Information efficiency in the EU ETS during Phase III

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Abstract

This study examines the market efficiency of the European Union Emission Trading Scheme (EU ETS). Since 2005 it has seen increased importance and growth in trading volume. The EU ETS is the largest emission trading system by transaction volume and in this study tests if the market exhibits predictability of prices. It tests whether overreaction or momentum exists in the carbon price and if so, whether profitable trading strategies can be employed. The thesis documents short term overreaction and momentum along various time-series within the EU ETS. Statistically significant alphas were found in a number of strategies tested. These strategies provide excess returns that remain achievable even after transaction costs have been taken into consideration. The results provide evidence that the EU ETS in Phase III is not informationally efficient.

Resumo

Este estudo examina a eficiência do mercado do Regime de Comércio de Licenças de Emissões da União Europeia (RCLE-UE). Neste mercado, desde 2005, tem vindo a registar-se um aumento da atividade comercial e um rápido crescimento. O RCLE-UE é o maior sistema de comércio de emissões em volume de transação. Este estudo testa se o mercado apresenta previsibilidade de preços. Mais precisamente, testa se existe uma reação excessiva ou momentum no preço do carbono e, caso exista, se podem ser utilizadas estratégias comerciais rentáveis. A tese documenta uma reacção excessiva e com momentum, a curto prazo, ao longo de várias séries temporais dentro do CELE da UE. Foram encontrados alfas estatisticamente significativos numa série de estratégias testadas. Estas estratégias proporcionam retornos em excesso que permanecem viáveis mesmo depois de os custos de transacção terem sido tomados em consideração. Assim, os resultados fornecem provas de que o CELE UE na Fase III não é eficiente do ponto de vista informativo.

Keywords: Time Series Momentum, EU ETS, Efficient Market Hypothesis

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Table of Content

List of Equations

List of Figures

List of Tables

1 Introduction

"Once climate change becomes a clear and present danger to financial stability it may already be too late to stabilise the atmosphere at two degrees.(…) Financing the transition to a low carbon economy is a major opportunity for investors and creditors."

Mark Carney, former Governor of the Bank of England, International Climate Risk Conference for Supervisors, Amsterdam (6th of April, 2018)

In this quotation, Mark Caney expressed the necessity in this day and age to give climate change as little leeway as possible, even in the financial industry. With the introduction of the EU ETS, the European Union has taken one of many possible paths to counter the threat of the climate crisis.

The aim of this thesis is to find out, if the European Union Emissions Trading Scheme (EU ETS) is informationally efficient. The European carbon market in its magnitude is the biggest existing in its form. The efficiency of this carbon market has great significance for investors. Inefficiency provide opportunity for investors in terms of predictability and therefore in achieving abnormal returns. According to Fama, markets are efficient if prices do not display predictability (Fama, 1970). Examining momentum strategies price predictability should be determined. Momentum describes the tendency of asset returns to follow their past direction. Appling momentum means buying the past winners and selling the past losers. First found by De Bondt and Thaler in 1985, overreaction describes the event where investors overreact by to new information in a market and pressure assets price beyond their fundamentals (De Bondt & Thaler, 1985). To profit from this behaviour, investors sell past winners and buy pas losers. If there is overreaction in the market an investor can profit from this strategy. Both phenomena imply, should they be found, that one can successfully make profits based on the information of past prices. This clearly violates one of the most important theoretical foundations in financial economics – the efficient market hypothesis.

This thesis should provide insights in how one of the biggest carbon markets in the world works and tests whether momentum and overreaction exist in it. Many studies have been published, which found momentum in different markets and asset classes. The carbon market is a rather unestablished market.

This Thesis not only contains theoretical concepts of momentum and overreaction but also explains the market and applies the strategies on the carbon market. It should contribute into the understanding of the dynamics in new emerging markets which incorporate regulatory elements.

This work is structured as follows: Chapter 2 explains the institutional background, giving insights of the EU ETS, its mechanisms, scope, and participants. Chapter 3 goes into relevant literature regarding emission trading, efficient market hypothesis momentum and overreaction and transaction costs. Chapter 4 presents the hypothesis, methodology and data used and chapter 5 provides the result. The thesis closes with chapter 6 which brings in the conclusion.

2 Institutional Overview

The European Union Emission Trading Scheme (EU ETS) works as an instrument against climate change in Europe. Participants of the EU ETS are the 27 member states of the European Union as well as Norway, Liechtenstein, Iceland. Since the Brexit the United Kingdom operates its own trading scheme, which is comparable to the EU ETS. The market exists since 2005, and its main purpose is to allocate greenhouse gas emissions, assign a value to them and obligate companies to verify these emissions by buying CO_2-Allowances.

This should incentivize companies to reduce their emissions. The ownership of an EUA allowance gives the right to the owner to emit one metric ton of CO_2 equivalent. Such allowances can be acquired in three different ways:

- Auctioned
- Acquired from a third person via the market
- Free allocation

In order to keep this market functioning, caps are implemented in the EU ETS which are regulated by the authorities of the European Union. During the period under review to which this study refers, the cap was set at 2,084 million tons carbon dioxide equivalents ($MtCO_2e$) from 2013 onwards, annually declining (International Carbon Action Partnership, 2022). To compensate CO_2 emissions each EUA can only be used once. However, as long as the EUA is not used to compensate, it remains on the account for later use or for trading purposes. Market participants are mainly companies which emit GHG. If they have access to the respective exchange, they can trade EUAs directly there. In case of the EU ETS these exchanges are the ICE in London or the European Energy Exchange AG (EEX) in Leipzig. Authorized for trading are the companies as well as every other private individual which are registered in the European Union Transaction Log and are authorized to trade on the respective exchange (Umweltbundesamt & Deutsche Emissionshandelsstelle, 2022). There is also the possibility of OTC-transactions.

To understand how the market operates it is essential to deepen the knowledge in some unique features of EU ETS:

The EU ETS can be split into different trading periods:

- Phase I: 3 years (2005-2007)
- Phase II: 5 years (2008-2012)
- Phase III: 8 years (2013-2020)
- Phase IV: 10 years (2021-2030)

The cap which also sets the supply for CO_2-Allowances was established bottom-up in Phase I. Based on the aggregation of the national allocation plans of each member state, Phase I started with a cap of 2,096 $MtCO_2e$ in 2005. Phase II started with a cap of 2,049 $MtCO_2e$ in 2009. In Phase III a single EU-wide cap was introduced for stationary sources, starting with a cap of 2,084$MtCO_2e$ in 2013. Until 2020 an annual decrease by a linear factor of 1.74 % (38.3 million allowances) decreased the cap to 1,816 $MtCO_2e$ in 2020. For Phase IV the cap was set at 1,572 $MtCO_2e$ with an annual linear reduction path of 43 million allowances. The decline will continue beyond 2030. Starting with 2021 the emissions from UK entities which were previously covered by the EU ETS are no longer considered in the cap (International Carbon Action Partnership, 2022).

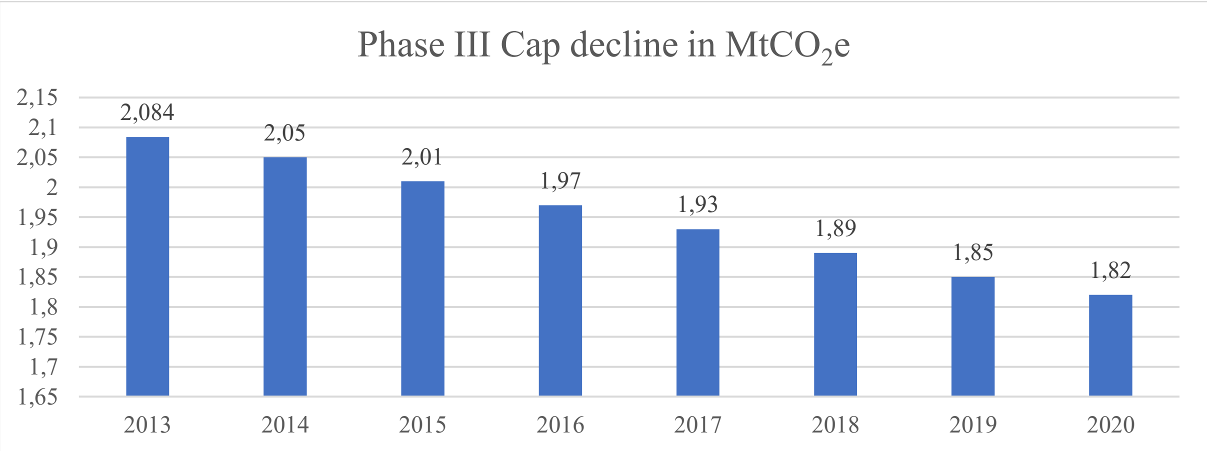

Figure 1 This figure shows the annual linear decline of the cap in Phase III

A further feature of the market is the way how the allowances are emitted into the market. In Phase I the allowances got emitted through godfathering. Some Member States used auctioning and some used benchmark-based allocation. In Phase II approximately 90 % of the allowances were allocated for free. Eight member states used auctioning to allocate the Allowances. (Germany, United Kingdom, Netherlands, Austria, Ireland, Hungary, Czech Republic, and Lithuania). (Commission, 2022)

57 % of allowances were auctioned over the entire trading period of Phase III. The remaining allowances were allocated through benchmarking. 88 % of the auctioned allowances were distributed to EU Member States based on verified emissions from 2005 or average 2005-2007 emissions. Subsectors in the manufacturing industry got free allocation based on product-based benchmarks. The benchmarks were based on activity levels in 2007-2008. Subsectors which were at risk of carbon leakage received free allocation at 100 %. Subsectors not at risk for carbon leakage hade free allocation at 80 % which gradually declined to 30 % of the respective benchmarks by 2020. (International Carbon Action Partnership, 2022)

Carbon leakage risk can be explained as the risk that companies which operate within Europe might settle their installations somewhere else due to increased costs due to the EU ETS. The risk was assessed against the following criteria:

- Direct and indirect cost increase of more than 30 %
- Non-EU trade intensity bigger than 30 % in magnitude, or
- Direct and indirect cost increase greater than 5 % and trade intensity greater than 10 %

In Phase III, the EU ETS faces the issue of a growing surplus of allowances. Therefore, as a short-term measure the auctioning of 900 million allowances from 2014-2016 was postponed to 2019-2020 which was called back-loading. As a result, the market stability reserve was created where these allowances were placed. The market stability reserve (MSR) became operational in 2019. The MSR is an instrument to counter future imbalances in the EU ETS (Commission, 2022). It is activated when certain thresholds are reached, which are measured in TNAC (total number of allowances in circulation). If the TNAC is less than 400 million, new allowances are emitted into the market. If it reaches a threshold of more than 833 million, allowances are going to be withdrawn from the market (International Carbon Action Partnership, 2022).

In Phase IV the benchmark values are updated twice in order to come up with the technological progress of the different sectors. The benchmark values will be adjusted for technological progress annually as well as an annual reduction rate will be determined for each benchmark. Furthermore, a third, more restricted carbon leakage list applies for the years 2021-2030. Instead of 175 different sectors, only 44 sectors are listed in the third carbon leakage list. However, there is the possibility for 28 sectors to be included retroactively. Free allocation for the remaining other sectors will be discounted by 2030. 57 % of allowances in Phase IV will be auctioned, from which 90 % will be distributed to the member states based on their share of verified emissions. If the highest bidding price is significantly below the prevailing secondary market, authorities have the right to cancel auctions. This serves to prevent market distortion (International Carbon Action Partnership, 2022).

From the beginning of the program in 2005 up to 2020 the EU ETS achieved a revenue of approximately € 70bn. These are revenues from the auctioning of allowances. At least 50 % of revenues should be used for climate- and energy-related purposes. How member states use the revenues must be reported to the European Commission. In 2019, member states spent on average 77 % of their revenues on domestic and international climate-related purposes (International Carbon Action Partnership, 2022).

The design of the EU ETS is made to meet efficiency in the sense that such an instrument equates marginal social benefits with marginal social costs. Both taxes and a cap-and-trade system are capable of doing so. Despite the absence of adequate information of damages or a political will to tackle an environmental economics problem a further feature for a policy instrument needs to be that it is likely to achieve given aggregate environmental targets at lowest costs. Again, either taxes or a cap-and-trade-system can meet it. Although Pigouvian taxes have been the sole economic response to the problem of externalities in the beginning of the 20th century, they are getting less and less used. First it is difficult to identify the appropriate tax rate due to not have good information on benefits and costs, Second, they are susceptible for causing political problems by the distributional consequences for regulated sources. Despite taxes might minimize the aggregate social costs, they may be more costly than comparable command- and control instruments for regulated firms. From 1960 on it became possible to think about a market-based approach to solving environmental problems. By clarifying pollution as property rights, these rights could be traded in a market and actors could allocate the use of this property in a cost-effective way. Regulators define the total quantity of allowed emissions (cap) and allow individuals to trade the permits until an optimal allocation has been reached. This procedure, in theory can solve the problems which taxes are not able to do so in this extent. (Hahn & Stavins, 2011)

3 Related Literature

3.1 Literature on carbon markets

In general, literature on the EU ETS is growing and very diverse. Relevant papers for this thesis can be divided into the following areas. First, papers concerning the economics of the EUA price and second, papers dealing with the economics of EU ETS and market efficiency.

Studies show that spot prices generated by the EU ETS depend on institutional design issues, energy prices and extreme weather events. Chevallier explains that CO_2 future prices of the EU ETS are only weakly connected to macroeconomic effects (Chevallier, 2009). Creti et al. come to the conclusion, using a different model, that the oil price, the equity price index and the switching prices between gas and coal seem to be significant long-run determinants of the EUA price during Phase II of the EU ETS. This seems to be a consistent pattern (Creti, Jouvet, & Mignon, 2012). Batten et al. investigate the key energy prices and weather explain the carbon prices. They find that the demand in electricity pushes the EUA price upwards. Coal price has a negative relation to the EUA. When coal prices rise, installations switch from coal to gas, which causes less CO_2. Therefore, positively related is the gas price. Weather results did not affect price, except for unanticipated temperature changes. They find less significant results for it in Phase I but significant results in Phase II and Phase III (Batten, Maddox, & Young, 2021). Zheng et al. conducted research on the impact of oil shocks on the EU ETS in Phase III. Under different market conditions they tested the effect on the returns on EUAs using a quantile regression method. The results showed that oil supply and demand shocks have a positive effect on the returns of EUAs, but oil risk shocks have a negative effect. They find clearer results of this price behaviour in bullish market conditions. Not only from the energy market (Zheng, Yin, Zhou, Liu, & Wen, 2021). Wang et al. studied the impact of the global stock market on the EU ETS. They showed that the S&P 500 affect the yield of EUAs indirectly (Wang & Zhao, 2021).

Another field of important literature for this thesis is about the EU ETS market efficiency. Aatola et al. find that the EU ETS market showed periods with not informationally efficiency in Phase I (Aatola, Olikka, & Ollikainen, 2014). A study conducted by Sebastian Görs comes to the same conclusion for trading Phase I. He performed Variance Ratios Tests and an autocorrelation and came to the conclusion that the EUA price did not follow a random walk.

The results point out that EUAs may have followed a random walk in Phase II (Goers, 2014). Crossland et al. conduct research, where they applied momentum and overreaction strategies with different look-back periods and holding periods to the EU ETS. Their results provide evidence that the EU ETS is not informationally efficient in Phase II (Crossland, Li, & Roca, 2013). Ibikunle et al. investigate liquidity and market efficiency on the EU ETS by using intraday short horizon return predictability as an inverse indicator of market efficiency. The predictability of returns from intraday order flow across 40 months of trading. They find evidence that return predictability occurs but has significantly decreased since the start of Phase II and seems to continue to decline (Ibikunle, Gregoriou, Hoepner, & Rhodes, 2016). Ghazani et al. analyse the efficiency of the European Emission Trading Scheme in the context of a dynamic approach. They used a rolling sample technique with different lengths consistent with the adaptive market hypothesis to trail the time variation of efficiency. First, they focused on checking the market efficiency in the AMH context, secondly the evolving behaviour on the market has been examined by shifting towards longer time windows (50 to 250 days). In the third phase they witnessed a more mature form of market which they lead back to the phase-out of free allocation, an EU wide emission cap on allowances and the establishment of the MSR (Ghazani & Jafari, 2021).

3.2 Efficient Market Hypothesis

The efficient market hypothesis (EMH), formulated by Fama and known as the theory of informational efficiency, is an economic theory which discusses the information processing in capital markets. According to this theory a market is considered efficient, if the price of a security at any time, fully reflects the available information. Hence all the information is already factored in the price observable and the realization of excess returns with data from the past is not possible. The implication is that in an informationally efficient market, the information of not just present and historical data is taken into account but also anticipated developments are also included in the process of price building.

From the EMH can be three different gradations derived. Strong market efficiency can be identified when the price reflects all of the available information on the market. This implies that publicly available and non-publicly available information is factored into the price. The gradation of semi-strong informational efficiency means that actual price levels fully reflect the information which is publicly available. This means that all historical and fundamental data is already considered into the price. Therefore, only the use of insider knowledge or non-publicly available information generates abnormal returns. The weak form of the Efficient

Market hypothesis states that the actual price fully includes information of historic price data which do not have any influence in future price developments. This implies that only the availability of additional information can lead to higher returns and the analysis of past price data as done by technical analysis does not lead to it (Fama, 1970).

3.3 Literature on momentum and overreaction

First described by Jegadeesh and Titman in 1993 momentum is the strategy which buys stocks that have performed well in the past and sell stocks that have performed poorly in the past. They find significant positive returns over 3- 12- month holding periods (Jegadeesh & Titman, Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency, 1993). In a further paper, written in 2001 they showed evidence which indicates that momentum profits have continued over time, which suggests that the results found before were not a product of data snooping bias but seems to be an ongoing pattern (Jegadeesh & Titman, Profitability of Momentum Strategies: An Evaluation of Alternative Explanations, 2001). To rule snooping bias out, Rouwenhorst attempt to address this concern earlier in 1998 by studying not only return patterns in U.S. stocks but in an international context using a sample of 2.190 stocks from 12 European countries in the period of 1978 to 1995. He focused only on patterns in medium-term returns. His results show that the European evidence is remarkably similar to findings for the United States documented by Jegadeesh and Titman. This makes it less likely that their finding was only due to chance (Rouwenhorst, 1998).

Similar to momentum Moskowitz et al. document an asset pricing anomaly which they describe as “time series momentum. According to the authors time series momentum is related but different to momentum. Momentum literature focuses on the relative performance of different securities in the cross-section. Time series momentum focuses only on a security’s own past return. Although these two types of strategies are distinct from each other in the authors’ results they show a significant relationship between time series momentum and cross-sectional momentum. Time series momentum reveals strong and consistent performance across many diverse asset classes, has small loadings on standard risk factors and performs well in extreme periods. This challenges the random walk hypothesis which is connected to the efficient market hypothesis (Moskowitz, Ooi, & Pedersen, 2012).

The intuition behind overreaction is that in a stock market, investors overreact to negative information and hence cause a negative direction for a security’s price. De Bondt and Thaler present two major outcomes. First that between 1926 and 1982 the market portfolios outperformed the market by approximately 19.6 % and secondly, showed statistically significant differences in the cumulative return of the losers and winners. Not only did the losing stocks outperform the winners by around 25 %, but they also showed less volatility (De Bondt & Thaler, 1985). Hong and Stein had a different approach. They modelled a market populated by two groups of rational agents to explain momentum and overreaction. "Newswatchers" which adapt the price slowly as private information diffuses slowly throughout the market and "momentum traders" who try to gain from underreaction by accelerating the price movement towards fundamentals. This creates an eventual overreaction to any new information (Hong & Stein, 1999).

Alves and Carvalho studied overreaction on 49 Morgan Stanley Capital International indices from 1970 to 2018.They found economically and statistically significant return reversals for three-year- as well as five-year investment periods. The contrarian strategy yields, on average an ER of 24 % three years after the ranking year. They found a divergence between overreaction in developed and emerging markets. When implemented in developed markets only, there is evidence that supports the overreaction hypothesis, although the excess returns are smaller. They show that the overreaction strategy is sensitive to the periods considered, which could indicate that its success is not time stationary (Alves & Carvalho, 2020).

3.4 Literature on trading costs

Key constraints faced by commodity investors are trading costs. Transaction costs can be significantly reducing an anomalies' profitability and significance. Especially for momentum-related strategies, which can be characterized by a considerable portfolio turnover. Lesmond et al. are talking about creating an illusion of profit opportunity. While the mean profit of a 6-month momentum strategy is at 7.826 % before trading costs, it dramatically declines after accounting for trading costs to a profit of only 0.128 %. They concluded that the profits of momentum investing strategies do not exceed trading costs (Lesmond, Schill, & Zhou, 2004). Novy-Marx and Velikov conducted research on transaction costs. In their research they analyse various anomaly strategies. In all cases transaction costs reduce the strategies' profitability and its associated statistical significance, which increase they concern related to data snooping (Novy-Marx & Velikov, 2016). Despite evidence against the profitability of trading costs empirical evidence shows that these strategies are regularly employed by fund managers. The implication of many papers like "The value of active mutual fund management: an examination of the stockholdings and trades of fund managers" by Chen et al. or "Momentum investment strategies, portfolio performance, and herding: a study of mutual fund behaviour" by Grinblatt et al. is that although trading costs may be significant, momentum strategies continue profitable.

Due to the nature of the EU ETS, there can be significant other transaction costs next to the ones mentioned above. The EU ETS is a Cap-and-Trade Market. Hahn and Stavins describe three major sources of transaction costs under the concept that transaction costs arise in the exchange of goods and services. The first source of transaction costs is search and information. Since information of different options how to treat the firms needs best is publicly available, markets can be underprovided this information. To reduce this trading cost brokers may step in to provide this kind of information to firms. The second source of transaction costs can be "bargaining and reaching a decision". They mention that there are real resource costs to a firm involved in entering negotiations for example time, fees for brokerage, legal and insurance services. The third source is costs monitoring and enforcement. This form is of costs are typically borne by the responsible governmental authority and hence do not fall within the notion of transaction costs incurred by firms (Hahn & Stavins, 2011). These three types mainly concern companies with installations. However, it is also significant for investors, who just want to invest since the majority of market participants inside the EU ETS are companies with installations.

4 Hypothesis, research methodology and data

4.1 Hypothesis

Similar to the paper "Is the European Union Emissions Trading Scheme informationally efficient" by Crossland, Li and Roca, this thesis focuses on time series momentum and overreaction. From a momentum perspective, asset prices continue in their current direction, while in overreaction, the prices reverse. The momentum anomaly can be found in various markets in the financial world and the carbon market works just like one of them. When not traded OTC, there are brokers and dealer, who facilitate the transactions. Besides buyers and sellers from affected industries, the market also provides opportunities for investors who's only seek is to make profit out of the market by opening up an account in the European Union Transaction Log. The EUA-Allowance can be traded in the same way as an ordinary commodity. The product can be traded on the spot, as well as in derivative transactions (Crossland, Li, & Roca, 2013).

Given these characteristics a similar study has been made for the Phase II in which they documented the existence of momentum in the market. Since the market evolved and matured in Phase III, with more players in it, my first Hypothesis (H1) is that:

Momentum exists in the EU ETS also in Phase III and profitable trading strategies based on momentum strategies exist as well.

Findings from Crossland et al. indicate overreaction in the Carbon market for Phase II Keeping in mind, the EU ETS has already evolved to its 3rd some can argue that the market in Phase III is still in its build-up phase. The EU ETS included more installations, the percentage of free allocated allowances decreased and in January 2019 the Market Stability Reserve started operating. Compared to other markets these features are rather unique and might have impacts on the price behaviour and making the market more sensitive since investors need longer to understand its impacts (Crossland, Li, & Roca, 2013). Hence the EU ETS could still follow a pattern of price reversal and therefore the second hypothesize (H2) states:

Overreaction also exists in the EU ETS

4.2 Research Methodology

Aim of this study is to identify if profitable time series momentum and reversal strategies are observable within the EUA Spot prices in Phase III of the EU Emission Trading Scheme. Therefore EEX EUA 3rd Phase Spot Prices get retrieved via DataStream. From this Prices, log-returns got calculated from which the risk-free rate is subtracted in keeping it up with the literature.

The daily EUA excess return data get used to build the J = 1, 3, 6, 8, 12, 15 “look-back” windows. To build the J-month/K-month strategies in the spirit of Jegadeesh and Titman the calculated returns get add up to investigate if the return in the specific look-back period is positive or negative (Moskowitz, Ooi, & Pedersen, 2012). After performing rolling windows according to the look-back periods, dummy-variables get assigned to the individual windows if the returns are either below or above zero. The dummy-variables assign the sign each excess return has in its related strategy. Note that the variable on every J^{th} return needs to be shifted by 1 to account for the fact that taking the desired position in the asset is only possible on the next day.

If the indexed return of the lookback window is positive, when applying momentum, the strategy is to hold the EUA at the current price for the following K-months. If the indexed excess return is negative, the strategy is to short the EUA at the current price for the next K-months. The contrarian strategy requires the opposite. A short position needs to be taken if the indexed excess return is positive and a long position when the indexed excess return is negative. Momentum and contrarian strategies provide each 36 strategies, considering the various iterations of the look-back and holding windows (Crossland, Li, & Roca, 2013).

One factor that should not be neglected is transaction costs. The literature shows that these costs can have significant impact on momentum strategies. Therefore, transaction costs are also included in these study as well as the theoretical profits achievable with zero transaction costs. The EEX has quoted over the period transaction costs between € 0.0020 per tCO_2[3] € 0.0025 per tCO_2[3] (EEX, 2022). With regard to a possible upward bias, this study assumes transaction costs of € 0.0075 per tCO_2[3]. This accounts to the fact that in this analysis brokerage fees or slipping costs are not considered because of a lack of data.

To get first insights into the time series predictability of the excess returns across different time horizons, as illustrated by Moskowitz et al. the sign of the returns of the lookback period is regressed by the sign of the accumulated returns of the holding period for each strategy. The regression can be captured as follows:

$$sign(r_{t+K}) = \alpha + \beta \, sign(r_{t-J}) + \varepsilon_{t+K}$$

(Equation 1)

The return of the K-month and J-month are equated to 1 or -1 if the returns are positive or negative respectively. While positive t-statistics may indicate potential momentum, negative t-statistics on the excess returns might indicate reversal (Crossland, Li, & Roca, 2013).

To measure the profitability of the strategies a multi-factor model needs to be employed, which accounts for risk and passive exposure to major asset-classes. Although the model follows Moskowitz et al. who also considered the Fama-French size factor (SMB), value factor (HML) and momentum factor (UMD) the multi-factor model is more oriented on the paper of Crossland, Li and Roca. In their paper they excluded these Factors since these factors have shown to be rather insignificant. The model in the spirit of Moskowitz et al. controls for passive exposure in the following asset classes: the stock market, the bond market, and the commodity market, and is structured as follows:

$$R_t^{TS-J,K} = \alpha + \beta_1(R_{M,t} - R_{f,t}) + \beta_2(R_{B,t} - R_{f,t}) + \beta_3(R_{C,t} - R_{f,t}) + \varepsilon_t$$

(Equation 2)

The dependent variable $R_t^{TS-J,K}$ is the excess return on each of the two portfolios of strategies, with J-months look-back window and K-months holding period. $R_{M,t}$ $R_{B,t}$ and $R_{C,t}$ are the returns on the MSCI World Index, the Barclays Euro Aggregate Bond Index and the Goldman Sachs Commodity Index. $R_{f,t}$ is the risk-free rate received from Kenneth French Website. The returns of these major asset classes are retrieved via Bloomberg (Crossland, Li, & Roca, 2013).

The intercept alpha describes the active return on the strategy. It is the return in excess of the compensation for risk. With this variable it is possible to identify if return of the strategy derives from compensation for exposure to the asset classes or if they are from the strategy itself. From the sign of the control variables, their relationship to the strategy can be derived.

In order to test if the time series of the regression is that it is non-stationary. Therefore, a Dickey-Fuller test is performed. The Null Hypothesis is that the time series is non-stationary if the ADF statistic or the t-statistic is lower than the critical value the Null Hypothesis is rejected.

4.3 Data

The Data consists of daily spot-prices for the EUA for Phase III of the EU ETS. The data are closing prices observed from the EEX, which represents the dominant EUA marketplace. In the beginning the use of both spot prices and futures prices were considered. Due to high cross-correlation between the markets for EUA futures and spot prices this thesis restricts itself to spot prices. This should not expose the results to inconsistencies, since in the overall market for EUAs the prices find to develop very closely across the marketplaces.

The Data is retrieved from Eikon for the period January 1st 2013, to December 31st 2019. It provides a time series of the spot prices in Phase III with 1.763 daily observations. Over the relevant time series, the data exhibits average daily excess return of 0.1283 % with a standard deviation of 3.345 % The average EUA spot price over the sample period of Phase III is € 10.05 with a price range from € 2.75 to a maximum of € 29.81. The standard deviation of the price is € 7.34.

EUA	**Phase III**
Number of observations	1763
Average daily excess return (%)	0.1283
Std. dev. Daily excess returns (%)	3.345
Max daily return (%)	26.90
Min daily return (%)	-35.08
Skewness	-0.3508
Kurtosis	12.428
Average price (€]	10.05
Std. dev. (€)	7.34
Max EUA price (€)	29.81
Min EUA price (€)	2.75

Table 1 This table provides the descriptive statistics for the Phase III of the EU ETS. Phase III is represented by 1.313 observations of EUA Spot Prices. Excess returns are calculated by subtracting the risk-free rate retrieved from the Fama French website

Although Phase III is the object of consideration in this thesis, it was taken into consideration to also include Phase I and II into the study. However, it is to highlight that Phase I can be considered as a trial period with lots of uncertainties in terms of over-allocation or the inability to bank and carry permits into the next Phase. In April 2006 EUA spot prices dropped significantly about -54 % before prices collapsed to near 0 in the year of 2007. (Crossland, Li, & Roca, 2013)

In Phase II a similar study has been made. During this period the market can be considered as more matured due to higher trading volumes, less volatility, and a bigger scope due to the introduction of the aviation sector and the expansion into Iceland, Liechtenstein and Norway.

However, a single EU-wide cap for stationary sources with an annual linear reduction factor was not installed yet and the number of allowances allocated for free was still high.

Figure 3 illustrates the daily volatility in the spot market throughout the Phase III. In the study of Crossland et al. who were conducting a similar study for Phase II, they indicated significant volatility with a maximum daily excess return at 199.98 % and a minimum excess return observed at -50.02 %. In Phase II they showed that the overall volatility seemed to have stabilized between 10.00 % and -10.00 % on the y-axis (Crossland, Li, & Roca, 2013). In Phase III the excess returns seem to operate on a similar level of stability. However, in the beginning of this period excess returns with a higher fluctuation range can be observed, which later on appears much more stable.

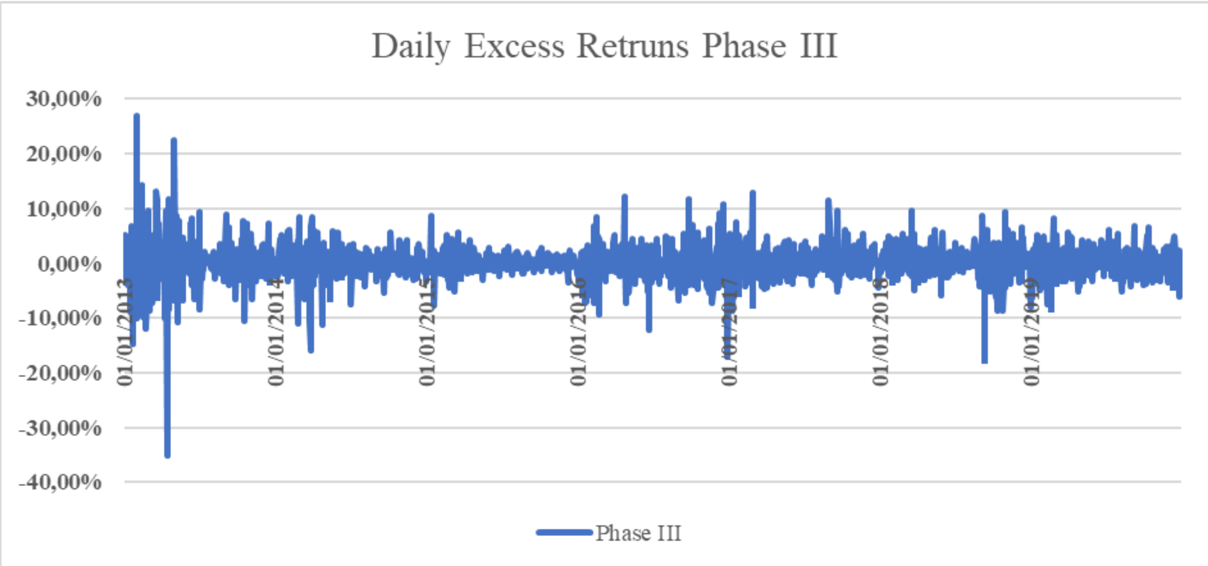

Figure 2 The daily excess returns over the period of Phase III

5 Results

5.1 Regression analysis: predicting momentum and overreaction

The first step in the analysis starts by testing the time-series predictability of the excess returns for different time periods. Moskowitz et al. test for each strategy by regress the K-month holding period excess returns on the previous J-months excess returns. By performing this regression, it is possible to calculate the significance of the predictability with t-statistics. Negative and significant t-statistics signal reversal in the performed strategies while positive and significant t-statistics indicate possible momentum. This can be a first hint of whether overreaction or momentum can be expected in the EU ETS.

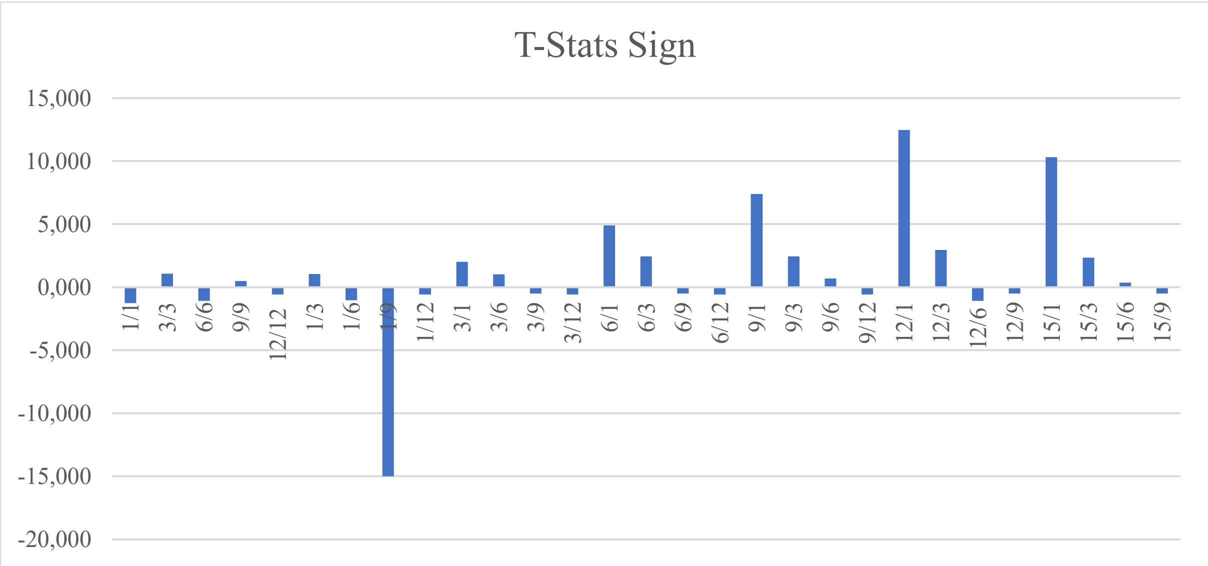

Figure 3 T-statistics for the intercept of J months returns. The regression equates the look-back period and holding period returns as either +1 or -, dependent on whether the returns are positive or negative respectively. Positive t-statistics are an indication for momentum. Negative t-statistics are an indication of overreaction and reversal EUA returns

The result from this regression shows indication for momentum in excess returns while statistically significant indication for overreaction is only observable in the J1K9 months strategy. Positive t-statistics indicate momentum for the look-back periods J = 1, 3, 9, 12 and 15 months. Looking at the holding periods, higher positive t-stats are observable for strategies with look-back periods of J = 1 month. The outcome differs from the study of Crossland et al. They find indication for both momentum as well as for contrarian strategies. Furthermore, they observed more signs which indicate overreaction than for momentum in the 2nd Trading Period (Crossland, Li, & Roca, 2013).

J-month/	Intercept coefficient	β_1 coefficient	R^2	J-month/	Intercept coefficient	β_1 coefficient	R^2
1/1	**0.3056**	-0.1944	0.038	**6/9**	0.6667	-0.3333	0.111
3/3	0.3000	0.3000	0.090	**6/12**	0.5000	-0.5000	0.250
6/6	0.3000	0.3000	0.090	**9/1**	0.1193	**0.7557**	0.571
9/9	0.6667	-0.3333	0.111	**9/3**	0.2424	**0.5758**	0.331
12/12	0.5000	-0.5000	0.250	**9/6**	0.3000	0.3000	0.090
1/3	-0.0417	0.2917	0.083	**9/12**	0.5000	-0.5000	0.250
1/6	-0.0833	-0.4167	0.174	**12/1**	0.0436	**0.8897**	0.792
1/9	0.000	**-1.000**	0.444	**12/3**	0.1500	**0.6500**	0.423
1/12	-0.5000	0.5000	0.250	**12/6**	0.3000	0.3000	0.090
3/1	**0.2931**	**0.2931**	0.089	**12/9**	0.6667	-0.3333	0.111
3/6	0.0833	0.4167	0.174	**15/1**	-0.0048	**0.8619**	0.722
3/9	0.6667	-0.3333	0.111	**15/3**	-0.0222	**0.5778**	0.313
3/12	0.5000	-0.5000	0.250	**15/6**	-0.1667	0.1667	0.028
6/1	0.2091	**0.6091**	0.371	**15/9**	0.6667	-0.3333	0.111
6/3	0.2424	**0.5758**	0.331				

Table 2 For each strategy the sign of the excess returns for K-months are regressed on the sign of the previous J-months. The regression equates the J-month and k-month returns as either +1 or -1, depending if the returns are either positive or negative. Provided is the intercept, β1 and R2 for each strategy. Coefficient on a statistically significant 5 % level are marked as bold and the corresponding t-stats are provided in parenthesis.

If we look more closely at the signs, we can see that even though the strategies have different look-back periods and holding times, some of them still have the exact same signs. This is due to the behaviour of the prices throughout the time series. In total, five sets with duplicate values are observable, for both momentum and contrarian strategies. The different sets of strategies with the same signs are as following:

Set A:	J6K6, J360K360, J3K12, J6K12, J9K6, J9K12, J12K6
Set B:	J9K9, J3K9, J6K9
Set C:	J9K3, J6K3
Set D:	J15K15, J1K15
Set E:	J15K3, J15K9

Table 3 This table provides the different sets of strategies which have the same sign. This is due to the behaviour of prices, which can be observed in the EU ETS.

5.2 Profitability of strategies

After first results in predicting the possibility of momentum and overreaction in the excess returns, in a following step the profitability of the strategies is considered in more detail. According to the signs of each strategies the excess returns get assigned to each of them. The sign gets assigned according to each strategies look-back period and is held for the following K-months. In the momentum strategy the buy signal is identified by a positive indexed return over the last J-months and vice versa. In the contrarian strategy the buy signal is identified by a negative indexed return over the last J-months. Afterwards average monthly and cumulative returns are calculated for each strategy.

MOM				**K-months**			
A. Monthly excess returns excl. transaction costs							
J-Months	**J/K**	**1**	**3**	**6**	**9**	**12**	**15**
	1	-1.31 %	2.14 %	2.17 %	0.13 %	4.43 %	0.56 %
	3	4.78 %	4.00 %	5.70 %	1.91 %	3.67 %	-0.91 %
	6	3.34 %	4.51 %	3.67 %	1.91 %	3.67 %	-0.91 %
	9	3.88 %	4.51 %	3.67 %	1.91 %	3.67 %	-0.91 %
	12	4.29 %	3.67 %	3.67 %	1.91 %	3.67 %	-0.91 %
	15	2.48 %	1.43 %	-1.46 %	0.44 %	-1.51 %	0.56 %
B. Monthly excess returns incl. transaction costs							
J-Months	**1**	-1,46 %	2,13 %	2,16 %	0,12 %	4,42 %	0,56 %
	3	4,75 %	3,99 %	5,69 %	1,90 %	3,66 %	-0,91 %
	6	3,32 %	4,50 %	3,66 %	1,90 %	3,66 %	-0,91 %
	9	3,87 %	4,50 %	3,66 %	1,90 %	3,66 %	-0,91 %
	12	4,28 %	3,66 %	3,66 %	1,90 %	3,66 %	-0,91 %
	15	2,47 %	1,42 %	-1,47 %	0,43 %	-1,52 %	0,56 %

Table 4 This table shows monthly excess returns of EUA Spot Prices Phase III momentum strategies. Panel A represents the monthly excess returns considering zero transaction costs, panel B includes transaction costs

OVERR.				**K-months**			
A. Monthly excess returns excl. transaction costs							
J-Months	**J/K**	**1**	**3**	**6**	**9**	**12**	**15**
	1	4.01 %	0,65 %	0,61 %	2.50 %	-1.70 %	2.19 %
	3	-2.04 %	-1.17 %	-2.83 %	0.88 %	-0.85 %	3.63 %
	6	-0.53 %	-1.67 %	-0.85 %	0.88 %	-0.85 %	3.63 %
	9	-1.05 %	-1.67 %	-0.85 %	0.88 %	-0.85 %	3.63 %
	12	-1.45 %	-0.85 %	-0.85 %	0.88 %	-0.85 %	3.63 %
	15	0.31 %	1.34 %	4.17 %	2.31 %	4.06 %	2.19 %
B. Monthly excess returns incl. transaction costs							
J-Months	**1**	3.96 %	0.64 %	0.60 %	2.49 %	-1.70 %	2.19 %
	3	-2.08 %	-1.19 %	-2.83 %	0.87 %	-0.85 %	3.62 %
	6	-0.55 %	-1.68 %	-0.85 %	0.87 %	-0.85 %	3.62 %
	9	-1.07 %	-1.68 %	-0.85 %	0.87 %	-0.85 %	3.62 %
	12	-1.46 %	-0.85 %	-0.85 %	0.87 %	-0.85 %	3.62 %
	15	0.30 %	1.34 %	4.16 %	2.30 %	4.06 %	2.19 %

Table 5 This table shows monthly excess returns of EUA Spot Prices Phase III overreaction strategies. Panel A represents the monthly excess returns considering zero transaction costs, panel B includes transaction costs

Table 4 presents the monthly excess returns for the several momentum strategies. While in panel A zero trading costs are assumed, panel B shows the result after the incorporation of trading costs. The effect of the transaction costs seems to have less impact on the respective excess return with an average monthly decrease of approximately -0.01 %. These findings provide first satisfactory evidence for the first hypothesis.

Table 5 provides the profits for the contrarian strategies. Panel A shows the monthly excess returns at zero transaction costs. Panel B provides the results while transaction costs are included. Same as in Table 4 transaction costs cause a downward effect on the results. On average the monthly excess return decrease is at approximately 0.009 %. There are few strategies with positive returns which is still in line with H2, but they are less profitable contrarian strategies observable than in the study from Crossland et al. (Crossland, Li, & Roca, 2013). In a further step the structure of each strategy's return will get examined more closely.

5.3 Multifactor analysis

This part of the thesis explores the structure of the returns retrieved from the strategies and if statistically significant alphas are observable. Therefore, a three-factor-model is employed according to the Model used from Moskowitz et al. To evaluate the performance of each momentum and overreaction strategy, each return series is regressed with the following factors:

$$r_{i,t}^{TS-J,K} = \alpha + \beta_1 MKT_t + \beta_2 BOND_t + \beta_3 GSCI_t + \varepsilon_t$$

(Equation 3)

$r_{i,t}^{TS-J,K}$ is the return on strategy *i* with J-months look-back period and K-months holding period. Note that *i* can be the return of either momentum or contrarian. The following table 6 shows the estimates of the coefficients, t-statistics, and R-squares from these time series. The provided intercept (α) can be interpreted as the residual return on each strategy. It describes the reward for the extra risk exposure of the strategies.

J-month/K-month	α	$\beta_1(MKT_t)$	$\beta_2(BOND_t)$	$\beta_3(GSCI_1)$	R^2
1/1	**1.5130 (2.008)**	0.0973 (1.776)	-0.5449 (-0.731)	-0.0660 (-1.075)	0.003
3/3	**1.8807 (2.501)**	0.0177 (0.323)	-1.0526 (-1.414)	**0.1555 (2.537)**	0.007
6/6	**1.6474 (2.190)**	0.0275 (0.500)	-0.8169 (-1.097)	**0.1431 (2.333)**	0.006
9/9	**1.7349 (2.331)**	0.1018 (1.870)	-1.1190 (-1.519)	**0.2828 (4.662)**	0.024
12/12	**1.6474 (2.190)**	0.0275 (0.500)	-0.8169 (-1.097)	**0.1431 (2.333)**	0.006
15/15	**2.0602 (2.759)**	-0.0415 (-0.760)	-0.7364 (-0.996)	**-0.2821 (-4.636)**	0.018
1/3	0.4605 (0.610)	0.0330 (0.599)	0.5242 (0.702)	-0.0171 (-0.278)	0.001
1/6	0.2401 (0.319)	0.0220 (0.399)	0.8095 (1.085)	-0.0710 (-1.156)	0.002
1/9	0.3824 (0.508)	0.0785 (1.427)	0.4878 (0.655)	0.0516 (0.841)	0.003
1/12	0.7829 (1.050)	-0.0541 (-0.993)	0.6095 (0.826)	**-0.3369 (-5.545)**	0.027
1/15	**2.0602 (2.759)**	-0.0415 (-0.760)	-0.7364 (-0.996)	**-0.2821 (-4.636)**	0.018
3/1	**2.2895 (3.038)**	0.0282 (0.511)	-1.2434 (-1.667)	-0.0728 (-1.185)	0.003
3/6	2.0829 (2.764)	-0.0413 (-0.749)	0.9269 (-1.242)	-0.1129 (-1.838)	0.004
3/9	**1.7349 (2.331)**	0.1018 (1.870)	-1.1190 (-1.519)	**0.2828 (4.662)**	0.024
3/12	**1.6474 (2.190)**	0.0275 (0.500)	-0.8169 (-1.097)	**0.1431 (2.333)**	0.006
3/15	**2.5623 (3.434)**	0.0922 (1.690)	**-1.8120 (-2.453)**	**0.1571 (2.582)**	0.014
6/1	**1.9670 (2.607)**	0.0172 (0.312)	-0.9794 (-1.311)	-0.0038 (-0.061)	0.001
6/3	**1.9331 (2.573)**	0.0282 (0.513)	-1.1226 (-1.509)	**0.1627 (2.658)**	0.008
6/9	**1.7349 (2.331)**	0.1018 (1.870)	-1.1190 (-1.519)	**0.2828 (4.662)**	0.024
6/12	**1.6474 (2.190)**	0.0275 (0.500)	-0.8169 (-1.097)	**0.1431 (2.333)**	0.006
6/15	**2.5623 (3.434)**	0.0922 (1.690)	**-1.8120 (-2.453)**	**0.1571 (2.582)**	0.014
9/1	**1.9353 (2.565)**	0.0166 (0.300)	-0.9327 (-1.249)	-0.0180 (-0.292)	0.001
9/3	**1.9331 (2.573)**	0.0282 (0.513)	-1.1226 (-1.509)	**0.1627 (2.658)**	0.008
9/6	**1.6474 (2.190)**	0.0275 (0.500)	-0.8169 (-1.097)	**0.1431 (2.333)**	0.006
9/12	**1.6474 (2.190)**	0.0275 (0.500)	-0.8169 (-1.097)	**0.1431 (2.333)**	0.006
9/15	**2.5623 (3.434)**	0.0922 (1.690)	**-1.8120 (-2.453)**	**0.1571 (2.582)**	0.014
12/1	2.2559 (2.991)	0.0093 (0.169)	-1.2347 (-1.654)	-0.0292 (-0.475)	0.002
12/3	**1.6474 (2.190)**	0.0275 (0.500)	-0.8169 (-1.097)	**0.1431 (2.333)**	0.006
12/6	**1.6474 (2.190)**	0.0275 (0.500)	-0.8169 (-1.097)	**0.1431 (2.333)**	0.006
12/9	**1.7349 (2.331)**	0.1018 (1.870)	-1.1190 (-1.519)	**0.2828 (4.662)**	0.024
12/15	**2.5623 (3.434)**	0.0922 (1.690)	**-1.8120 (-2.453)**	**0.1571 (2.582)**	0.014
15/1	**2.6916 (3.579)**	0.0395 (0.719)	**-1.6660 (-2.238)**	-0.0643 (-1.050)	0.002
15/3	**1.7267 (2.296)**	0.0446 (0.811)	-0.8313 (-1.116)	0.0603 (0.984)	0.003
15/6	**1.6247 (2.162)**	0.0273 (0.497)	-0.6264 (-0.842)	-0.0261 (-0.427)	0.001
15/9	1.0659 (1.422)	0.0758 (1.383)	-0.3307 (-0.446)	**0.1891 (3.096)**	0.010
15/12	1.4632 (1.948)	-0.0381 (-0.694)	-0.1233 (-0.166)	**-0.3023 (-4.939)**	0.020

Table 6 Momentum strategy factor regressions. Statistically significant (at a 5 % level) coefficients are highlighted in bold. T-stats are provided in parenthesis next to it. Based on the Dickey Fuller test, all variables have been found stationary

J-month/K-month	α	$\beta_1(MKT_t)$	$\beta_2(BOND_t)$	$\beta_3(GSCI_1)$	R^2
1/1	0.5646 (0.748)	-0.1023 (-1.855)	0.4739 (0.634)	0.0652 (1.060)	0.003
3/3	0.1970 (0.261)	-0.0228 (-0.415)	0.9817 (1.316)	**-0.1562 (-2.545)**	0.007
6/6	0.4302 (0.571)	-0.0326 (-0.592)	0.7460 (0.999)	**-0.1439 (-2.341)**	0.006
9/9	0.3427 (0.458)	**-0.1068 (-1.960)**	1.0480 (1.414)	**-0.2836 (-4.648)**	0.024
12/12	0.4302 (0.571)	-0.0326 (-0.592)	0.7460 (0.999)	**-0.1439 (-2.341)**	0.006
15/15	0.0174 (0.023)	0.0364 (0.663)	0.6655 (0.895)	**0.2813 (4.597)**	0.018
1/3	**1.6171 (2.138)**	-0.0381 (-0.690)	-0.5951 (-0.795)	0.0163 (0.265)	0.001
1/6	**1.8375 (2.431)**	-0.0271 (-0.490)	-0.8804 (-1.177)	0.0702 (1.140)	0.002
1/9	**1.6952 (2.240)**	-0.0836 (-1.511)	-0.5584 (0.456)	-0.0523 (-0.849)	0.003
1/12	1.2948 (1.739)	0.0490 (0.900)	-0.6805 (-0.923)	**0.3361 (5.538)**	0.027
1/15	0.0174 (0.023)	0.0364 (0.663)	0.6655 (0.895)	**0.2813 (4.597)**	0.018
3/1	-0.2119 (-0.281)	-0.0332 (-0.603)	1.1725 (1.570)	0.0720 (1.171)	0.001
3/6	-0.0053 (-0.007)	0.0362 (0.658)	0.8559 (1.149)	0.1121 (1.828)	0.002
3/9	0.3427 (0.458)	**-0.1068 (-1.960)**	1.0480 (1.414)	**-0.2836 (-4.648)**	0.024
3/12	0.4302 (0.571)	-0.0326 (-0.592)	0.7460 (0.999)	**-0.1439 (-2.341)**	0.006
3/15	-0.4847 (-0.643)	-0.0973 (-1.764)	**1.7410 (2.332)**	**-0.1578 (2.568)**	0.013
6/1	0.1107 (0.146)	-0.0223 (-0.404)	0.9084 (1.215)	0.0030 (0.048)	0.001
6/3	0.1445 (0.192)	-0.0333 (-0.605)	1.0517 (1.411)	**-0.1635 (-2.665)**	0.008
6/9	0.3427 (0.458)	**-0.1068 (-1.960)**	1.0480 (1.414)	**-0.2836 (-4.648)**	0.024
6/12	0.4302 (0.571)	-0.0326 (-0.592)	0.7460 (0.999)	**-0.1439 (-2.341)**	0.006
6/15	-0.4847 (-0.643)	-0.0973 (-1.764)	**1.7410 (2.332)**	**-0.1578 (2.568)**	0.013
9/1	0.1424 (0.188)	-0.0217 (-0.392)	0.8617 (1.153)	0.0172 (0.279)	0.001
9/3	0.1445 (0.192)	-0.0333 (-0.605)	1.0517 (1.411)	**-0.1635 (-2.665)**	0.008
9/6	0.4302 (0.571)	-0.0326 (-0.592)	0.7460 (0.999)	**-0.1439 (-2.341)**	0.006
9/12	0.4302 (0.571)	-0.0326 (-0.592)	0.7460 (0.999)	**-0.1439 (-2.341)**	0.006
9/15	-0.4847 (-0.643)	-0.0973 (-1.764)	**1.7410 (2.332)**	**-0.1578 (2.568)**	0.013
12/1	-0.1783 (-0.236)	-0.0144 (-0.262)	1.1638 (1.558)	0.0284 (0.462)	0.002
12/3	0.4302 (0.571)	-0.0326 (-0.592)	0.7460 (0.999)	**-0.1439 (-2.341)**	0.006
12/6	0.4302 (0.571)	-0.0326 (-0.592)	0.7460 (0.999)	**-0.1439 (-2.341)**	0.006
12/9	0.3427 (0.458)	**-0.1068 (-1.960)**	1.0480 (1.414)	**-0.2836 (-4.648)**	0.024
12/15	-0.4847 (-0.643)	-0.0973 (-1.764)	**1.7410 (2.332)**	**-0.1578 (2.568)**	0.013
15/1	-0.6140 (-0.812)	-0.0446 (-0.807)	**1.5951 (2.132)**	0.0635 (1.032)	0.004
15/3	0.3509 (0.463)	-0.0497 (-0.898)	0.7604 (1.014)	-0.0611 (0.991)	0.003
15/6	0.4529 (0.597)	-0.0324 (-0.584)	0.5555 (0.740)	0.0253 (0.410)	0.001
15/9	1.0117 (1.342)	-0.0809 (-1.467)	0.2598 (0.348)	**-0.1899 (-3.090)**	0.010
15/12	0.6144 (0.826)	0.0330 (0.607)	0.0524 (0.071)	**0.3015 (4.972)**	0.020

Table 7contrarian strategy factor regressions. Statistically significant (at a 5 % level) coefficients are highlighted in bold. T-stats are provided in parantheses next to it. Based on the Dickey Fuller test, all variables have been found stationary

Table 6 shows the achieved abnormal returns and t-statistics of the momentum strategies. Positive alphas are found in nearly every strategy besides J = 1. Positive alphas exhibit, that returns are not compensation for passive exposure to the risk factors Market, Bond nor Commodity but instead result from the strategy itself. The table below reveals the positive and significant alpha as a result of the contrarian strategies. Significant alphas can be found only in the lookback period J = 1 strategy.

A possible obstacle of the data could be if the variables of the time series regression are non-stationary. Therefore, a Dickey-Fully test has been performed testing the stationary of each variable. The results showed that all variables are stationary hence the multifactor analysis result will not be subject to the spurious regression issue.

There is a positive relationship between the momentum strategies and the commodity factor observable, indicated with the positive beta coefficient. This indicates that rising commodity prices result in rising EUA Prices. In comparison to the Study of Crossland, Li and Roca in Phase II of the EU ETS momentum and the commodity factor showed a negative relationship (Crossland, Li, & Roca, 2013).

As shown in table 7 the inverse holds for the overreaction portfolio. The commodity factor has a negative relationship to the contrarian strategies. Whereas the market factor shows significant negative relation in some contrarian strategies, in the momentum strategies the market seems to play no significant role. The market factor in overreaction portfolio follows the one observable in the study of Crossland et al. There the relationship indicated a statistically significant negative relationship to the returns, too.

6 Conclusion

This thesis investigates the behaviour of momentum and contrarian strategies on the EU ETS market. In every look-back period at least one time-series momentum strategy can be documented with statistically significant alphas. Except for the look-back period J = 1 month these returns contain in the majority of the different holding periods statistically significant alphas. This illustrates the robustness of the momentum strategy on the EU ETS in the third trading period. Longer term momentum is furthermore consistent with the literature, where many studies have shown momentum with 12-months look-back periods. (Jegadeesh & Titman, Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency, 1993)

While momentum alphas are significant at various time horizons, contrarian strategy alphas can only be documented in short term look-back periods; J = 1 month. Medium-term reversal as well as long-term reversal cannot be indicated for Phase III in the EU ETS. Short-term reversal is consistent with the literature to the extend where investors are sensitive to new information and drive prices beyond fundamental values before being corrected over time. This pattern was very well documented also for mid-term reversal in the second trading period. To an extend it seems that investors have pushed back the reaction time to a shorter time-series in Phase III since reversal in mid- term or long term cannot be observed with statistically significance.

By looking at the regression it can be stated that this market can be characterized with short-term reversal (overreaction) followed by medium to long term momentum (underreaction). The market only seems to overreact in short term look-back periods. In comparison to Crossland et al. who observed short term underreaction, followed by mid term overreaction before switching again to momentum at the 12-month mark, it can be stated that the disappearance of the varying behaviour through time can be interpreted as the maturing of the carbon market in its 3rd Phase.

Momentum and overreaction open the discussion to behavioural finance. The behavioural model by Hong and Stein describes the existence of these two anomalies as a result of interactions between the two types of agents mentioned in the literature section. "News-watcher" adjust prices slowly as private information streams steadily into the market which causes underreaction in the market. "Momentum-Traders" seek to gain profit by accelerating price movements towards fundamentals as soon as they appear, which causes overreaction in an early stage (Hong & Stein, 1999). Similar behaviour can be observed for the EU ETS in Phase III where overreaction happens in an early stage before transforming into underreaction in mid and long terms.

More important than whether a particular momentum or contrarian strategy can be shown, the thesis rather aims to identify if momentum or contrarian behaviour is observable, measurable and exploitable in the EU ETS. The objective is to find out if the information routed in the historical prices of the EUAs provide evidence of a violation of the Efficient market hypothesis in its weak form.

For H1 can be concluded that the null hypothesis is supported. There is strong evidence of momentum in the EUA price. For H2 it can be stated the following. Although strategies with statistically significant alphas can be observed for much less time horizons than in Phase II, overreaction did not vanish from this market. Therefore, the null hypothesis cannot be rejected. The implication from the results is that the EU ETS in its Phase III is not informationally efficient and therefore violates the weak form of the Efficient market hypothesis.

The results of this thesis were not totally unexpected. Phase III can be seen as a more mature period in which the distribution of allowances could already draw on the experience of the two previous periods. The cap was not established bottom up, but as a single EU-wide cap for stationary sources, more branches got included which increased the magnitude of the market and fewer allowances were allocated for free. The reduction of external pricing factors through regularities might make the EU ETS appear more comparable to traditional markets and hence could be a possible explanation why the observation of overreaction declined and lead more into observable underreaction strategies.

Although the study was conducted using data provided by a reputable provider of consistent data, and recognized methods were used, there are ways to make such studies even more ideal. Using overreaction and underreaction to determine if a market is efficient according to the EMH is just one way on doing it. To obtain more clarity of the existence of any violation of the EMH studies regarding the random walk hypothesis can be conducted. Görs analysed random walk properties such as the unit root, autocorrelation, and variance tests. (Goers, 2014) Transaction costs can significantly affect results. The method used in this thesis is in line with that of Crossland et al. and conservatively estimated. Nevertheless, more sophisticated models can be incorporated to generate a model that is even closer to reality by conduct further research of brokerage fees or slippage costs. For setting up the time series momentum strategies Moskowitz et al. set up a position size and set the position size to be inversely proportional to the instrument's ex ante volatility. They primarily doing this to make it easier to aggregate strategies across instruments, which is not the case in this study but also it is helpful to have time series with relatively stable volatility so that the strategy is not dominated by a few volatile periods. (Moskowitz, Ooi, & Pedersen, 2012)

In further research it would be interesting to see how the results for Phase III are affected in terms of more sophisticated TAC and also taking volatility into consideration. Since the EU ETS is still ongoing, future studies could show how the market behaves in Phase IV, under the impression of much more restricted caps, the aftermath of the pandemic and in the face of troubling times in the oil and gas market. The EU ETS is just one but an important instrument against climate change. Accordingly important is conducting research on it, in order to evaluate and improve the effectiveness of this market.

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