms. The implications of a negative price of risk of the DMC factor is that firms that are highly exposed to carbon risk, i.e. dirty firms, will generate negative expected returns. The negative price of the DMC factor could explain why dirty firms realized negative returns during the sample period which begins in 2009 and ends in 2016.

The mentioned empirical findings support our second hypothesis. Dirty firms are highly exposed to carbon risk, which is why they demand higher expected returns than clean firms. During the period of time when firms received free carbon allowances, the high and significant dirty carbon premium could be explained by a positive and significant price of the DMC risk factor. However, when the dirty carbon premium dissipates so does the size and significance of the price of the DMC factor. This provides further understanding as to why there was a high and significant dirty carbon premium in the initial stages of the ETS.

7. Discussion

The EU's cap-and-trade program has been widely observed by the financial markets since its inception in 2005. It has since become the world's largest market for trading carbon emission allowances, and a key tool for the EU to fight climate change. By writing this paper, we take a closer look into the complex implications that environmental policy has on the stock performance of firms. In particular, we analyse how the change in methodology concerning the allocation of carbon allowances affects the performance of firms listed on the Frankfurt Stock Exchange. We focus on Germany since they have the highest carbon emissions in the EU. During the initial two stages of the ETS, beginning in 2005 and ending in 2012, carbon emitting firms predominantly received carbon allowances for free. However, it was announced through the passing of an EU law in 2009, that beginning in 2013, carbon emitting firms would have to start purchasing carbon allowances in auctions, since they would no longer be allocated for free. As a result, when this is made public in 2009, carbon emitting firms experience increased concern and uncertainty regarding their future cash flows. By analysing a wide range of sample periods, we are able to draw conclusions concerning how the different carbon allocation methods impacted the stock performance of firms trading on the Frankfurt Stock Exchange.

Our empirical analysis shows the following findings. (i) For the first sample period, beginning in 2003 and ending in 2009 there is a high and significant dirty carbon premium, higher than 16%. This dirty carbon premium emerges in a time when carbon emitting firms receive carbon allowances for free and expect these to be free in future as well. (ii) When carbon emitting firms are made aware in 2009 that they will have to start purchasing carbon allowances from 2013, the size and significance of the dirty carbon premium dissipates. Therefore, the dirty carbon premium disappears in a time when carbon emitting firms expect carbon allowances to be free but find out they will have to start paying for them. This new knowledge results in future concern and uncertainty surrounding future cash flows, which is reflected in the current stock price. (iii) Looking at what happens in the immediate future after carbon emitting firms are aware that they will have to start paying for carbon allowances, we find the emergence of a high and significant clean carbon premium that is higher than 18%. This finding could be subject to further discussion, since the high and significant clean carbon premium arises in a time when firms are aware that they will have to purchase carbon allowances in the future, and this knowledge should be reflected in the stock price at the beginning of the sample period. A possible reason for the emergence of the clean carbon premium is that the market by far underestimated the costs of having to purchase carbon allowances in the future. (iv) There is a high and significant price of risk of the DMC factor during the initial sample period, explaining the high expected returns for firms with high exposure to carbon risk, i.e. carbon emitting firms. Over time, the price of risk of the DMC factor decreases in size and significance to eventually become negative, which could explain the decreasing expected returns of the DMC portfolio.

Apart from the two key economic mechanisms that explain our findings, namely the cash flow effect and the carbon risk effect, it is also worth discussing a third one, concerning the method of allocation to carbon emitting firms. As previously found, dirty firms outperform clean firms during the initial stages of the ETS, whereas the results are reversed for the later stages. Interesting to analyse are the different approaches to the allocation of free allowances that were taken during the different phases of the ETS. The grandfathering approach which was used in Phase I and II were advantageous for dirty firms whereas the benchmarking approach on the other hand is beneficial for firms e.g. investing in R&D to lower total emissions. Therefore, we argue that the institutional change that was made, i.e. changing allocation method to a benchmarking approach, possibly exacerbated the decline in the DMC factor over the periods. It is important to bear in mind, that even after trading of Phase III of the ETS began, freely allocated allowances still account for a non-negligible amount of total allowances, see Figures 2 and 3. However, if the grandfathering method had never been replaced, it is reasonable to assume that the DMC factor would have declined less sharply.

Finally, another subject of discussion worth mentioning is the introduction of the MSR, which has primarily led to (i) higher prices for carbon allowances and (ii) price stability of carbon allowances. This has naturally disadvantageous effects for carbon emitting firms that need to purchase large amounts of allowances, since their costs increase when prices rise. This could have had a negative impact on the price of carbon risk, which for extended sample periods decreased in size and significance. Furthermore, the price stability that the MSR has created implies that the market is able to assess the prices of carbon allowances with greater certainty than ever before, resulting in more reliable projections of future cash flows concerning carbon emitting firms. One could therefore argue that after the introduction of the MSR, the effects of the ETS have been more efficiently reflected in the current stock price of carbon emitting firms.

On a final note, we show in this paper the great implications of changing allocation methods of carbon allowances in the ETS. During the initial stages, when carbon allowances were freely allocated, carbon emitting firms proved to be the system's beneficiaries. However, a slight modification to the allocation system resulted in reversed roles. The notion that changes in environmental regulation can have monumental impacts on the firms affected by a system of this kind is supported by the findings in Zhang and Gregory-Allen (2018). What this implies for future policy makers is that the design of how a system will function is equally as important as the overall mission of that same system. Taking the ETS as an example, the mission is to reduce carbon emissions by 40% until 2030, which intuitively would affect carbon emitting firms negatively. However, we show in this paper, that the allocation method of allowances during the initial two phases of the ETS resulted in carbon emitting firms being the large beneficiaries of this new trading system.

8. References

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9. Appendix

Table 1. Timeline of Events

This table provides a detailed timeline of events concerning the ETS.

2003	November	EU passes law establishing features of Phase I and II of ETS
2005	January	Phase I of ETS begins
2005	April	EUA trading begins
2007	December	Phase I of ETS ends
2008	January	Phase II of ETS begins
2009	March	EU passes law establishing features of Phase III of ETS
2012	December	Phase II of ETS ends
2013	January	Phase III of ETS begins
2020	December	Phase III of ETS ends
2021	January	Phase IV of ETS begins
2030	December	Phase IV of ETS ends

Table 2. Descriptive Statistics

This table shows descriptive statistics for the 65 firms which have been analysed in this paper. These firms are either included in the DAX or MDAX index and are therefore listed on the Frankfurt Stock Exchange. ME refers to the average market value of equity measured over our extended sample period, from November 2003 to June 2016, in million euros. Free Allowances refers to the annual average number of carbon allowances that have been freely allocated to each firm during the first, second and third phase of the ETS, measured in millions.

				Free Allowances		
	Firm	*Industry*	*ME*	*Phase I*	*Phase II*	*Phase III*
1	RWE	Electric	24868	109.633	57.720	1.341
2	E.ON	Electric	45906	42.033	28.980	0.075
3	ThyssenKrupp	Iron/Steel	11905	24.033	24.000	16.706
4	Salzgitter	Iron/Steel	3066	10.200	12.000	6.084
5	Heid. Cement	Building Material	9029	5.500	4.780	4.176
6	BASF	Chemical	47397	4.867	5.520	7.268
7	Volkswagen	Auto Manufacturer	37297	2.504	1.986	0.417
8	K+S	Chemical	5483	1.441	1.140	0.658
9	Suedzucker	Food	3404	0.785	0.887	0.537
10	Henkel	Household Products	11176	0.560	0.491	0.088
11	Daimler	Auto Manufacturer	50525	0.383	0.376	0.269
12	Bayer	Chemical	48826	0.290	0.283	0.065
13	BWM	Auto Manufacturer	32831	0.272	0.294	0.126
14	Merck	Pharmaceutical	5738	0.141	0.108	0.061
15	Krones	Machinery	1557	0.078	0.073	0.000
16	Continental	Auto Parts	16514	0.077	0.069	0.004
17	MAN	Machinery	9985	0.055	0.024	0.027
18	Infineon	Semiconductors	7224	0.038	0.017	0.000
19	Hochtief	Construction	3827	0.034	0.033	0.000
20	Fresenius Med.	Healthcare Products	12672	0.027	0.032	0.039
21	Lufthansa	Airline	6190	0.019	0.020	0.014
22	Siemens	Manufacturing	68904	0.015	0.016	0.005
23	Aurubis	Metal	1394	0.008	0.008	0.358
24	Heid. Druck.	Machinery	1202	0.005	0.006	0.000
25	Aareal Bank	Bank	1190	0.000	0.000	0.000
26	Adidas	Apparel	10423	0.000	0.000	0.000
27	Allianz	Insurance	48904	0.000	0.000	0.000
28	Axel Springer	Media	3546	0.000	0.000	0.000
29	Baywa	Retail	922	0.000	0.000	0.000
30	Beiersdorf	Cosmetics	12756	0.000	0.000	0.000
31	Bilfinger Berger	Construction	2202	0.000	0.000	0.000

32	Celesio	Pharmaceutical	4443	0.000	0.000	0.000
33	Commerzbank	Bank	11531	0.000	0.000	0.000
34	D. Bank	Bank	35617	0.000	0.000	0.000
35	D. Boerse	Financial	11128	0.000	0.000	0.000
36	D. Euroshop	Real Estate	1243	0.000	0.000	0.000
37	D. Post	Transportation	22243	0.000	0.000	0.000
38	D. Telekom	Telecommunication	53540	0.000	0.000	0.000
39	Deutz	Machinery	576	0.000	0.000	0.000
40	Douglas	Retail	1378	0.000	0.000	0.000
41	Elringklinger	Auto Parts	1150	0.000	0.000	0.000
42	Fielmann	Retail	2685	0.000	0.000	0.000
43	Fraport	Construction	4111	0.000	0.000	0.000
44	Fresenius	Healthcare Products	8185	0.000	0.000	0.000
45	FUCHS Petrolub	Oil & Gas	1224	0.000	0.000	0.000
46	GEA	Food and Energy	4142	0.000	0.000	0.000
47	Gerry Weber	Apparel	769	0.000	0.000	0.000
48	Gildemeister	Machine Tools	941	0.000	0.000	0.000
49	Hannover Reuck.	Insurance	5438	0.000	0.000	0.000
50	Hugo Boss	Apparel	1691	0.000	0.000	0.000
51	KUKA	Machine Tools	926	0.000	0.000	0.000
52	Leoni	Electrical	948	0.000	0.000	0.000
53	Linde	Chemical	17012	0.000	0.000	0.000
54	Metro	Food	12110	0.000	0.000	0.000
55	Munich Re	Insurance	24015	0.000	0.000	0.000
56	Prosieben	Media	3334	0.000	0.000	0.000
57	Puma	Apparel	3431	0.000	0.000	0.000
58	Rational	Home Furnishings	1948	0.000	0.000	0.000
59	Rheinmetall	Machinery	1685	0.000	0.000	0.000
60	Rhoen-Klinikum	Healthcare Services	1982	0.000	0.000	0.000
61	SAP	Software	54521	0.000	0.000	0.000
62	SGL Carbon	Chemical	1546	0.000	0.000	0.000
63	Stada	Pharmaceutical	1722	0.000	0.000	0.000
64	TUI	Travel	3604	0.000	0.000	0.000
65	Vossloh	Electrical	926	0.000	0.000	0.000

Table 3. Portfolio Returns

This table shows the annualized mean return of the various portfolios for each given sample period. The dirty portfolio consists of those firms that received on average more than a million annual free carbon allowances during the initial three phases of the ETS. The medium portfolio consists of those firms that received on average more than zero but less than a million annual free carbon allowances during the initial three phases of the ETS. The clean portfolio consists of those firms that did not receive any free carbon allowances during the initial three phases of the ETS. The DMC portfolio is a zero-investment portfolio that implies taking a long position in a dirty portfolio and a short position in a clean portfolio. All portfolios are equally weighted.

Nov 03 to Mar 09	*Nov 03 to Dec 12*	*Nov 03 to Jun 16*	*Apr 09 to Jun 16*
Mean Annualized Return			
Dirty Portfolio			
0.142	0.095	0.046	-0.025
Medium Portfolio			
-0.044	0.062	0.070	0.156
Clean Portfolio			
-0.022	0.066	0.062	0.124
DMC Portfolio			
0.164	0.029	-0.016	-0.149

Table 4. The Carbon Premium

This table shows the annualized carbon premium, denoted as alpha, for the dirty, medium, clean and DMC portfolio for each sample period. *t*-statistics are reported in parentheses. Asterisks *, ** and *** represent statistical significance at the 10%, 5% and 1% respectively.

November 2003 to March 2009			*November 2003 to December 2012*		
CAPM-α	*FF3- α*	*FF4- α*	*CAPM- α*	*FF3- α*	*FF4- α*
Dirty Portfolio			*Dirty Portfolio*		
0.122**	0.123**	0.125**	0.012	0.009	0.004
(2.44)	(2.53)	(2.46)	(0.33)	(0.25)	(0.12)
Medium Portfolio			*Medium Portfolio*		
-0.062*	-0.045	-0.010	-0.021	-0.026	-0.002
(-1.70)	(-1.35)	(-0.32)	(-0.72)	(-0.92)	(-0.08)
Clean Portfolio			*Clean Portfolio*		
-0.041	-0.011	0.036	-0.013	-0.009	0.015
(-0.95)	(-0.31)	(1.18)	(-0.40)	(-0.33)	(0.58)
DMC Portfolio			*DMC Portfolio*		
0.162***	0.134***	0.089	0.025	0.018	-0.011
(3.19)	(2.68)	(1.86)	(0.60)	(0.46)	(-0.28)

November 2003 to June 2016			*April 2009 to June 2016*		
Dirty Portfolio			*Dirty Portfolio*		
-0.033	-0.047	-0.038	-0.156***	-0.170***	-0.155***
(-1.03)	(-1.44)	(-1.11)	(-4.03)	(-4.31)	(-3.61)
Medium Portfolio			*Medium Portfolio*		
-0.008	-0.013	0.019	0.045	0.035	0.070**
(-0.34)	(-0.56)	(0.80)	(1.51)	(1.15)	(2.18)
Clean Portfolio			*Clean Portfolio*		
-0.012	-0.016	0.017	0.023	0.002	0.027
(-0.47)	(-0.73)	(0.80)	(0.83)	(0.08)	(0.96)
DMC Portfolio			*DMC Portfolio*		
-0.022	-0.031	-0.056	-0.179***	-0.172***	-0.182***
(-0.59)	(-0.87)	(-1.49)	(-3.96)	(-3.73)	(-3.62)

Table 5. The Price of Carbon Risk

This table shows the price of carbon risk after having performed cross-sectional regressions based on the Fama and Macbeth (1973) two-step procedure. The numbers below show the percent monthly factor risk premiums for the different factors. DMC is the dirty-minus-clean factor, RmRf is the market excess return factor, SMB is the small-minus-big factor, HML is the high-minus-low factor and WML is the momentum factor. *t*-statistics are reported in parentheses. Asterisks *, ** and *** represent statistical significance at the 10%, 5% and 1% respectively.

	November 2003 to March 2009				*November 2003 to December 2012*			
DMC	1.04***	1.03***	0.70***	0.67**	0.77***	0.77***	0.70***	0.69***
	(3.08)	(3.17)	(2.65)	(2.50)	(6.69)	(6.29)	(5.47)	(5.27)
RmRf		0.57	0.78***	0.66**		0.47***	0.54***	0.49***
		(1.37)	(2.64)	(2.07)		(3.24)	(3.56)	(3.64)
SMB			1.27***	1.25***			0.58***	0.53***
			(3.91)	(4.07)			(3.90)	(3.55)
HML			1.67	2.21*			0.21	0.22
			(1.61)	(1.99)			(1.37)	(1.43)
WML				2.13				0.21
				(0.73)				(0.92)
	November 2003 to June 2016				*April 2009 to June 2016*			
DMC	0.63**	0.36***	0.32***	0.25**	-1.10*	-0.67*	-0.55*	-0.36
	(2.49)	(3.08)	(2.94)	(2.43)	(-1.71)	(-1.68)	(-1.69)	(-1.51)
RmRf		1.30*	1.32**	0.88***		-1.24	-1.42	-0.51
		(1.80)	(2.40)	(2.68)		(-1.01)	(-0.99)	(-0.43)
SMB			1.42**	1.36**			-1.52	-1.38
			(2.10)	(2.03)			(-1.36)	(-1.38)
HML			2.03*	2.67*			2.25	0.97
			(1.82)	(1.95)			(0.79)	(0.45)
WML				8.04				-1.55
				(0.55)				(-0.56)

Figure 1. The Cash Flow Effect

This figure illustrates a supply and demand diagram to show the effect of carbon regulation on the profits of a perfectly competitive industry.

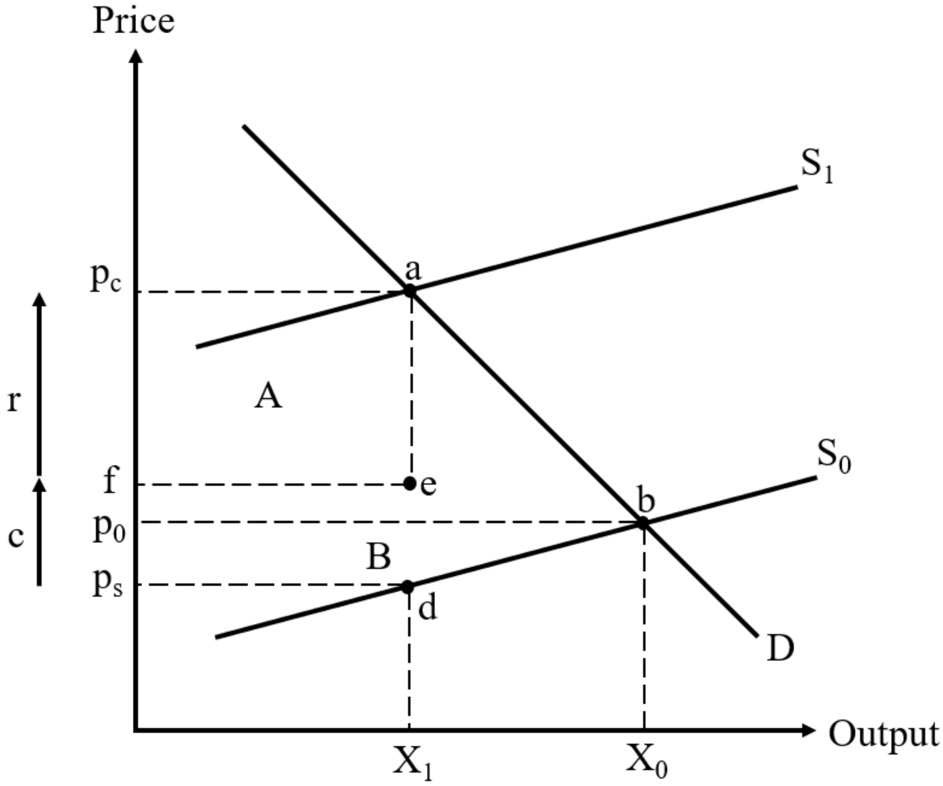

Figure 2. Free Allocation of Carbon Allowances

This figure shows the amount of allocated free allowances (in millions) between the inception of the program until 2018.

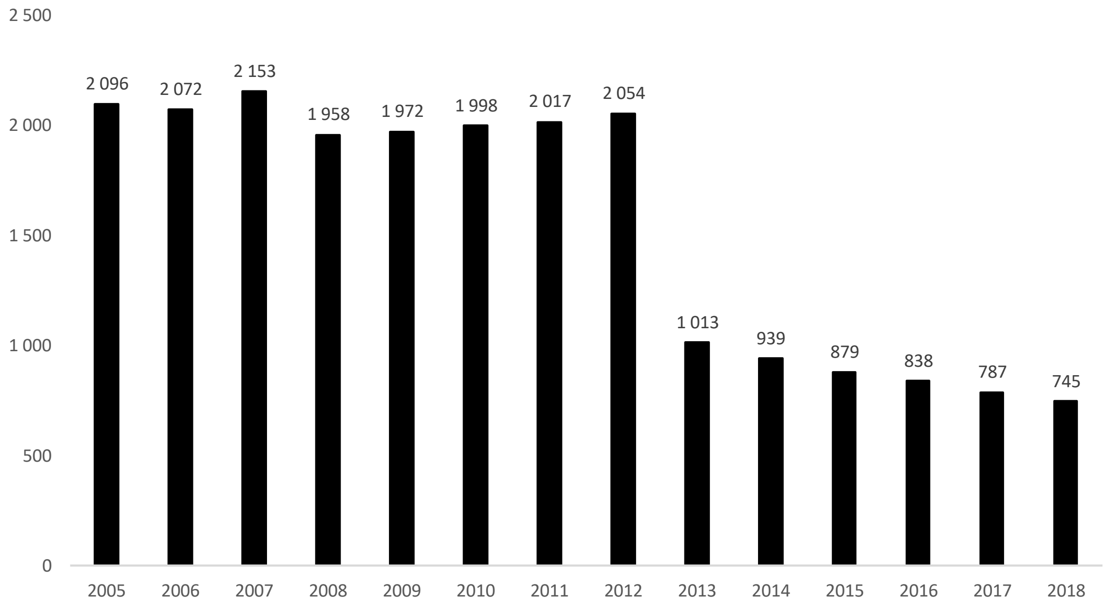

Figure 3. Auctioned or Sold Carbon Allowances

This figure shows the amount of allowances auctioned or sold (in millions) between the inception of the program until 2018.

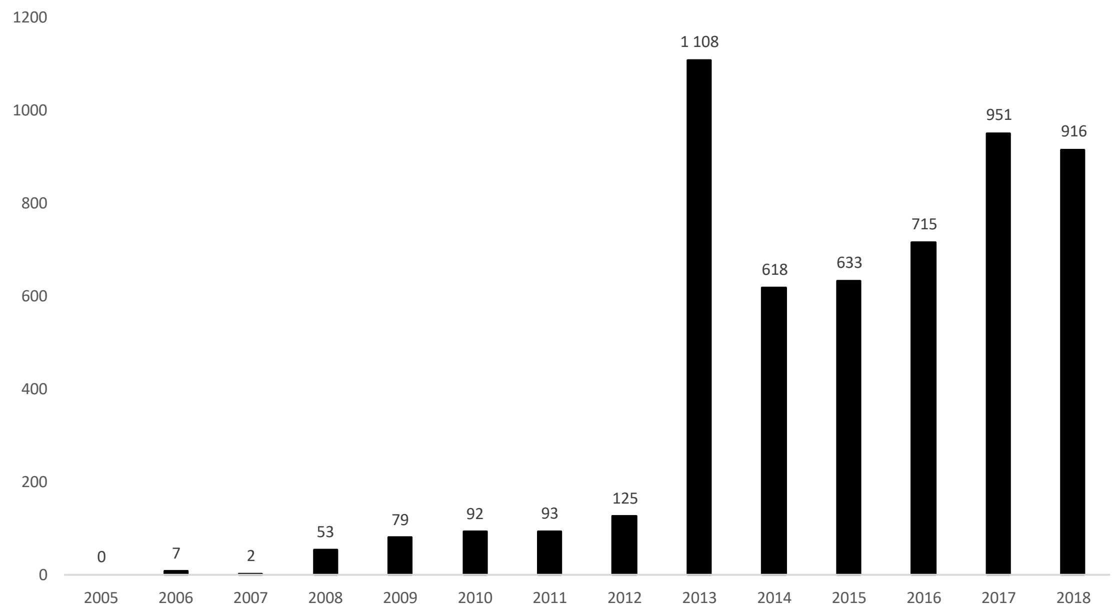

Figure 4. Price of Carbon Emissions Futures

This figure shows the price development of Carbon Emissions Futures from 2008 until 2020. All numbers are in euros.