Price Relationships between EUAs and Energy and Commodity Prices

Prissammenhenger mellom EUA, Energi og varemarkedet

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Foreword

This 30-credit master thesis concludes my two-year master's degree in Business Administration at the Norwegian University of Life Sciences School of Economics and Business.

The thesis is an empirical analysis of relationships between the price of CO_2 quotas in the European Union Emissions Trading Scheme (EU ETS) and electricity, oil and commodity prices, where I explore what relationships exist between these for the period 2008-2011. The EU ETS started in 2005 and is organized in several phases. Phase I, from 2005-2007, has proven to be a relatively turbulent introductory period, and the system is now well into Phase II (2008-2012) with many lessons learned from Phase I. Phase III is scheduled to start in 2013, with much anticipation of the future of EU Emissions Allowance (EUA) trading.

In this thesis, price relationships are explored mainly to learn more about this immature market, but also for forecasting purposes. The results from testing are presented and discussed further in this thesis.

I wish to thank everyone who has contributed to the completion of this thesis, my family and especially my sister Liv Oline Nordby for their input and motivating words, as well as my supervisor Ole Gjølberg for his guidance.

Ås, August 15th 2011

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Jill Françoise Nordby

Abstract

This thesis concentrates on relationships between EUA prices and the European and Scandinavian electricity markets, as well as oil and commodity prices. The main purpose of the paper is to explore what relationships exist between these both in the short and the long term. Are there any significant connections between the markets, and does one affect the other or vice versa, and do they move together in the long term?

This type of exploration is interesting because of the nature of the EU ETS, a highly regulated market governed by national requirements. Politics is an important factor in both the trade and pricing of EUAs, and the market is especially interesting as Phase I saw a collapse of the system. Phase II, starting in 2008, has seen a rebirth in trade as well as a number of turbulent events, making the market an interesting and unpredictable one. The analyses in this thesis attempts to find connections in the data. The strong connection between electricity and oil and emissions, and how commodity production is related to oil prices suggests a relationship between these which this thesis explores and attempts to uncover.

Short-term relationships are explored for the period from 26.02.2008 to 01.04.2011, the start of Phase II of trade. This analysis does not uncover any evidence of oil or commodity prices having a significant effect on movements in EUA prices, but we can see that both European and Scandinavian electricity prices may have an explanatory value on them. In all cases, there are signals that the EUA price is affected by its own earlier movements. In reverse, there is no evidence that EUA prices have an effect on electricity, oil or commodity prices, but that oil prices as well as electricity traded on NordPool show evidence of being affected by their own previous movements.

The long-term analysis uses cointegration tests to test for long-term relationships between the markets. In order to test for cointegration, there must be no evidence of stationarity, the tests for which did not show any evidence of this. Then, the residuals of regressions between EUAs and electricity, oil and commodity markets are tested for stationarity, indicating cointegration. No evidence of long-term relationships was found here. Then, spreads between EUAs and electricity, oil and commodity markets are tested for stationarity and cointegration, and the only relationships here were found between the spreads in ln EUA prices and ln oil and ln commodity prices, indicating that these move similarly in the long term.

An event study is included in order to see whether or not three specific news events have had a noteworthy effect on not only the EUA market, but also related markets. First, the hacking scandal where CO_2 quotas were stolen digitally shows evidence of not only shaking the EUA market, but also the European electricity market. Second, the dramatic increase in oil prices during the spring of 2011

shows evidence of similar but delayed effects on the EUA market, with more extreme reactions to a drop in oil prices than an increase in oil prices. The final event explored in the event analysis is the earthquake in Japan in March 2011, which sparked a reaction in Europe in the form of the decision to close numerous nuclear power plants with immediate and more long-term effect. The announcement of this decision in Europe naturally sparked a great reaction in the European electricity price, causing a dramatic increase from the day of the announcement. In regards to EUA prices, there is evidence of a more gradual increase in prices in the days following the announcement, but again a jump can be seen around a month later, indicating a delayed reaction to the increase in European electricity prices.

Although the empirical analyses do not indicate any relationship between either electricity, oil or commodity markets and the EUA market, the event study still displays some evidence that shocks in European electricity as well as the oil market will lead to a delayed shock in the EUA market, with varying effects.

Sammendrag

Denne oppgaven tar for seg sammenhenger mellom CO_2-kvoteprisen og strømpriser både i Europa og i Skandinavia, samt olje- og råvaremarkedspriser. Hovedmålet med oppgaven er å undersøke hvilke sammenhenger som finnes mellom disse både på kort og lang sikt. Er det slik at markedene er relatert til hverandre, påvirker et market et annet, og hører de sammen på lang sikt?

Denne typen undersøkelse er interessant på grunn av karakteristikkene til EU ETS, et svært regulert market basert på nasjonale behov. Politikk er naturligvis en viktig faktor i både handel og prising av kvoter, og markedet er spesielt interessant da fase I så en kollaps av systemet. Fase II, med oppstart i 2008, har sett en gjenopprettelse av handel samt en rekke turbulente hendelser, noe som gjør at dette markedet skiller seg ut i sin uforutsigbarhet. Analysene i denne avhandlingen forsøker å finne sammenhenger i dataene. Den sterke sammenhengen mellom elektrisitet og olje og CO_2-utslipp, samt hvordan råvaremarkedet er relatert til oljeprisen, tyder på en sammenheng mellom disse som oppgaven utforsker og forsøker å avdekke.

Kortsiktige sammenhenger er utforsket i perioden 26.2.2008-1.4.2011, starten av Fase II. Denne analysen avdekker ingen bevis for at olje- eller råvaremarkedet har en betydelig effekt på bevegelser i EUA-priser, men vi ser at både europeiske og skandinaviske strømpriser kan ha en forklarende verdi for kvoteprisene. Det kommer derimot fram tydelige signaler på at CO_2-kvoteprisen påvirkes av sin egen tidligere endring. Videre finner analysen ingen bevis for at EUA-prisene har en effekt på elektrisitets-, olje- eller råvarepriser, men at oljeprisen samt strøm handlet på NordPool viser tegn på å være påvirket av sine egne tidligere bevegelser.

Den langsiktige analysen bruker tester for ko-integrasjon for å se om det finnes langsiktige relasjoner mellom markedene. En forutsetning for ko-integrasjonstester er ikke-stasjonæritet, og ingen av stasjonæritetstestene viste tegn på dette. Deretter er residualene fra regresjonen mellom hvert marked og EUA-markedet testet for stasjonæritet, noe som vil indikere ko-integrasjon dersom denne er positiv. Ingen bevis på langsiktige sammenhenger ble funnet i denne testen. Videre testes også spreaden mellom EUA-priser og elektrisitet, olje og råvarer, og den eneste sammenhengen ble funnet mellom spreadene i ln EUA priser og ln olje- og ln råvarepriser, noe som indikerer at disse hører sammen på lang sikt.

En eventanalyse er inkludert i oppgaven for å avdekke om tre spesifikke hendelser i 2011 har hatt en betraktelig effekt på ikke bare CO_2-kvoteprisen, men også relaterte markeder. Hackingskandalen der tusenvis av kvoter ble stjålet digitalt rystet ikke bare EUA-markedet, men også det europeiske strømmarkedet. Senere samme år så vi en dramatisk økning i oljeprisen, og vi kan se at CO_2-kvoteprisen hadde en lignende men forsinket og mindre reaksjon på dette. Et interessant punkt her

er at analysen tyder på at en markant økning i oljeprisen ikke har en like stor effekt på EUA-prisen som en brå reduksjon. Til slutt vil jeg ta for meg effekten av jordskjelvet i Japan i mars 2011, som forårsaket at flere Europeiske ledere besluttet å stenge en rekke kjernekraftverk, både med umiddelbar og mer langsiktig effekt. Kunngjøringen av denne avgjørelsen hadde naturligvis en dramatisk effekt på europeiske elektrisitetspriser, og vi kan se en mer gradvis reaksjon i CO_2-kvotepriser, med et større hopp ca en måned etter kunngjørelsen. Dette kan igjen indikere at EUA har en noe forsinket reaksjon til ulike kunngjørelser i forhold til andre markeder.

Selv om den empiriske analysen ikke indikerer noe forhold mellom elektrisitet, olje eller råvaremarkedet og CO_2-markedet, kan eventanalysen likevel tyde på at sjokk i det europeiske elektrisitetsmarkedet samt oljemarkedet kan føre til et forsinket sjokk i EUA-markedet, med varierende effekt.

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1 Introduction

1.1 THE "WHAT"

Every day, we are bombarded with information about the constantly deteriorating state of our planet earth. Pollution of our air and water, depletion of natural resources and the growing threat of global warming are all on political agendas in large parts of the western world. We can see a clear trend towards more environmentally-friendly industries, but there is still a long way to go. Along with more environmentally friendly consumer products such as electric-powered cars and electricity-saving showers and light bulbs, corporations have become more aware of the environment and more and more are shifting focus towards reducing activities with a negative impact on the environment. Consumers are urged to recycle waste and save electricity, and the more aware consumers are of environmental questions, the more it is affecting their choices and corporations with a clear green profile are growing in popularity. Although these developments are undoubtedly positive for the conservation of the planet, the world still relies on emissions-intensive industries and the use of fossil fuels.

To counteract this pressing issue, world leaders of a number the most powerful nations met in Kyoto in 1997 in order to set up a legally binding plan to reduce emissions of greenhouse gases. Soon afterwards the European Union started developing plans to put into place a system to reduce European emissions. What emerged from these plans was a quota system where a limited amount of quotas would be issued, and businesses subject to this new system are obligated to ensure possession of sufficient quotas to make up for their emissions that year. Trading between businesses is then encouraged so that a more even distribution is possible, and that businesses with excess quotas have the possibility to sell these to businesses who do not have sufficient quotas to cover their emissions. This system, known as the EU ETS, was put into effect in 2005 and has since experienced a turbulent start during the first, rather experimental stage. We are now in the second phase of the trade, and little is known about this relatively new and immature market.

As with many new and underdeveloped markets, price movements are relatively unpredictable and many such markets tend to be influenced by more established markets operating in similar industries. At the same time, these markets also react quite dramatically to events happening in their and other, related, markets.

This thesis analyzes the price movements of EUAs in order to understand how they move, and how they are influenced by other markets. It focuses on price relationships in order to gain more understanding of EUA prices and its reactions to movements on other markets.

1.2 THE "WHY"

Why is the EU ETS a topic of interest?

The quota system brings with it a range of decisional choices for companies using the system. In order to operate according to the EU ETS, companies must either purchase sufficient quotas to cover their emissions, invest in emissions-reducing measures, or face fines at the end of the period. Each of these decisions comes with an attached cost, and the choice will naturally depend on this. Because the EU ETS is a relatively new market, little is known about how it operates and reacts to different forces. In addition to this, there are few studies exploring the second phase of trade, although many have concentrated on the collapse of the system which took place during Phase I. From 2008 and onwards, known as Phase II, the market has stabilized somewhat, but it is still a young and underdeveloped market which we know little about. Because of its immaturity, it is prone to react dramatically to news stories and this period has been anything but uneventful. With the cyber theft of quotas, the nuclear breakdown following the earthquake in Japan, as well as the dramatic increase in oil prices all have taken place in 2011, the world has seen a rather turbulent period for many markets.

Because of this, having the ability to forecast future price movements of EUAs will represent an advantage in the form of being able to time purchases and sales to make profits or save costs. This ability will also be beneficial for traders in this market, who concentrate on trading quotas as well as derivatives of these. As in any other market, traders will explore relationships to see whether there is any forecasting power of a statistical model, as well as look at news in relevant markets, such as natural disasters, war or new policies or other political decisions affecting not only the market itself but also parallel and complimentary markets.

Understanding the EUA market is not solely interesting for companies and traders directly handling them on a day-to-day basis. The additional cost of EUAs for companies will ultimately and inevitably be transferred to the final customer, making the movements of this price interesting for the everyday consumer. Consumers today are the most informed in history, with constant access to information almost anywhere in the world. Being able to check price movements of any stock, electricity or oil markets and getting notified instantly of new developments in world news gives today's customers more power to make informed choices of their purchases. This means that people are becoming more aware of what electricity provider to use, what car dealership offers the best deals for more eco-friendly cars, and what companies actively make an effort to improve not only environmental, but also ethical issues. Understanding the CO_2 market may well become more interesting for the everyday consumer, as an increase in these may motivate them to switch to more eco-friendly producers or decide to stop using a specific product altogether. We can see this development where consumers consciously choose products using less of our limited resources. This choice may be as affected by environmental motivations as well as the ever-increasing price of power. Consumers today are more aware of the seasonality of electricity prices and this affects consumption during high-priced seasons, and petrol prices are a part of everyday conversation. This could be the future for CO_2 quotas, as this grows in importance in future production of products, electricity and travel.

1.3 THE "HOW"

Understanding the EUA market is the result of in-depth analyses of historical prices. This thesis will concentrate on the period starting in Phase II of EUA trading, starting in 2008. Daily prices are collected in the period 26.02.2008-01.04.2011 for not only EUAs, but also energy and commodities. This is to look for connections between these and EUA prices, and explore whether or not movements in any of these other markets have an effect on CO_2 prices.

Although technical analyses can uncover relationships between price series, it is important to keep in mind that these analyses solely concentrate on the factors included in the model. Out of the numerous factors that may affect the EUA price, these analyses focus mainly on the relationships between EUAs and electricity, oil and commodities on a statistical and econometric level. In order to get a full understanding of price movements, a more in-depth analysis also including qualitative factors is required. This thesis touches on the qualitative subject by including an event study where specific time periods around a few selected world events are examined.

The analysis starts in chapter four with descriptive statistics, summarizing the most basic explorations of the data. Time series of daily closing spot prices are examined for each market on a rather elementary level giving us an idea of the nature of the data. This step presents each market's key statistical values, giving an impression of the general price level, how volatile the prices are and how far they deviate from "normality".

The second step is in the comparison between markets. This is done by looking at how correlated the markets are, or to what degree they move in a similar pattern. Although this is a useful tool, the following chapter will explore causality further.

Chapter five, containing the empirical analyses, further investigates the price series and explores the EUA price as a function of itself and a selection of other markets. First is an exploration of short-term relationships, attempting to uncover whether or not a small time period before and after "today" have an effect on "today's" price. Lead-lag correlations with up to three-day lags and regressions with up to five-day lags are tested for statistical significance to see if another market has an explanatory value for today's price. Next, long-term relationships are explored, using tests for stationarity and cointegration to see if prices are related to each other on a longer time horizon. Chapter five concludes with a forecasting analysis, looking at the accuracy of using the EUA market itself or in conjunction with the other markets to forecast future prices.

The sixth and final analysis chapter of this thesis will investigate if three selected events in 2011 have *shocked* the market and how long it takes for it to stabilize and at what level.

> The first event was the hacking scandal where thousands of quotas were stolen digitally, and the following "Safe Harbor Initiative" where all trade was suspended for a period of around two weeks.
>
> March 2011 saw a serious earthquake in Japan, resulting in widespread fear of the breakdown of a number of nuclear reactors in the area. As a result, European leaders announced the shut-down of nuclear reactors in central Europe as a safety precaution, some with immediate effect. For instance, seven nuclear power plants were shut down in Germany in the days following the earthquake, and a plan was put in place to shut down the remaining reactors before 2020.
>
> The last event explored is the enormous price increase in oil in the period from February to June 2011.

In the following chapters, an introduction to CO_2 quota trading will be found. Following this, an introduction to the markets which will be analyzed in this thesis is presented. The three analysis chapters are found after this, and conclusions and discussions are found in chapter seven.

2 CO_2 Allowance Trading: A Short History

This chapter aims to give a short introduction to the background of CO_2 allowance trading, how the system works and how the EU ETS has performed since its start in 2005. As the EU ETS is divided in three phases, this chapter is divided into three subsections. After a short general history below, section 2.1 will summarize Phase I of trade, and sections 2.2 and 2.3 will present Phase II and Phase III respectively.

Under the Kyoto Agreement in 1997, several developed countries agreed to take legal responsibility to reduce emissions of CO_2 and other greenhouse gases (GHG). This was based on the acknowledgement and documentation by the United Nations' (UN) Intergovernmental Panel on Climate Change (IPCC) that the earth's climate is threatened as a consequence of constantly increasing pollution. The EU ETS was launched in 2005 as a part of a collective effort to reduce pollution and global warming. It is, however, limited in the sense that it only concentrates on CO_2, and limits itself to only a subsector of the economy – namely the power sector, specified industrial sectors, and all combustion facilities with a thermal input of more than 20 MW regardless of sector. The EU ETS therefore covers about half of total EU CO_2 emissions and only 40 percent of GHG, and other measures are necessary to limit emissions from other sectors as well as emissions of other gases (Ellerman & Joskow, 2008).

Although the greenhouse effect was discovered in the early 1800s, as well as numerous studies indicating increasing global temperatures during the 1930s, 40s and 50s, little attention was given to the issue until the landmark conference on "Causes of Climate Change" in August 1965 in Boulder, Colorado. The conference in Geneva in 1979 forced the climate question onto the political agenda and created a World Climate Program, while the June 1992 Earth Summit in Rio de Janeiro gathered representatives from 178 countries to confront fundamental environmental problems. The latter produced the United Nations Framework Convention on Climate Change (UNFCCC), a common goal to face environmental problems such as climate change and threats to biodiversity, but without specific measures. Finally, the Kyoto Protocol of December 1997 was the first agreement in history to legally oblige industrialized countries to reduce emissions causing global warming. This agreement took effect in 2005 and was adopted most major industrial nations (Lin, Revkin, Roth, Tarchak, & Weart, 2009).

In Europe, an important consequence the Kyoto Agreement was the establishment of the EU Emissions Trading System (EU ETS) where carbon quotas (or 'emission allowances') are traded. The aim of the EU ETS is to hold all member countries responsible to reach specific goals, ensuring that the global goals stipulated in the Kyoto Protocol are reached. Global emissions are to be reduced by 5 percent from the 1990-level during the period 2008-2012, and individual countries are assigned specific goals. An example is Norway's specific goal of never having average emissions more than 1 percent over the 1990-level between 2008 and 2012 (EU, 2008).

Quotas, or allowances, represent the right to emit one ton of CO_2 within a predetermined upper limit, or 'cap', on total CO_2 emissions (EU, 2008). Companies must purchase sufficient carbon quotas to cover their emissions, or face heavy fines at the end of the year, the price of which increase for each trading period[1]. Trading between companies is permitted, so that companies who either have purchased too many quotas or reduced emissions sufficiently have the opportunity to sell emission allowances to other companies. Companies who have not managed to reduce emissions therefore have the choice between investing in emissions-reducing measures such as new technology or alternative energy sources or buying allowances on the market. The choice therefore falls on an evaluation of relative costs – thereby reducing total emissions on the most cost-effective way (EU, 2008). The number of quotas available is reduced over time to reach the 2020 goal of 21 percent less emissions than in 2005.

In January 2005, the EU Emissions Trading System (ETS) opened for EU-wide greenhouse gas (GHG) emissions trading, whereby the right to emit CO_2 became a tradable commodity (Benz & Trück, 2009). It operates using a "cap and trade" principle, whereby a limit on the total amount of certain greenhouse gases that can be emitted is determined, and each company receives emission allowances within this limit (European Commission Climate Action, 2010). In Phase 1 (2005-2007), the system limits itself to carbon emissions, but in Phase 2 (2008-2012) other greenhouse gases are included in the system (United Nations). This means that one allowance can be used either to cover one ton of CO_2 or emissions of other gases equal to one ton of CO_2. It is now the largest carbon trading scheme globally, operating in 30 countries (27 EU Member States and Iceland, Liechtenstein and Norway) and accounting for almost 80 percent of carbon credit markets in terms of the value of credits traded (Klepper, 2011), (European Commission Climate Action, 2010).

Although there are challenges regarding the reduction of emissions, as well as insufficient reduction targets, the establishment of the EU ETS has contributed to creating the developed market for CO_2 permits we see today (Klepper, 2011). Facilities under the ETS are only required to possess allowances matching emissions once a year, resulting in a less liquid market than other commodity markets. This also leads to temporary mismatches between buying and selling orders, resulting in high fluctuations and more volatility (Abadie & Chamorro, 2008). In January 2008, members of the EU suggested that a larger portion of quotas were to be sold directly to companies rather than allocating quotas at the start of a trading period. This was approved, meaning that at the start of Phase 3 in 2012, no CO_2 allowances will be allocated to any companies, but must be purchased at the start of the trading period (EU, 2008).

[1] In Phase 1, the fine for emissions not covered by quotas was €40 per ton of CO_2, while it increased to €100 per ton emitted in Phase 2 (European Commission Climate Action, 2010).

2.1 Phase 1 of the EU ETS (2005-2007)

The first phase of the EU ETS, from 2005 to 2007, affected around 11 000 companies responsible for approximately 40 percent of EU CO_2 emissions (BBC, 2006) and is considered an initiation period designed to give more insight in how such a system works and how it can improve.

According to a study conducted by Point Carbon in 2006, a total of 362 million tons of CO_2 was traded on the spot market in 2005, for a total price of 7.2 billion Euros (Point Carbon, 2006). In addition to this, a significant number of futures and options were traded this year. Prices peaked in April 2006 at around €30 per emissions allowance, but dropped rapidly to a level of €0.10 per emissions allowance in September 2007 as a result of over-allocation of quotas.

In retrospect, one noticed that companies had been allocated too many quotas, meaning that they had not been pressured to reduce emissions. By the end of 2007 allowances became virtually worthless due to a lack of scarcity, but Phase 1 of the EU ETS still managed to impose a price on CO_2 emissions, defined cap levels, and created a foundation for further development in Phase 2 (Ellermann & Buchner, 2007).

Although the first phase of the EU ETS is generally not considered a success in terms of reducing CO_2 emissions significantly, it proved to be very successful in providing information on how such a system works and areas in which it can improve. This is confirmed in an MIT study on the initial phase of the EU ETS system which found that although the implementation of the system did not reduce emissions significantly in the first phase, the marginal reduction in CO_2 did not have any negative macroeconomic effects. This means that what was achieved in emissions reduction was done in the most cost-effective way. Further, the study shows that permitting “banking and borrowing”; letting companies save quotas for next year, or borrow quotas from next year to cover this year’s emissions, made the system more efficient. Emissions allowances are in this way distributed to when they are needed most, and companies have more freedom to decide when to purchase more allowances. Ellerman and Joskow (2008) go on to emphasize the importance of accurate reporting and communication, a lesson learned early in the first phase when emissions data was unavailable. Lastly, the study showed that the system is controversial and the allocation of quotas to polluting industries will be disputed (Ellerman & Joskow, 2008).

2.2 Phase 2 of the EU ETS (2008-2012)

The second phase of the EU ETS, from 2008 to 2012, is often referred to as the ‘Kyoto Phase’ as it aims to reach the goals stipulated in the Kyoto Agreement of 1997. Since Phase 1, there have been significant design changes in the ETS system, which came in the form of amendments proposed by a Directive called the ETS Review. Most importantly, the EU-wide cap was determined centrally, and the distribution of allowances in member states was largely determined by mandatory auctioning for the power sector, and national registries were collected in the central EU registry (Ellerman & Joskow, 2008).

The caps for Phase 2 are significantly lower than in Phase 1, as much as 25-35 percent in some markets mostly concentrated in and around Eastern Europe. This dramatic reduction may in part be a result of the miscalculations of emissions in Phase 1, indicated by the vast differences in caps – the 15 EU states have caps up to 9 percent lower for the second trading period (Ellerman & Joskow, 2008).

In terms of carbon price, Phase 2 has so far presented a more stable and healthy progression than in Phase 1. Carbon spots traded on BlueNext (BNX) have been varying between €10 and €30 per emissions allowance, depending on levels of demand and the likely impact of the recent financial crisis. Futures traded on the European Climate Exchange (ECX) with maturities December 2008 to December 2010, have also shown a relatively stable price path (Chevallier, 2010).

2.2.1 Events in Phase 2

As we have seen in Phase 1 of the EU ETS, the announcement of new information and events has a dramatic impact on the price of CO_2 allowances. This is illustrated in Figure 1, where we clearly can see a fall in the price from over €30 to under €15 in a very short period in April 2006. The reason for this large drop in prices followed the release of verified emissions data and the following realization that too many emissions allowances had been issued. The restriction on saving quotas to use in Phase 2 led to that many companies who had too many allowances tried to sell the excess quotas and therefore the price collapsed (Ellerman & Joskow, 2008). Such a dramatic reduction in prices indicates that the market is inefficient, and we can assume that future events will have large impacts on CO_2 prices.

Since 2008, the EU ETS has had to adjust to unusual events in the market. In this time, there has been a financial crisis, the post-Kyoto negotiations have been delayed due to the Copenhagen Summit, and the EU Commission has made decisions regarding allocation in the Eastern European countries (Chevallier, 2010).

2.3 Phase 3 of the EU ETS (2013-)

From 2013 and beyond is the third phase of the EU ETS. This phase differs from the first two in the sense that emission caps will not be set based on previous emission and Kyoto targets, but in line with the goal of achieving the 2020 target of emissions 20 percent below 1990-level (Ellerman & Joskow, 2008). To achieve this, the total number of allowances will decrease in a linear manner from 2013.

In the fourth trading period, starting in 2021-2028 and beyond, caps will be determined by results in phase 3 and will be revised by 2025 at the latest. This is in order to achieve the 60 %-80 % emission reductions from 1990-level that are necessary by 2050 to reach the goal of limiting the global average temperature increase to not more than 2˚C above pre-industrial levels (EU, 2008).

Another major difference in this phase is that the EU ETS will include more sectors and greenhouse gases. Phase 3 will also include the capture, transport and geological storage of greenhouse gas emissions, as well as industries such as aviation (EU, 2008).

3 Previous Research on Price Drivers of CO_2 Allowances in the EU ETS

New commodity markets such as the EU ETS generally need time to mature and realize price discovery, and since establishment in 2005, this market has experienced a large degree of volatility. The main price drivers of carbon are policy issues, energy prices, temperature events and economic activity (Alberola, Chevallier, & Chèze, 2008), and fluctuations in these are likely to cause fluctuations in carbon prices.

Benz and Trück (2008) argue that policy and regulatory issues have a long-term impact on allowance prices. In the short term, they realize that changes in policy directives and regulations may have a substantial effect on supply and demand, which again can affect short-term price behavior. However, most decisions made regarding changes in policy and regulatory issues are thoroughly investigated to determine economic effects, opening for companies to hedge themselves against these effects.

The most influential price driver on CO_2 is the price of energy, and an important aspect of this is the ability of power generators to switch between fuel inputs (Alberola, Chevallier, & Chèze, 2008). The two most common fuel inputs in Europe are natural gas and coal, and switching between these represents an opportunity to reduce CO_2 emissions in the short term. The main decision factor between coal and the more environmentally friendly natural gas is the carbon equilibrium price, above which it is more profitable to use natural gas, and below which coal is used. (Kanen, 2006). Power plants must therefore pay close attention to dark and spark spreads. The spark spread is the, "theoretical gross margin of gas-fired power plants from selling one unit of electricity, having bought the fuel to produce this unit of electricity" (Webster's Online Dictionary), and the dark spread represents the same value for an oil-fired plant. Clean spark and dark spreads refer to these values adjusted for ETAs, and the equilibrium between these values represents the "switching price" of carbon, under which it is more profitable to burn coal, and over which natural gas is used.

Weather conditions have an impact on allowance prices, but Mansanet-Betaller (2007) is the only research finding empirical evidence of this. They logically argue that abnormal weather conditions will drive energy prices upwards, as more heating is required in abnormally cold periods and more cooling is required in abnormally hot periods.

Political and institutional decisions may also have an impact on carbon prices, as local governments make decisions regarding business, emissions, and other functions such as exports and taxes. These may all have a significant impact on the daily operations of any company, which again affects the trading of CO_2 allowances. The same applies to decisions made on the institutional level, affecting companies' overall operations.

3.1 Price volatility in the EU ETS

Benz and Trück (2009) analyze the price dynamics of CO_2 emissions with the aim of managing price risk. They look at consequences of changes in regulatory or policy issues, and examine the effect these have on the volatility of carbon prices.

Generally, CO_2 production depends on several factors such as weather data (temperature, rain fall and wind speed), fuel prices and economic growth. It is also found that the price shows specific price behavior depending on fluctuations in production levels. Especially abnormal weather events and changes in fuel spreads will shock the demand and supply side of CO_2 allowances. This can be explained by power manufacturers switching energy sources, which leads to price uncertainty of allowances, which again increases volatility (Benz & Trück, 2009).

Ellerman and Joskow (2008) give a report on the first phase of the EU ETS and analyze price movements with regard to price volatility. They highlight that allowance prices tripled in the first six months of the trial period, and then collapsed by half in a one-week period in April 2006, before declining to zero in the following twelve months. This is displayed in Figure 1.

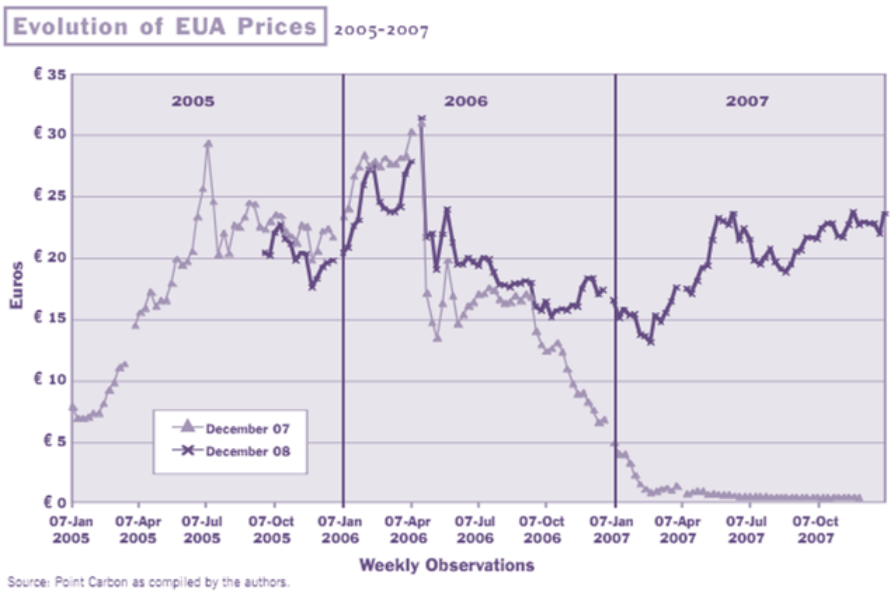


Figure 1: Evolution of EUA Prices. (Ellerman & Joskow, 2008)

Price movements such as the ones above are not unusual for cap-and-trade systems, and the authors compare these to the similar SO_2 allowances in the US Acid Rain Program introduced in 1995. Further, price volatility is not limited to the start-up of such programs, which we have learned from the Acid Rain Program. The report points out that in the EU ETS, volatility in phase 1 was intensified by restrictions on trading between first and second periods. Further, the release of emissions data in April 2006 caused phase 1 prices to fluctuate more than expected (Ellerman & Joskow, 2008).

Further, the report states that phase 1 saw greater volatility due to the compounded effects of annual reporting in this self-contained three-year trial period. Emissions data was not available before almost half of the trading period had passed, which left little time to adjust and less opportunity to create demand before the end of the period. The similar US SO_2 and NO_X programs require quarterly reporting, which allows for earlier adjusting to new information, and therefore lower volatility. The authors however find that, when data from April 2006 are excluded, price volatility for CO_2 allowances is no greater than that for gas and electricity markets (Ellerman & Joskow, 2008).

Betz and Sato (2006) explain that price volatility has great impacts on long-term investment risk and therefore reduces dynamic efficiency. Referring to the sharp drop in prices in April 2006 following the release of verified emissions data, they recommend that greater transparency in the market may reduce volatility. Further, the authors believe that more structured and regular information disclosure is necessary, as well as more certainty after 2012 to drive more long-term investments in the EU ETS will help stabilize the market. In addition to this, banking into post-2012 as well as setting a minimum price-floor in auctions may contribute to minimizing volatility in the future (Betz & Sato, 2006; Hepburn, Grubb, Neuhoff, Matthers, & Tse, 2006).

To solve the problem of price volatility, a number of Member States, particularly Poland and later the French Presidency, suggested actions such as market monitoring and a target price corridor. The Commission has outlined several new design elements in order to reduce price volatility in phase 3. Among these is the fact that verified emissions data will have been available for several years, making correct allocation of allowances easier. Ensuring banking between phase 2 and phase 3 will contribute to avoiding an abrupt price drop towards the end of the phase as we saw in phase 1. Furthermore, if a predictable cap is fixed well before the beginning of phase 3, member states and member business will be better equipped to plan future allowance needs (Kettner, Köppl, & Schleicher, 2009).

3.2 The futures market for CO_2 allowances

The futures market for carbon allowances has grown substantially since its start in 2004, but despite this growth trading has been low in futures contracts, excluding those expiring in December (Abadie & Chamorro, 2008). Chevallier (2010) highlights that EUA futures prices tend to be more actively traded than spot allowances, and therefore these are more reliable for modeling and forecasting. Chevallier (2009) looks at carbon futures with expected delivery during Phase 2 of the EU ETS, and studies the relationship between carbon futures and macroeconomic risk factors by using variables which have been previously shown to possess forecast power.

The Samuelson hypothesis states that volatility in futures prices increases as the expiration date approaches. This has been found to hold also for the carbon market. Further, Chevallier (2009) has found a statistically significant link between stock and bond market variables, where these explain variation in carbon future prices.

3.3 Efficiency in the carbon market

Montagnoli and de Vries (2010) explore the Efficient Market Hypothesis (EMH) in the carbon market, and test for weak form efficiency using the random walk hypothesis and variance ratio tests. The EMH states that market prices fully reflect all information, making it impossible for investors to consistently outperform the market, because all investors have the same information. This is typical for young markets with thin trading, a strong characteristic of the EU ETS in Phase 1. Although the study indicates inefficiency in Phase 1, it identifies efficiency in the beginning of Phase 2, showing signs of maturation of the carbon market (Montagnoli & de Vries, 2010).

Kemfert, Kohlhaas and Truong (2006) estimate significant efficiency gains from trading under the EU ETS in phase 1 and compare this to a situation without inter-sectoral and inter-regional trade. They find that this gives net welfare gains in most countries, except for the Netherlands and Italy, and that inter-sectoral trading gives higher efficiency gains than inter-regional trading (Betz & Sato, 2006; Kemfert, Kohlhaas, & Truong, 2006).

4 Energy and Commodity Markets: An Introduction to the Markets

The purpose of this chapter is to give a brief introduction of each market that is tested in this thesis, namely EEX, NordPool, oil and commodities. This is in order to gain more understanding of how these markets may be related to the EU ETS market, and how they differ from each other. Here, the dynamics behind each market is presented so that we can see how they function, what they are based on and how this relates to our topic. The first section presents the two electricity markets; the European market and the Scandinavian market, named EEX and NordPool respectively. Section 4.2 will give an introduction to the oil market and its background, and the last section will present the commodity index that is used in this thesis.

4.1 Electricity Markets: EEX and NordPool

Many studies that seek to find an explanation for the movements in CO_2 prices have started by exploring electricity prices. This may be due to that electricity is closely linked to CO_2 emissions and that, logically, a connection should be apparent.

4.1.1 European Energy Exchange (EEX): Background, Major Players and its Connection to the EU ETS

Germany's energy exchange, located in Leipzig and founded in 2002 as a result of a merger between the two German power exchanges Leipzig and Frankfurt, is the leading energy exchange in Central Europe. EEX holds 50% of the EPEX Spot SE located in Paris which operates short-term trading in power for Germany, Austria, France and Switzerland (EEX, 2011).

	Germany	
	GhW produced Nov 2010	Change since Nov 2009
Combustible Fuels	33 324	2.5 %
Nuclear	11 592	1.8 %
Hydro	1 953	22.2 %
Geoth./Wind/Solar/Other	3 404	-28.0 %
Indigenous Production	**50 273**	**0 %**
Imports	3 359	26.3 %
Exports	5 131	-12.1 %
Electricity Supplied	**48 501**	**3.0 %**

Table 1: German Electricity Production, November 2010. (International Energy Agency, 2010).

As seen in Table 1, both production and consumption of electricity in Germany is significantly higher than in Scandinavia. Most of the energy produced is from combustible fuels, mostly coal. The production of electricity from coal cannot readily be regulated, as shutting down and starting up production is expensive. Therefore, prices are higher during the day and lower during the night, and we can therefore see a larger variation in prices than in Scandinavia.

4.1.2 NordPool (NASDAQ OMX Commodities): Background, Major Players and its Connection to the EU ETS

In 1996, Norway and Sweden established a common electricity market and power exchange called Nord Pool. At that time, this was the first multi-national power exchange in the world, and in later years Denmark and Finland were included. Before the establishment of Nord Pool, power was traded primarily in highly regulated markets, but this new market introduced a new and liberalized market with free competition. One major difference between this market and other multinational power markets is that around half of electricity traded is hydroelectricity, which, because this type of electricity is more easily stored, entails that the spot price varies according to supply and demand (Xanthopoulos & Syrgkanis, 2005).

In 2009, Nord Pool Clearing ASA merged with NASDAQ OMX Commodities AS and in 2010 NASDAQ OMX acquired Nord Pool ASA following Stanett's and Svenska Kraftnät's decision to exercise their option to sell the shares in their companies (NASDAQ OMX Commodities, 2010). NASDAQ OMX Commodities is today the single financial energy market for Norway, Sweden, Denmark and Finland.

	Norway		**Sweden**		**Finland**		**Denmark**	
	GhW produced Nov 2010	Change since Nov 2009	GhW produced Nov 2010	Change since Nov 2009	GhW produced Nov 2010	Change since Nov 2009	GhW produced Nov 2010	Change since Nov 2009
Combustible Fuels	499	17.1 %	1 981	34.9 %	3 922	17.5 %	2 674	9.5 %
Nuclear	0	0%	4 482	40.3 %	1 970	1.4 %	0	0 %
Hydro	11 598	-2.0 %	6 076	8.4 %	1 038	22.1 %	3	50 %
Geoth./Wind/Solar/Other	98	1.0 %	468	40.1 %	77	-3.7 %	895	2.6 %
Indigenous Production	**12 195**	**-1.3 %**	**13 007**	**22.7 %**	**7 007**	**12.8 %**	**3 572**	**7.8 %**
Imports	1 202	164.8 %	1 241	-30 %	1 346	-0.3 %	579	-21.2 %
Exports	832	-59.8 %	764	210.6 %	375	25.4 %	959	-3 %
Electricity Supplied	**12 565**	**13.6 %**	**13 484**	**11.2 %**	**7 978**	**9.9 %**	**3 192**	**4.3 %**

Table 2: Electricity Production in Scandinavia, November 2010. (International Energy Agency, 2010)

Table 2 displays the member nations' production of electricity in November 2010. The largest producer is Sweden with a production of 13 007 GhW, mostly from hydropower. All countries excluding Norway have increased their energy production, and all have increased electricity supplied. Norway increased imports by 164.8% while the other countries have decreased their imports the last year. This could be due to the low water levels in this period.

4.2 The Oil Market: Background, Major Players and its Connection to the EU ETS

Crude oil, or petroleum, is one of the world's most important resources, and has a wide range of uses. Because most of the world's markets are dependent on the price of oil and are affected by even minor changes, it seems that the entire world is focused on what is happening to the oil price. One reason for this is the vastly important role crude oil plays in almost every aspect of the modern world.

A common misconception is that oil equals only petrol, but in reality oil is an important resource in a much wider range of uses. It is used in a number of different types of fuels, from butane, petrol and jet fuel to kerosene, fuel oil and diesel fuel. In addition to this, oil has played an increasingly important part in agriculture, and is now used in the production of most modern fertilizers and pesticides. Besides this, it plays an important part in the production or manufacturing of certain plastics, lubricants, waxes and asphalt.

Oil is a naturally occurring liquid and found in geologic formations below the earth's surface. The number of nations producing and exporting oil is for this reason limited to those positioned in areas with specific oil-producing conditions. Among the largest oil producers are Saudi Arabia, Russia and USA, whereas Saudi Arabia and Russia are joined by Norway in being the largest exporters. USA, China and Japan top the list of oil consuming nations.

Only six of the fifteen top world oil producers are also among the top fifteen top world oil consumers. This is interesting because many of the world's most intensive oil consumers do not produce any oil themselves (US Energy Information Administration). Further, we can see that USA is by far the nation in the world that consumes the most oil, and only produces about half this amount. Therefore, USA is highly dependent on oil imports from overseas, but does not export in any substantial quantities. The same can be said for China, which also produces only about half of its consumption. At the same time, Iraq, Norway, Nigeria and Algeria all appear on the list of top world producers, but none of them are among the largest consumers of oil.

Not unexpectedly, USA, China and Japan top the list of top importers, supporting the fact that these three are also the largest consumers. Also unsurprising is the presence of Japan, Germany, South Korea, France, Italy, Spain, Netherlands and Turkey on the list of top importers, as none of these nations produce oil domestically and depend entirely on imported oil. Again, we can see that Iraq, Norway, Nigeria and Algeria are among the top exporters of crude oil, as these nations are not heavily oil-dependent but export most of their production.

Instead of using an index consolidating a range of oil prices, this thesis will explore prices of crude oil traded on the American domestic spot market in Cushing, Oklahoma. The reason for this is twofold. Firstly, USA is one of the largest producers, consumers and importers of crude oil, and this particular spot market is chosen because it serves as a reference or “marker” for pricing a range of other crude streams (US Energy Information Administration). The second reason is that this market trades every day and that historical daily spot prices are available from the U.S. Energy Information Administration website. This is beneficial because prices between EUAs and oil will be comparable, and the data set will be large enough to draw statistical conclusions.

In addition to spot prices, futures prices for oil will also be explored in order to uncover whether or not EUA prices have a connection with future expected prices. The four contracts that have been included in the analysis are for delivery in one, two, three or four months.

4.3 Commodity Markets: Background, Major Players and its connection to the EU ETS

Commodity markets trade standardized contracts of raw or primary products on regulated commodities exchanges worldwide. This market consists of direct physical trading, which means purchasing contracts promising actual physical delivery of a product at a specific time, and derivatives trading, including futures, options and swaps.

In 2010, the global volume of traded commodities contracts increased by a fifth, to around 2.5 billion million contracts worldwide. At the same time, physical exports fell by two per cent worldwide in the period from 2008-2010. There is a clear trend towards trading in China and India, two markets which have gained importance in recent years because they are quickly emerging as major commodities consumers and producers. China, for example, accounted for more than sixty per cent of exchange-traded commodities in 2009 (Maslakovic, 2011). An overview of the six largest commodities exchanges in the world based on trading volume shows us that that China and India are emerging in the commodity market, and that USA may one day cease to dominate the commodities market (CME Group, 2011).

The S&P GSCI (formerly the Goldman Sachs Commodity Index) is a composite index of commodity sector returns representing an unleveraged, long-term investment in commodity futures that is broadly diversified across the spectrum of commodities (Goldman Sachs, 2011). Now tradable and readily available to market participants of the CME Group, it was originally developed by Goldman Sachs, and ownership was later transferred to Standard & Poors (S&P) in 2007, who currently own and publish it. A reason why this particular index was chosen was because it contains a much higher exposure to energy than other commodity price indices.

5 Pricing of EUAs: Descriptive Statistics

This chapter aims to describe the price development of CO_2 prices, as well as the prices of electricity, oil and commodities in the period 26.02.2008-01.04.2011. Here, we will get a general idea of how the prices have moved on the different markets, before a more thorough empirical analysis is presented in Chapter 5.

The chapter will also include an event analysis, where electricity, oil, commodities, (stock) and CO_2 markets will be compared in periods of abnormal growth or decline in order to uncover whether or not a “shock” in one price leads to a “shock” in the other, and if there is a connection, how long it takes for the other market to respond.

5.1 EUAs: Descriptive Statistics

A visual representation of EUA prices, presented in Figure 2, gives us a general impression of how the prices have moved during the period of interest. We can see a decline as the world saw a financial crisis in late 2008 and running into early 2009, followed by a moderate period of recovery. The abrupt but brief fall to zero in early 2011 is due to the suspension of trade as a result of the discovery of the hacking scandal.

The price of CO_2 quotas reached a peak price of just under € 29 in July 2008 to a low of around eight Euros in March the following year. Since then, the price has stabilized and has stayed between ten and fifteen Euros, with a price of €14.99 at the end of our data set on April 1st, 2011. This represents a recovery to about 51 per cent of its peak price.

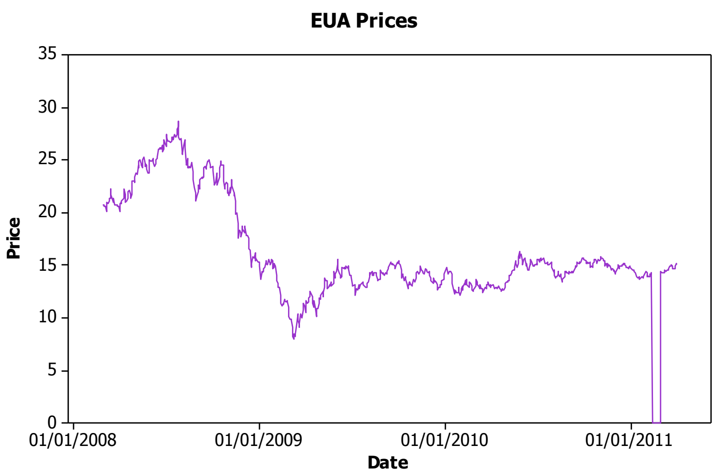


Figure 2: EUA Prices

4.1.1 EUA Descriptive Statistics

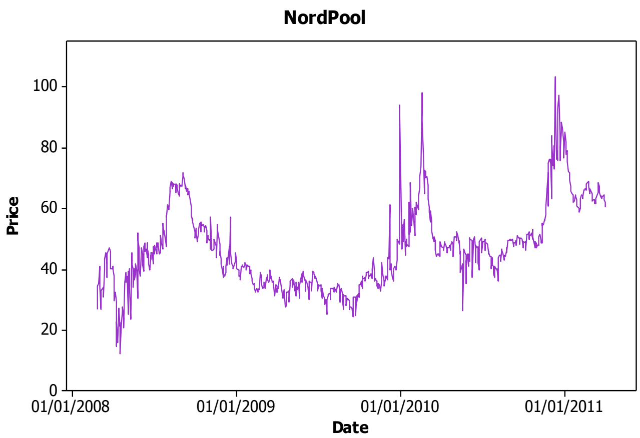
	EUA Prices	EUA Returns
Mean	16.08	-0,001
Standard Deviation	4.85	0.043
Variation Coefficient	0.3017	-0.013

Table 3: EUA Descriptive Statistics,
daily prices and daily returns 26.02.2008-01.04.2011

The descriptive statistics in the table above show a summary of the key statistics for this data set, but for actual prices and returns expressed as per cent changes in prices[2]. These will be compared to other markets in subsequent sections.

The Standard Deviation tells us something about the diversity in the data sets. In order to easier compare these in subsequent sections, the variation coefficient is calculated by dividing each data set's mean by the standard deviation. CO_2 prices show a relatively large variation coefficient, which may be due to the period in February 2011 where all trade was suspended for over two weeks. This makes the prices seem more volatile, meaning that they show large fluctuations. Removing the no-trade period in February 2011 reduces the variation coefficient from 30.2 per cent to 27.5 per cent.

5.2 Electricity Prices and CO_2 Descriptive Statistics



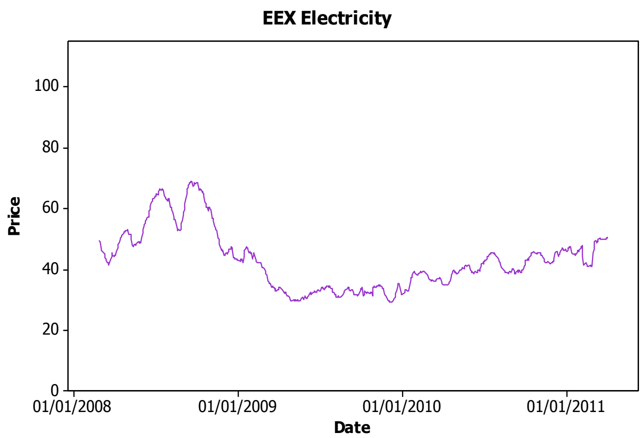
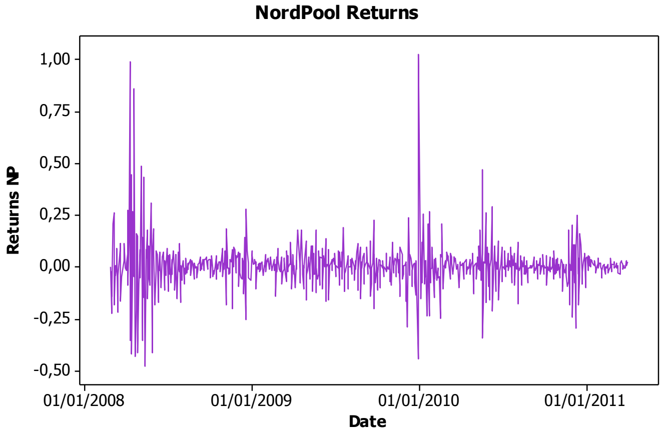


Figure 3: Daily Electricity Spot Prices 26.02.2008-01.04.2011

[2] Daily returns are calculated using $r_t = \left(\frac{x_{t-1} - x_t}{x_t}\right)$

The daily spot prices of the two electricity markets presented in this thesis are shown in Figure 3 above. By looking at the graphical representation, it appears that electricity prices on NordPool have experienced larger and more frequent fluctuations than electricity traded on EEX. This notion is supported by looking at the graphical representation of returns on the two electricity markets, shown below.



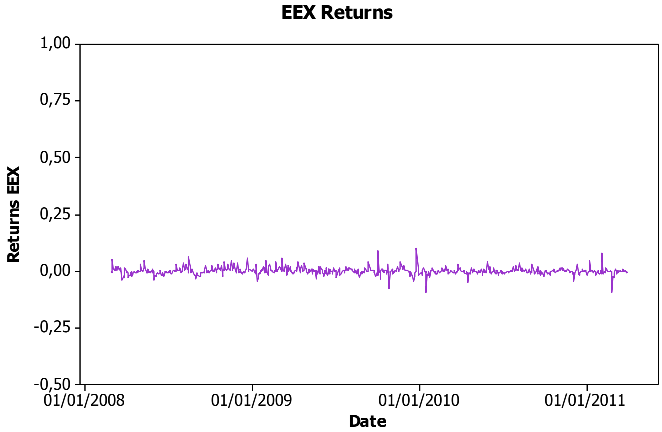


Figure 4: Daily Electricity Market Returns, 26.02.2008-01.04.2011

5.2.1 Electricity Prices: Descriptive Statistics

The statistics summary displayed in Table 4 shows the key statistics in the data set. Not surprisingly, the mean for CO_2 quotas, 16.08, is much lower than the means for European and Nordic electricity, 42.85 and 46.95 respectively. Electricity traded on NordPool has the highest mean and has also reached the highest price in this time period. We cannot, however, assume that NordPool consistently has a higher price than EEX, as its minimum is lower than the minimum for EEX.

	EEX Electricity	EEX Returns	NordPool	NordPool Returns
Mean	42,85	0.00008	46,95	0.005
Standard Deviation	9,79	0.015	13,92	0.111
Variation Coefficient	0,2284	0.005	0,2964	0.043

Table 4: Electricity Descriptive Statistics,
Daily prices and daily returns 26.02.2008-01.04.2011

Comparing variation coefficients uncovers that EUA has the largest, 0.302, compared to 0.228 and 0.296 for EEX and NordPool respectively. The difference is however not large. This is also proven in the graphical representation in Figure 3, where it becomes clear that the variations in prices on the NordPool are larger than on the other markets.

5.2.2 Correlations: Electricity Markets and CO_2

	EUA	EEX	NordPool
EUA	1		
EEX	0,776	1	
NordPool	0,050	0,366	1

Table 5: Correlation Matrix, EUA, EEX and NordPool.
Daily prices 26.02.2008-01.04.2011

The correlation coefficient gives an indication of how similar the data sets are. These are presented in Table 5. We can see that there is a positive correlation between all the markets, with the strongest positive correlation between CO_2 prices and the electricity prices traded on EEX, of 77.6 per cent. The weakest correlation is between electricity traded on NordPool and CO_2 prices traded on EuroNext with only 5 per cent. Interestingly, this suggests that there is no connection between the price of CO_2 quotas and electricity prices in the northern region of Europe. The relationships between the two data sets will be examined more thoroughly using empirical analysis in the following chapters.

5.3 Oil and CO_2 Descriptive Statistics

This section focuses on finding a connection between oil prices and CO_2 quotas. This is relevant because we are likely to find a connection because carbon dioxide emissions are usually linked to the burning of fossil fuels, of which oil is most widely used in the EU.

First, the aim will be to look at daily crude oil spot prices and attempt to link these to CO_2 prices, and then endeavor to find a connection between oil futures prices and CO_2 prices. If there is a connection between these two, we may assume that CO_2 follows a more future-oriented price movement in accordance with future prices of oil.

Oil prices and futures oil prices are found on energy.gov, which provides daily historical data for both spot and futures.

5.3.1 Descriptive Statistics: Oil Spot Prices

This section presents the price development of oil in the period 26.02.2008-01.04.2011. Here, I will look at basic statistics which give some information about the data. This is a basic interpretation of the general price movements and a more in-depth analysis will be presented in Chapter 5.

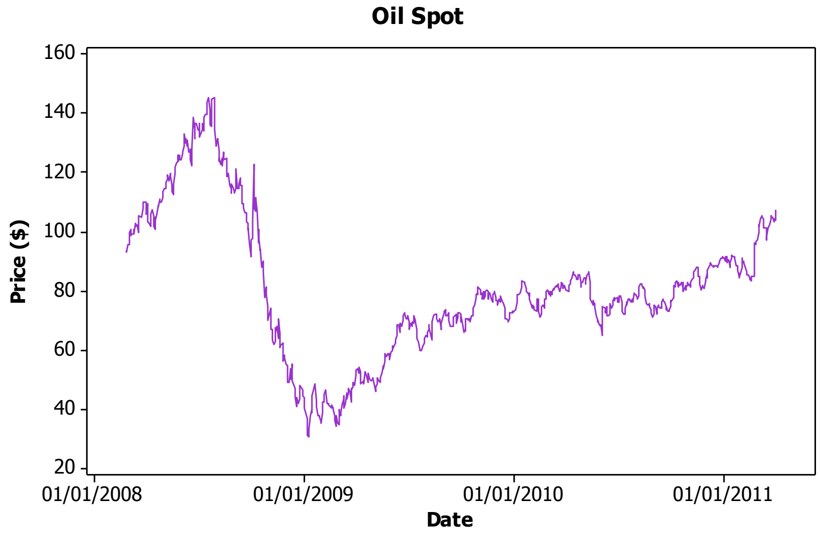


Figure 5: Daily Oil Spot Prices, 26.02.2008-01.04.2011

As we can see in Figure 5, there seems to be some major changes in oil prices during the period, with prices ranging from a maximum of $145.31 in mid-July 2008, to a low $30.28 in early January 2009. Since this low point, it seems that oil prices have been rising relatively steadily until today, reaching a price of $107.55 on April 1st, 2011, a level approximately 74 per cent of its maximum price in this period.

	Oil Spot	Oil Returns
Mean	81,10	0.0003
Standard Deviation	23,83	0.031
Variation Coefficient	0,29	0.010

Table 6: Oil Spot Price Descriptive Statistics, Daily prices and daily returns 26.02.2008-01.04.2011

In Table 6, we can see the basic summary statistics for the oil prices. Here, we cannot compare mean values directly as oil is traded in US Dollars, whereas CO_2 quotas are traded in Euros. We can see that both the standard deviation and variance are relatively large, indicating high volatility in this period. If we compare the variation coefficient to those of EUA, EEX and NordPool prices (0.30, 0.23 and 0.30 respectively), we can see that the oil price variation is in the same range as that for electricity and CO_2 prices.

5.3.2 Descriptive Statistics: Oil Futures Prices

As we can see from Figure 6, the markets for futures contracts are relatively similar graphically. These are the contracts for Crude Oil (Light-Sweet, Cushing, Oklahoma) and represent delivery in one, two, three or four months (US Energy Information Administration, 2011). The more in-depth analysis in the following chapter will tell us more about whether or not the CO_2 spot price is connected to the futures price. A connection between the spot price for CO_2 and any futures price may indicate that quotas are traded with a long-term perspective on future movements in oil prices.

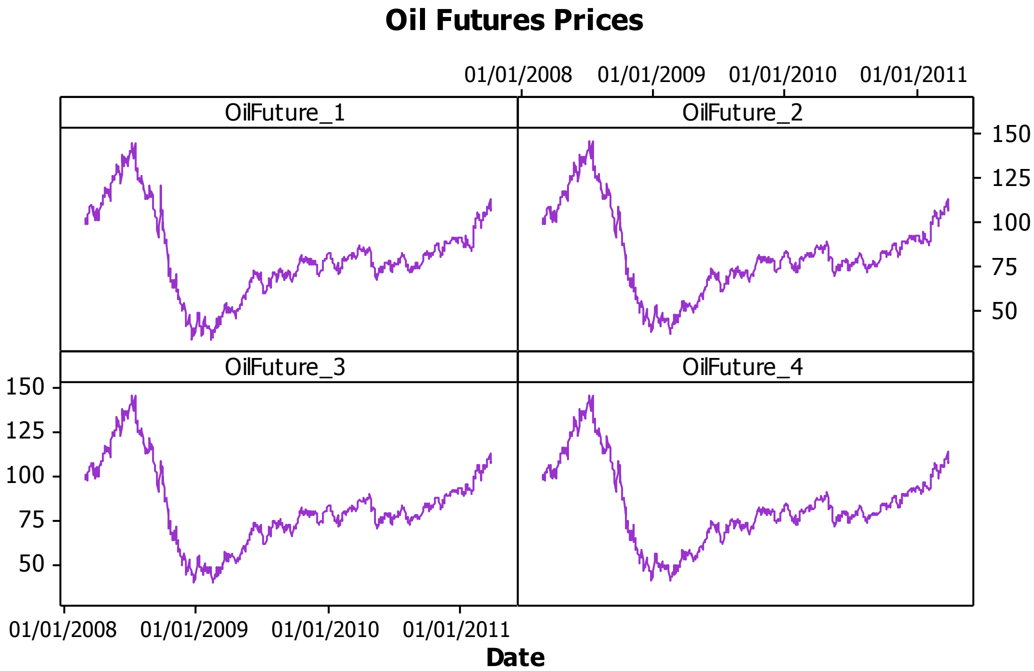


Figure 6: Daily Oil Futures Prices, 26.02.2008-01.04.2011

In Table 7, we can see the descriptive statistics for the four futures contracts. The variation and standard deviations are much higher than those for any of those for EUA, EEX or NordPool, but unsurprisingly similar to those for oil prices. The variation coefficients for the four contracts are, however, in the same range as those for EUA and electricity as well as oil.

	OilFuture_1	OilFuture_2	OilFuture_3	OilFuture_4
Mean	81,39	82,38	83,20	83,83
Standard Deviation	23,87	23,15	22,66	22,29
Variation Coefficient	0,29	0,28	0,27	0,27

Table 7: Oil Futures Descriptive Statistics, Daily prices 26.02.2008-01.04.2011

5.3.3 Correlation: Oil and CO_2 prices

Correlation coefficients between oil prices (spot and futures) and EUA, EEX and NordPool are presented in Table 8. The electricity markets are presented purely for comparative reasons, and connections between oil prices and electricity prices will not be explored further. As we can see, EUA prices have a relatively high correlation with the spot price of oil, with a coefficient of 70 per cent. This, surprisingly, is higher than the correlation for any of the electricity prices. From Table 8 it becomes evident that correlation coefficient is lower for futures prices, and gets consecutively lower the further into the future delivery is. Conversely, this is the opposite than for electricity prices, which become more correlated with futures prices for oil the further into the future delivery is.

	EUA	EEX	NordPool
Oil Spot	0,700	0,663	0,342
Oil Futures 1	0,626	0,581	0,314
Oil Futures 2	0,623	0,585	0,319
Oil Futures 3	0,621	0,588	0,324
Oil Futures 4	0,619	0,590	0,329

Table 8: Correlation coefficients EUA, EEX, NordPool, Oil Spot Prices, and Oil Futures. Daily observations 26.02.2008-01.04.2011.

5.4 Commodities and CO_2

This section endeavors to find a connection between commodity prices and CO_2 prices. Because the EUA market has often been referred to as a commodity market, we can assume that there may be some connection between the two. Instead of choosing some commodities and attempting to find links between these and EUA prices, this section will focus on the Goldman Sachs Commodity Index (GSCI), which, due to a broadly diversified spectrum of commodities included, gives a realistic overview of the general movements across commodity markets. This index represents an unleveraged, long-only investment in commodity futures, and data is collected from Wikiposit, where historical daily, weekly, monthly and yearly data is published (Wikiposit, 2011).

5.4.1 Descriptive Statistics: Commodity Prices

Purely observing the graph below visually, there is evidence that the shape is similar to that of oil spot and future prices. Commodity prices do, however, seem to have recovered more rapidly from the financial crisis of 2008/2009, with prices hitting a low point of \$306.77 in early March 2009, only few months after its peak of \$890.29 in late July 2008. It had by April 2011 reached \$731.44, a solid 82 per cent of its peak price.

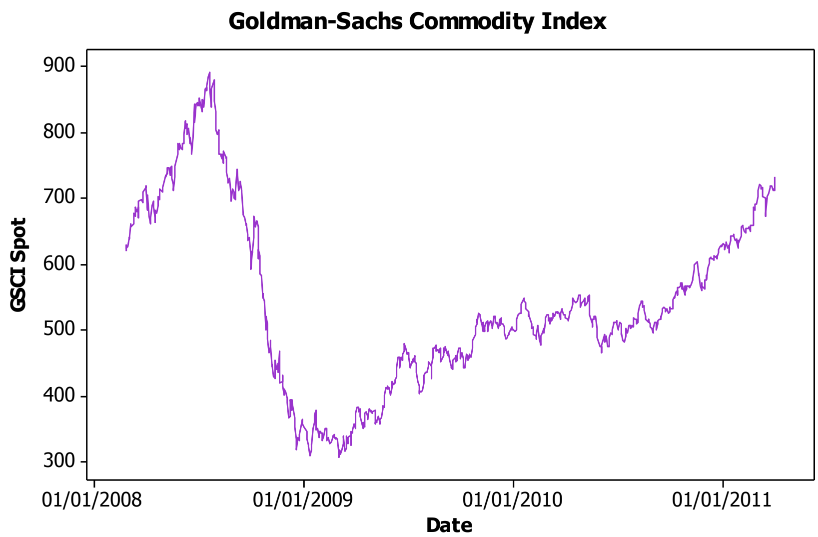


Figure 7: Daily GSCI Prices, 26.02.2008-01.04.2011

A summary of descriptive statistics can be found in Table 9 below, and the statistics for EUAs, EEX, NordPool and oil are also included in this table for comparison purposes. We can observe the largest coefficients for standard deviation in GSCI compared to all other markets analyzed so far. This may indicate that commodity prices have been more volatile than EUA, electricity and oil prices during this period. The variation coefficient does, however, somewhat disprove this as it does not drastically deviate from the values which we have observed earlier.

	EUA	EEX	NordPool	Oil Spot	GSCI Spot
Mean	16,08	42,85	46,95	81,10	542,43
Standard Deviation	4,85	9,79	13,92	23,83	133,43
Variation Coefficient	0,3017	0,2284	0,2964	0,29	0,25

Table 9: Descriptive Statistics, EUA, EEX, NordPool, Oil Spot and GSCI
Daily prices 26.02.2008-01.04.2011

In addition, descriptive statistics for the returns of each market have been collected and summarized in the table below. Here, we can see that NordPool seems to show the highest variation based on the variation coefficient, and that GSCI shows the lowest.

	EUA Returns	EEX Returns	NordPool Returns	Oil Returns	GSCI Returns
Mean	-0,001	0.00008	0.005	0.0003	-3.7E-06
Standard Deviation	0.043	0.015	0.111	0.031	0.020
Variation Coefficient	-0.013	0.005	0.043	0.010	-0.0001

Table 10: : Descriptive Statistics, EUA, EEX, NordPool, Oil Spot and GSCI Returns
Daily prices 26.02.2008-01.04.2011

5.4.2 Correlation between commodity and CO_2 prices

Below is a correlation matrix including both electricity markets, the oil market as well as the commodity index. Of all the markets, the CO_2 market is most closely correlated with electricity traded on EEX, and least correlated with the NordPool market. Correlation is highest between the oil spot prices and EUA prices and relatively high for commodity markets and CO_2 prices as well. The empirical analysis in Chapter 5 will uncover more information about the causality of these connections, giving us a better impression of whether one market has an effect on the other or vice versa.

	EUA	GSCI	EEX	NordPool	Oil Spot
EUA	1				
GSCI	0,646	1			
EEX	0,772	0,675	1		
NordPool	0,030	0,403	0,366	1	
Oil Spot	0,700	0,981	0,663	0,342	1

Table 11: Correlation coefficient matrix between EUA, GSCI, EEX, NordPool and Oil Spot Prices.
Daily observations 26.02.2008-01.04.2011

6 Econometric Analyses: Short- and Long Term Relationships between EUA Prices and Electricity, Oil and Commodity Prices

This chapter presents the econometric results from the empirical analysis in which I attempt to uncover connections between electricity, oil and commodity prices and emissions allowances. The chapter is divided into three parts, where section 5.1 will explore short-term relationship between EUA prices and each electricity market as well as the oil and commodity markets by using lead-lag correlations. The second section will attempt to uncover long-term relationships by testing for cointegration, which requires non-stationarity (which is tested for first). The final section in 5.3 is a brief event analysis to see whether specific events have had an effect on EUA prices.

6.1 Short-Term Analyses: Lead-Lag and Moving Correlations and Regression Analyses

Short-term relationships between each market and EUA prices are explored in this section. First, lead-lag correlations are calculated for each market versus EUA prices. Then, the same values are calculated for ΔP, or price changes in per cent, for each market.

In section 5.1.2, regressions are estimated for EUA prices as the dependent variable and its own lagged prices as well as each market's lagged prices as the independent variables. T-values will then be observed in order to determine significance.

6.1.1 Lead-Lag correlations between EUA prices and Electricity, Oil and Commodity Prices

The correlation coefficients shed light on whether or not there is a linear relationship between two variables, but a high correlation coefficient does not necessarily imply causality between them. Logically, we can expect that there are relatively high correlations between all markets and EUA prices. This is due to several factors. First, a large portion of electricity produced in the EU is from coal, the burning of which emits CO_2. If production of electricity from coal increases, the producers are required to purchase more quotas, making electricity more expensive. Further, we can expect the same pattern for oil and EUA prices, due to the fact that oil is used as fuel in both electricity production and in other industries. The more oil that is utilized, the more CO_2 is released, leading to an increase in purchased quotas, which results in a higher oil price. Lastly, we can expect positive correlations between EUA and GSCI prices as this commodity index focuses mainly on the energy sector, which is directly affected by EUAs, many of them purchasing both coal and oil in order to produce electricity.

The table below presents lead-lag correlations between EUA prices versus EEX and NordPool prices, oil spot and commodity spot prices. The values are based on daily observations during the entire period from 26.02.2008-01.04.2011. It is worth noting that the ETS no-trade period from 14.02.2011-

28.02.2011 has been removed from the data set for all markets in order to eliminated abnormalities and get a more accurate picture of the real lead-lag correlations between the EUA market and each of the other markets.

	EUA_{t-1}	EUA_{t-2}	EUA_{t-3}	EUA_{t+1}	EUA_{t+2}	EUA_{t+3}
EEX	0.825	0.817	0.810	0.834	0.836	0.838
NordPool	0.101	0.094	0.085	0.111	0.115	0.119
OilSpot	0.779	0.777	0.775	0.776	0.772	0.769
GSCI	0.751	0.748	0.744	0.751	0.746	0.742

Table 12: Lead-Lag Correlations between daily EUA prices and EEX, NordPool, OilSpot and GSCI prices 26.02.2008-01.04.2011

The columns labeled EUA_{t-i} with i=1,2,3 show correlation coefficients for today's electricity, oil and commodity index prices and EUA prices from one, two and three days earlier. The last three columns, labeled EUA_{t+i} with i=1,2,3 present the correlations between lagged electricity, oil and commodity index prices and today's EUA price. This means that the column labeled EUA_{t+2} presents values for EUA versus the price for electricity, oil and commodity index two days earlier.

The results presented in Table 12 show relatively high positive correlations between each variable and the EUA price, with the exception of NordPool. A possible reason for this may be that the Scandinavian electricity market is less dependent on fuels which emit large amounts of CO_2 than the European electricity market. This is mainly due to the fact that only around 25 per cent of electricity produced in Scandinavia is from combustible fuels, and that electricity production is mainly based on hydroelectric and nuclear power in Norway and Sweden. Finland and Denmark produce significantly less electricity than Norway and Sweden, but mainly base this production on combustible fuels.

The highest correlation coefficients are found between EEX and EUAs. A possible explanation for this is that these both mainly operate in the same geographical area, whereas both oil and commodity prices are global prices. The significance of operating in the same geographical location is that factors only affecting this area will affect both markets. Such factors can include extreme weather conditions, as well as the general economic condition in that area. The correlations between oil and EUAs are higher than those for commodities and EUAs. This may be because the Goldman-Sachs Commodity Index includes a wide range of commodities, some of which may be either un- or negatively correlated with EUAs.

There does not seem to be any obvious differences between correlation coefficients across the lead-lag spectrum. In other words, the correlation coefficients seem to be rather similar regardless of whether or not the prices are lagged or not.

Very high correlation coefficients may in some cases be evidence of multicollinearity, in which case the t-values for the regression analyses in the next section will be unreliable. In order to remove this problem, lead-lag correlations are calculated again, this time using the per cent changes[3] in prices rather than the prices themselves. The values are presented in the table below:

	ΔEUA_{t-1}	ΔEUA_{t-2}	ΔEUA_{t-3}	ΔEUA_{t+1}	ΔEUA_{t+2}	ΔEUA_{t+3}
ΔEEX	0.029	0.080	0.047	0.019	0.042	0.021
ΔNordPool	0.072	0.069	-0.020	-0.023	-0.006	-0.036
ΔOilSpot	0.039	-0.024	-0.017	0.008	-0.036	0.055
ΔGSCI	-0.019	0.047	0.052	0.026	0.026	-0.050

Table 13: Lead-Lag Correlations between daily per cent price changes, EUA vs EEX, NordPool, OilSpot and GSCI for the period 26.02.2008-01.04.2011

Lead-lag correlations for percentage changes in prices, presented in Table 13, show very different results from the values shown in Table 12. We can observe that the coefficients are much lower than previously, and that some of the values are negative.

ΔEEX is the only variable with positive coefficients for each lag and lead of EUA prices. This indicates that there is indeed a positive relationship between these two, the possible reasons for which were discussed previously. These are however, in likeness with the correlation coefficients for the other markets, relatively close to zero, indicating no correlation. Although there are negative correlation coefficients, these are relatively close to zero, and we can generally conclude with low correlation between ΔEUA and ΔEEX, ΔNordPool, ΔOilSpot and ΔGSCI.

6.1.2 Moving Correlations between EUA prices and Electricity, Oil and Commodity Prices

Further, we can look at the moving correlation between EUA, EEX, NordPool, Oil and GSCI. Correlations are calculated for a specific period, e.g. a month, and then moved downwards one day at a time, so that a new series is created with correlations for the last month. In this section, these moving correlations are first calculated for one month, then six months. The graphical representation of these moving correlations can give an impression of how they change over time, and whether or not there are periods with higher correlations than others. This is relevant in order to uncover whether or not specific periods in the data set are more or less stable, or more or less correlated.

First, daily correlations are calculated based only on the last month, then graphed in order to get a realistic visual representation of these. They are shown in Figure 8.

[3] These are calculated using $\left(\frac{P_t - P_{t-1}}{P_{t-1}}\right)$ for each observation.

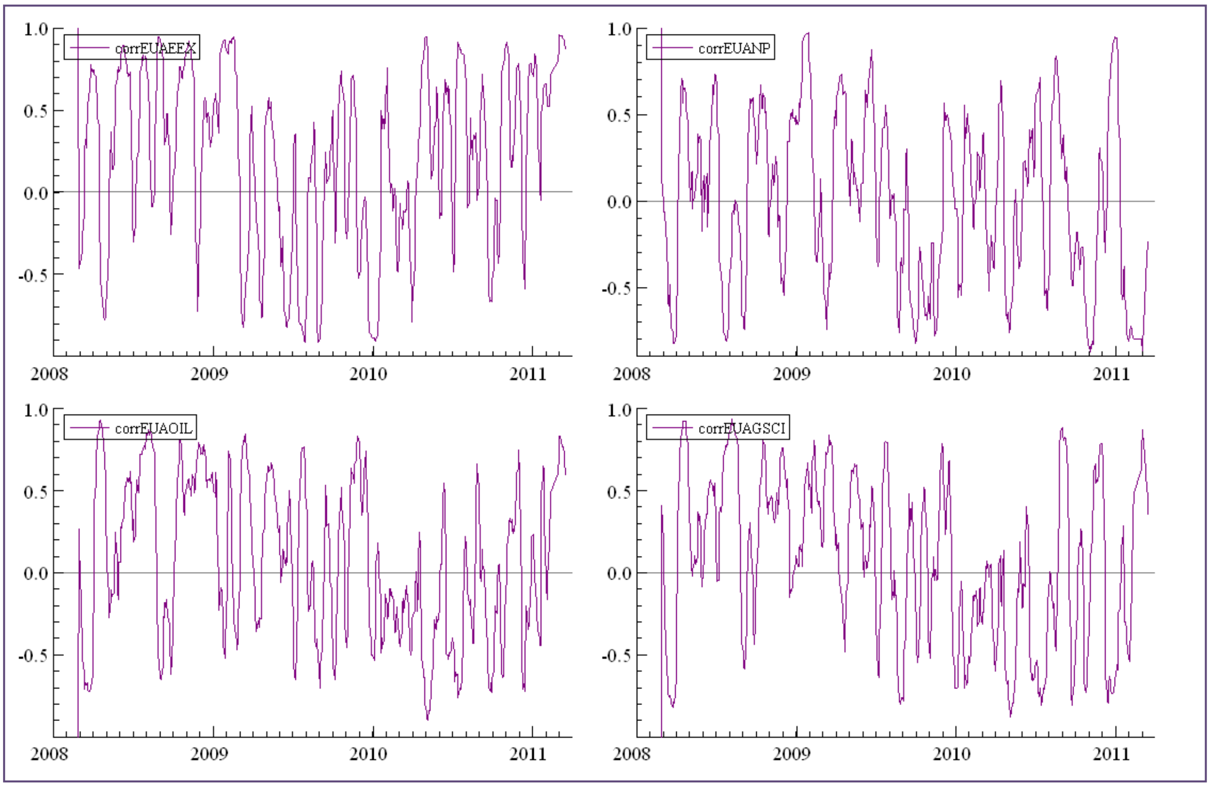


Figure 8: Moving correlations for periods of one month (30 days) between EUA and EEX, NordPool, Oil and Commodity prices, 26.02.2008-01.04.2011

The moving correlations represented above seem to display widely varying results. EEX and NordPool appear to produce monthly moving correlation coefficients relatively evenly based around zero, indicating no correlation. Oil and commodity prices also seem to generally display the same behavior, but it may appear that moving correlation coefficients for a period in the beginning of 2010 move towards -1. If we choose a longer period for moving correlations, for example six months, we may get a clearer idea of whether or not there exists periods of more or less correlation. These have been calculated and are presented below.

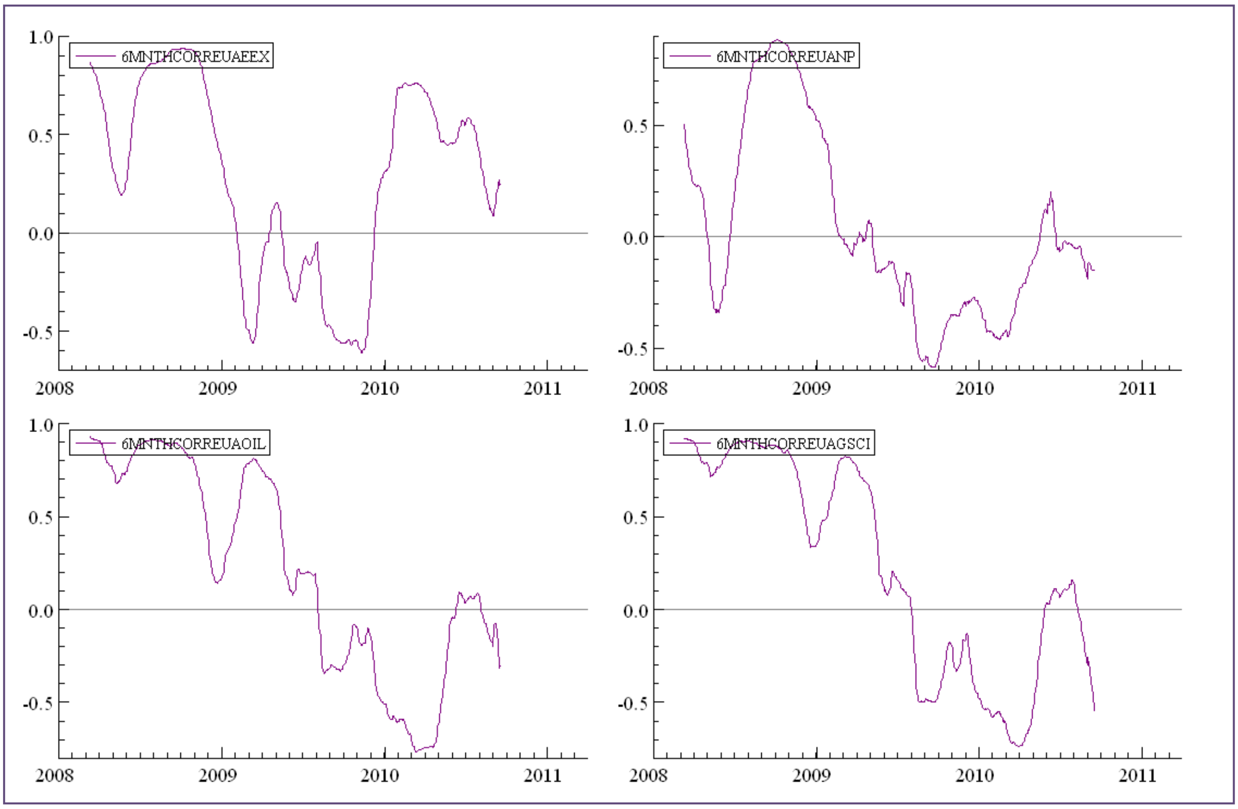


Figure 9: Moving correlations for periods of six months (daily observations) between EUA and EEX, NordPool, Oil and Commodity prices, 26.02.2008-01.04.2011

The graphs in Figure 9 give a very different and less volatile picture of the movements in correlation coefficients between the markets. Until 2009, EEX and NordPool prices seem to be highly positively correlated with EUA, but then experience a significant drop and become almost perfectly uncorrelated with EUA during 2009, before a period of instability and highly varying correlations occurs. We can see a similar development in correlation coefficients between oil and commodity prices versus EUA prices, where the first half of the data seems to be positively correlated, but then dropping to becoming almost perfectly uncorrelated in early 2010.

Taking this idea further, lead-lag correlations are calculated for the period 26.02.2008-01.01.2009, the period that appears to be the most highly correlated. This is done for comparative reasons, to see whether the values generated here indicate higher correlation for this period than for the entire period altogether.

	EUA_{t-1}	EUA_{t-2}	EUA_{t-3}	EUA_{t+1}	EUA_{t+2}	EUA_{t+3}
EEX	0.688	0.688	0.687	0.680	0.672	0.663
NordPool	0.269	0.284	0.304	0.239	0.226	0.206
OilSpot	0.871	0.862	0.853	0.886	0.893	0.901
GSCI	0.853	0.843	0.831	0.872	0.880	0.887

Table 14: Lead-Lag Correlations between daily EUA prices and EEX, NordPool, OilSpot and GSCI prices 26.02.2008-01.01.2009

With exception to EEX, all the lead-lag correlations have been improved by removing the period after 01.01.2009. This is consistent with what was shown in the graphical representation of the 6-month moving correlations. As previously, multicollinearity may again be a problem in this data set, so lead-lag coefficients for per cent price changes are also graphed and calculated in order to gain a more realistic view of correlations in this period.

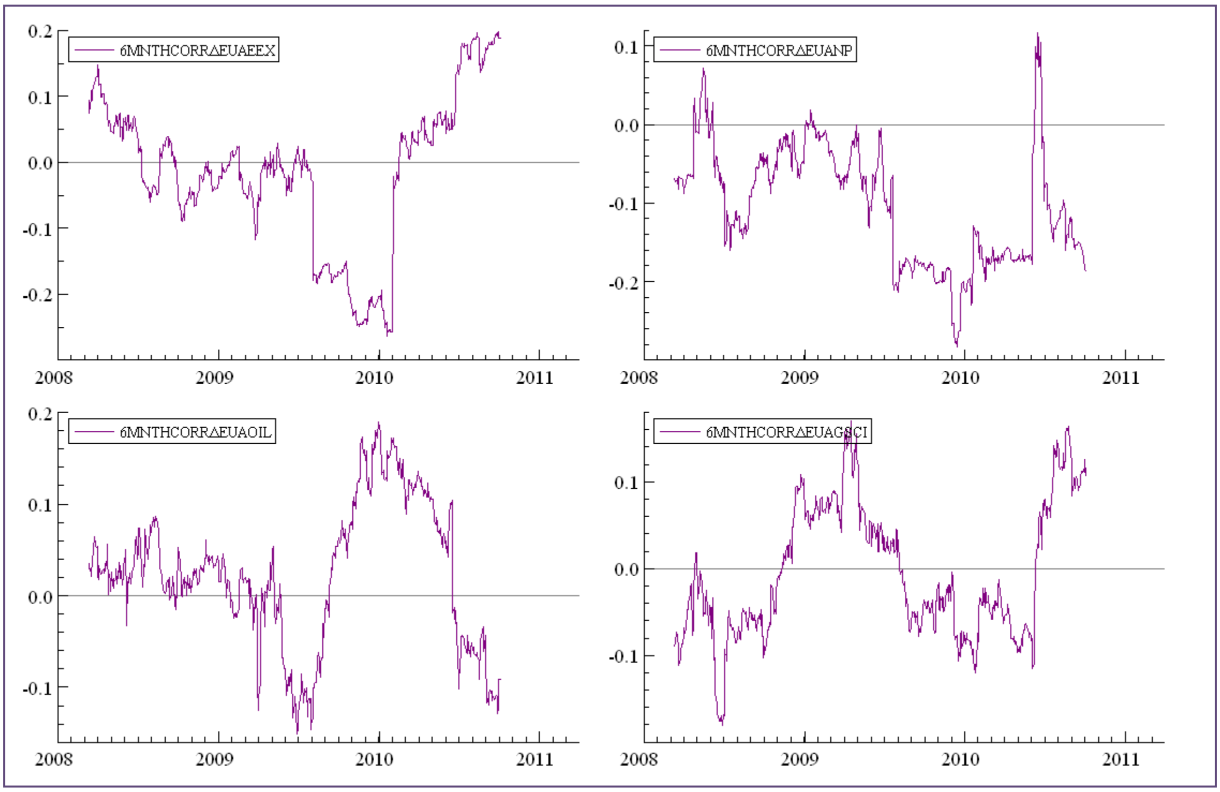


Figure 10: Moving correlations for periods of six months between ΔEUA and ΔEEX, ΔNordPool, ΔOil and ΔCommodity prices, 26.02.2008-01.04.2011

In contrast to what the moving correlations for the actual prices showed, we can see that moving correlation coefficients for percentage price changes are much lower than those for the actual prices, which is consistent with previous findings presented in Table 12 and Table 13. Interestingly, the graph for moving six-month correlations between ΔEUA and ΔOilSpot seem to be a somewhat inverted version of the graph for six-month correlations between EUA and OilSpot, whereas the other three markets seem to display similar patterns on price level and on percentage price change level.

Table 15 below summarizes lead-lag correlations for percentage price changes between EUA and EEX, NordPool, oil and commodities. These are, as expected, much lower than those for prices, but do not show a drastically different picture than what was shown previously in Table 13.

	ΔEUA_{t-1}	ΔEUA_{t-2}	ΔEUA_{t-3}	ΔEUA_{t+1}	ΔEUA_{t+2}	ΔEUA_{t+3}
ΔEEX	0.076	0.036	0.085	0.060	0.147	0.154
ΔNordPool	-0.009	-0.079	-0.030	0.151	-0.072	-0.056
ΔOilSpot	-0.007	0.012	0.063	-0.074	0.085	0.040
ΔGSCI	0.043	0.028	0.016	0.132	0.042	-0.132

Table 15: Lead-Lag Correlations between daily per cent price changes, EUA vs EEX, NordPool, OilSpot and GSCI for the period 26.02.2008-01.01.2009

Although there may be some evidence of higher correlations between 2008 and 2009 than for the rest of the period, a splitting of the period will not be utilized further in this thesis. The reason for this is twofold: First, the differences do not seem to be significantly large. Second, although correlations are marginally higher in this period, we can assume that they will not be useful for forecasting as this period is characterized as very unstable on a global basis, and until we can see stabilization in world prices and correlations between markets, using this period will not benefit us. A third possible factor that counts against using the period 26.02.2008-01.01.2009 further in this thesis is that the period is too short to base a forecasting model on, regardless of the fact that daily price data is available.

6.1.3 Regression Analysis between ΔEUA, ΔEEX, ΔNordPool, ΔOilSpot and ΔGSCI

Although correlation coefficients give insight as to whether or not a linear relationship is present between two variables, a regression analysis gives more insight as to whether or not there exists *causality* between the variables; i.e. whether or not and to what degree the variables affect each other. In order to do this, an Auto Distributive Lag (ADL) model is estimated as shown in the equation below:

$$Y_t = \sum_{i=1}^{N} \beta_i Y_{t-i} + \sum_{i=1}^{N} \delta_i X_{t-i} + \varepsilon_i$$

In the first four regressions, Y_t will represent ΔEUA and the independent variable Y_{t-i} will represent lagged values of ΔEUA. The other independent variable X_t will represent each different markets' ΔP as well as their lagged values. After this, regressions will be estimated for each market as the dependent variable Y_t, their lagged values being Y_{t-I} and ΔEUA with lags represented by X_t.

Regressions estimated with ΔEUA as the dependent variable

The first four regressions, the results of which are presented in the four tables below, the dependent variable Y_t = ΔEUA. The independent variables are listed under *variable* in the tables below.

Dependent Variable Y_t = ΔEUA

Variable	Coefficient	t-value
Constant	0.0006	0.7731
ΔEEX Lag 1	0.0143	0.2465
ΔEEX Lag 2	0.1073	1.8290
ΔEEX Lag 3	0.0421	0.7240
ΔEUA Lag 1	0.0944	2.628*
ΔEUA Lag 2	-0.1419	-3.981*
ΔEUA Lag 3	0.0815	2.274*
R^2	3.7 %	
Durbin-Watson	2.01	
N	777	

Dependent Variable Y_t = ΔEUA

Variable	Coefficient	t-value
Constant	0.0004	0.5201
ΔNordPool Lag 1	0.0230	2.8640*
ΔNordPool Lag 2	0.0195	2.3170*
ΔNordPool Lag 3	0.0050	0.6230
ΔEUA Lag 1	0.0999	2.7780*
ΔEUA Lag 2	-0.1332	-3.7280*
ΔEUA Lag 3	0.0879	2.4490*
R^2	4.3 %	
Durbin-Watson	2.01	
N	777	

Dependent Variable Y_t = ΔEUA

Variable	Coefficient	t-value
Constant	0.0007	0.8046
ΔOilSpot Lag 1	0.0306	1.1350
ΔOilSpot Lag 2	-0.0196	-0.7275
ΔOilSpot Lag 3	-0.0066	-0.2434
ΔEUA Lag 1	0.0987	2.7460*
ΔEUA Lag 2	-0.1411	-3.9480*
ΔEUA Lag 3	0.0854	2.3770*
R^2	3.3 %	
Durbin-Watson	2.01	
N	777	

Dependent Variable Y_t = ΔEUA

Variable	Coefficient	t-value
Constant	0.0006	0.7967
ΔGSCI Lag 1	-0.0163	-0.3917
ΔGSCI Lag 2	0.0553	1.3310
ΔGSCI Lag 3	0.0546	1.3140
ΔEUA Lag 1	0.0971	2.7060*
ΔEUA Lag 2	-0.1402	-3.9270*
ΔEUA Lag 3	0.0817	2.2770*
R^2	3.5 %	
Durbin-Watson	2.01	
N	777	

Table 16: Regression results, dependent variable: ΔEUA, Independent variables: lagged ΔEUA and lagged ΔP for each market, 26.02.2008-01.04.2011

Significant t-values are indicated by a star (*), which means that the corresponding coefficients are significant. As Table 16 displays, ΔEUA is significantly dependent on its own lagged Δ prices. In all four cases, these significant coefficients are positive for one and three lags, but negative for two lags. This means that a positive price change one and three days ago will indicate a positive price change today, and a positive price change two days ago will indicate a negative price change today.

Contradictory to our previous results, where we found the weakest connection between NordPool and EUA, the regression analysis with ΔNordPool as the independent variable shows significant values for both two and three lags. This is more than for any other regression. The coefficients for these two significant values are positive, also in contradiction to previous findings, indicating that positive movements in ΔNordPool two and three days ago will entail positive movements in ΔEUA.

The R^2 value for all four correlations is relatively low, indicating that only a very small amount of ΔEUA is explained by the variables in the regression. This means that we can assume that ΔEUA is explained by other variables than those included in the model. The Durbin-Watson test statistic is also included in order to find evidence of autocorrelation in the residuals, which is relevant as one of the OLS assumptions is that this does not exist. In our regressions, these values are all relatively close to 2, indicating that there is no autocorrelation.

Regressions estimated with ΔEEX, ΔNordPool, ΔOilSpot and ΔGSCI as dependent variables

Below, four additional regression analyses are estimated using the same ADL model as above. In this set of regressions, the dependent variable Y_t will represent each markets' percentage change in price, and the independent variables will be their own lagged ΔP as well as lagged ΔEUA prices. The results from these four regressions are presented below:

Dependent Variable Y_t = ΔEEX

Variable	Coefficient	t-value
Constant	9.99E-05	0.1898
ΔEUA Lag 1	0.0072	0.3209
ΔEUA Lag 2	0.0225	1.0180
ΔEUA Lag 3	0.0065	0.7705
ΔEEX Lag 1	0.1925	1.18E-07
ΔEEX Lag 2	0.1087	0.0029
ΔEEX Lag 3	0.0449	0.2136
R^2	6.7 %	
Durbin-Watson	1.99	
N	777	

Dependent Variable Y_t = ΔNordPool

Variable	Coefficient	t-value
Constant	0.0088	2.318*
ΔEUA Lag 1	-0.1941	-1.2080
ΔEUA Lag 2	-0.0758	-0.4746
ΔEUA Lag 3	-0.2558	-1.5960
ΔNordPool Lag 1	-0.3683	-10.270*
ΔNordPool Lag 2	-0.1873	-4.981*
ΔNordPool Lag 3	-0.0985	-2.739*
R^2	12.5 %	
Durbin-Watson	2.05	
N	777	

Dependent Variable Y_t = ΔOilSpot

Variable	Coefficient	t-value
Constant	0.0005	0.4020
ΔEUA Lag 1	0.0304	0.6407
ΔEUA Lag 2	-0.0611	-1.2930
ΔEUA Lag 3	0.0780	1.6440
ΔOilSpot Lag 1	0.0188	0.5259
ΔOilSpot Lag 2	-0.0455	-1.275
ΔOilSpot Lag 3	0.1235	3.457*
R^2	2.2 %	
Durbin-Watson	2.00	
N	777	

Dependent Variable Y_t = ΔGSCI

Variable	Coefficient	t-value
Constant	8.99E-05	0.1225
ΔEUA Lag 1	0.0235	0.7569
ΔEUA Lag 2	0.0258	0.8350
ΔEUA Lag 3	-0.0409	-1.3160
ΔGSCI Lag 1	-0.0415	-1.1540
ΔGSCI Lag 2	-0.0044	-0.1216
ΔGSCI Lag 3	0.0455	1.2630
R^2	0.8 %	
Durbin-Watson	1.99	
N	777	

Table 17: Regression results, dependent variable: ΔP for each market, Independent variables: lagged ΔEUA and lagged ΔP for each market, 26.02.2008-01.04.2011

Reversing the dependent and independent variables has produced the regression results presented in Table 17. Again, we can see that there are few significant coefficients, none at all for either ΔEEX or ΔGSCI, but with few for both ΔNordPool and ΔOilSpot, although these are with their own lagged values.

As with the previous set of regressions, the R^2 values are again relatively low, meaning that these models do not explain a large degree of price change in each of the markets. The Durbin-Watson values for all regressions are again relatively close to 2, indicating no autocorrelation.

6.2 Long-Term Analyses: Testing for Stationarity and Cointegration between EUA and Electricity, Oil and Commodity Prices

Evidence of cointegration between prices is a good indication of a long-term relationship. In order to test for cointegration, however, one must first ensure that the data sets are non-stationary. The data sets in this thesis are first tested for stationarity using an Augmented Dickey-Fuller test, and then the differences between EUA prices and each market are tested for stationarity using the same method. The t-values from these tests are displayed in the table below:

	t-values from ADF-test	
	constant	constant + trend
EUA	-1.416	-1.435
EEX	-1.446	-1.326
NordPool	-1.968	-2.225
OilSpot	-1.219	-1.005
GSCI	-0.845	-0.588
ln_EUA	-1.579	-1.610
ln_EEX	-1.358	-1.170
ln_NordPool	-1.950	-2.189
ln_OilSpot	-1.478	-1.388
ln_GSCI	-0.943	-0.830

Table 18: t-values of ADF-test for all markets and daily log prices, 26.02.2008-01.04.2011 (excluding no-trade period)

None of the t-values in Table 18 are significant, indicating non-stationarity. Log prices for all markets were also tested for stationarity, but there were no significant t-values for these series either. This means that the mean and variance of the data does not change over time, entailing that we can test for cointegration.

If the markets are cointegrated, we can conclude that there is a long-term relationship between them. In order to test for this, differences between two markets are calculated and then tested for stationarity using the ADF-test. Here, differences between log prices are also utilized in order to see whether stationarity can be uncovered on log level. The results from these tests for are presented in Table 19 below.

	t-values from ADF-test	
	constant	constant + trend
Diff EEX_EUA	-1.907	-1.853
Diff NP_EUA	-2.002	-2.577
Diff OIL_EUA	-1.332	-1.221
Diff GSCI_EUA	-0.845	-1.617
Diff lnEEX_lnEUA	-2.640	-3.122
Diff lnNP_lnEUA	-1.921	-2.694
Diff lnOIL_lnEUA	-2.298	-3.163
Diff lnGSCI_lnEUA	-1.898	-3.292

Table 19: t-values from ADF-test of differences between markets, 26.02.2008-01.04.2011 (excluding no-trade period)

Again, none of the t-values are significant, indicating that there is no cointegration between the EUA market and either of the two electricity markets, oil or commodity markets. We can therefore not assume any long-term relationships between these markets when using the whole period from 26.02.2008-01.04.2011. Below, the graphical representation of the differences between markets is shown.

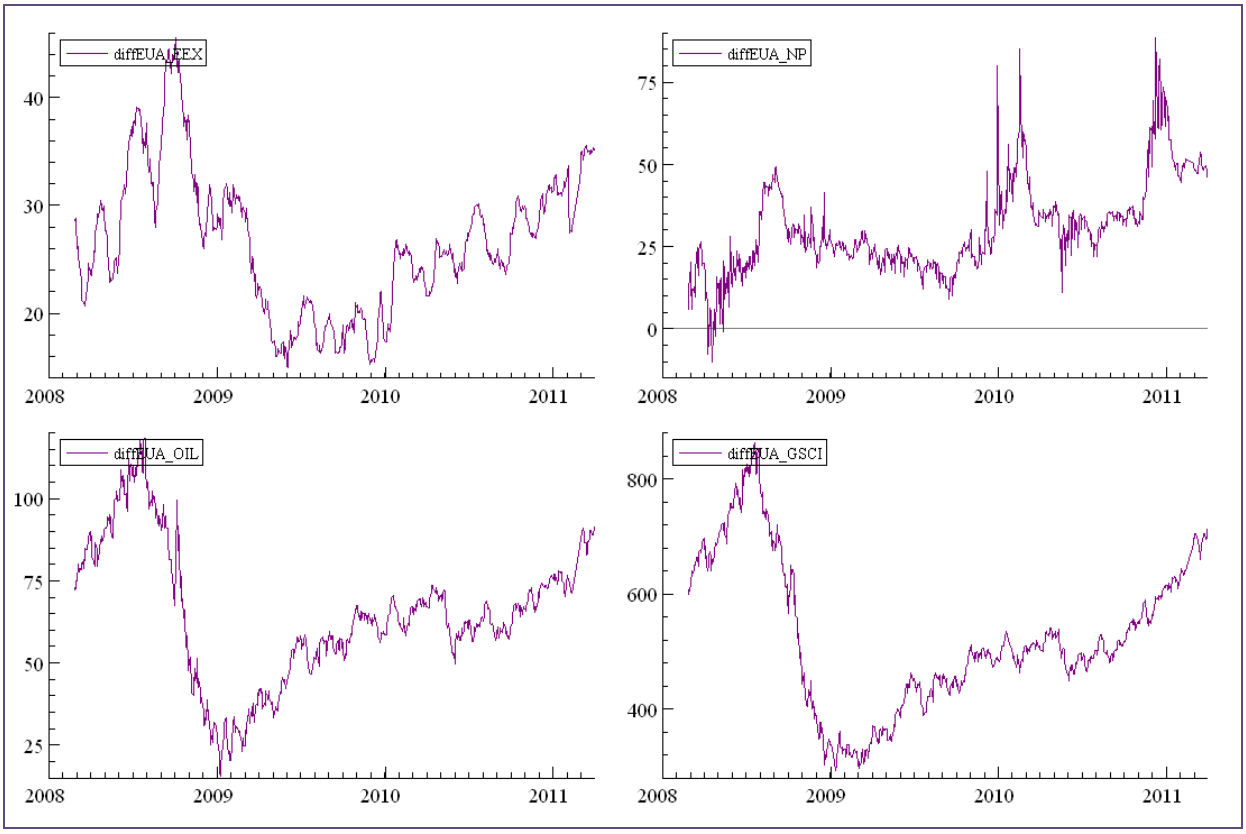


Figure 11: Graphical representation of differences between EUA and EEX, NordPool, OilSpot and GSCI 26.02.2008-01.04.2011 (excluding no-trade period)

The beginning of this period, from 26.02.2008 and until the beginning of 2009 displays large differences between the price of EUAs and the price of electricity on EEX, as well as oil and commodity prices. NordPool, however, displays quite different and erratic behavior and it seems that the difference between EUA and NordPool have become larger since the end of 2009. Interestingly, the other three markets seem to be moving similarly since the start of 2009, presumptively as a result of the world economy stabilizing after the global financial crisis.

It is therefore interesting to see whether there can be found any long-term relationships between EUA and EEX, NordPool oil and commodity prices if only the period from 15.01.2009-01.04.2011 is included in the analysis. Using the same method as above, the differences between the markets are tested for stationarity in order to uncover whether or not they are cointegrated. The t-values from these tests are presented below:

	t-values from ADF-test	
	constant	**constant + trend**
Diff EEX_EUA	-1.260	-2.740
Diff NP_EUA	-1.628	-2.481
Diff OIL_EUA	-1.618	-3.054
Diff GSCI_EUA	-0.248	-2.021
Diff lnEEX_lnEUA	-2.209	-2.481
Diff lnNP_lnEUA	-1.721	-2.151
Diff lnOIL_lnEUA	-3.480**	-4.228**
Diff lnGSCI_lnEUA	-2.939*	-3.788*

Table 20: t-values from ADF-test of differences between markets and differences between log market prices, 15.01.2009-01.04.2011 (excluding no-trade period)

One star (*) indicates significance with 95 per cent confidence, while two stars (**) indicate significance with 99 per cent confidence. The t-values in Table 20 display evidence of cointegration between lnOilSpot and lnEUA, as well as lnGSCI and lnEUA to a weaker degree. We can therefore conclude that there are long-term relationships between lnOil and lnCommodity prices and lnEUA prices.

7 Forecasting the EUA price

The ability to forecast future EUA prices based on information available today is interesting to traders as well as the around 12 000 companies operating under the EU ETS system. Traders buy and sell quotas, futures and swaps, and are commonly interested in short-term forecasting, on a daily or weekly basis. Having a forecast for the expected price on a short horizon will aid traders in decision-making.

Further, both power producers and other companies under the EU ETS system have an interest in forecasting of future EUA prices, but with a longer horizon. Having an impression of what the price will be in the future will aid in production planning as well as production investments. This means that these companies can easier plan when to purchase EUA quotas, or whether to invest in emissions-reducing measures instead.

This section is divided into three sections, each looking at a different time horizon. The first section concentrates on daily forecasts, meaning the accuracy of predicting the price one day ahead, the second on weekly and the third on monthly forecasts. In order to test the accuracy of the forecasting models, we will assume that today is 01.01.2011, and that the data from 26.02.2008 to this date is our observation period. The forecast is therefore based on the period from 26.02.2008-31.12.2010, and tested on the period from 01.01.2011-01.04.2011.

7.1 One-day EUA forecasting

The first forecast in this chapter is on a daily basis. In Table 21 (next page), daily forecasts, the actual price that date and errors are presented for the last 40 days of the data set, from 21.01.2011-01.04.2011.

1-step forecasts for EUA (SE based on error variance only)				
Horizon	**Forecast**	**Actual**	**Error**	**t-value**
21.01.2011	13.7037	13.7400	0.0362516	0.096
24.01.2011	13.7337	13.8400	0.106281	0.280
25.01.2011	13.8489	13.7500	-0.0988914	-0.261
26.01.2011	13.7341	13.9000	0.165932	0.438
27.01.2011	13.9293	14.1200	0.190704	0.503
28.01.2011	14.1191	14.2100	0.0909464	0.240
31.01.2011	14.1946	14.3800	0.185422	0.489
01.02.2011	14.4053	14.3200	-0.0852794	-0.225
02.02.2011	14.3180	13.9600	-0.357984	-0.945
03.02.2011	13.9620	14.0100	0.0479801	0.127
04.02.2011	14.0630	13.9000	-0.163047	-0.430
07.02.2011	13.8609	13.8900	0.0290644	0.077
08.02.2011	13.8812	14.1400	0.258839	0.683
09.02.2011	14.1542	14.1800	0.0258016	0.068
10.02.2011	14.1462	14.2500	0.103784	0.274
11.02.2011	14.2656	14.1500	-0.115642	-0.305
01.03.2011	14.1562	14.3500	0.193760	0.511
02.03.2011	14.3813	14.2700	-0.111317	-0.294
03.03.2011	14.2405	14.3000	0.0594665	0.157
04.03.2011	14.3168	14.3300	0.0131832	0.035
07.03.2011	14.3371	14.3400	0.00285930	0.008
08.03.2011	14.3332	14.5100	0.176763	0.466
09.03.2011	14.5230	14.5500	0.0270362	0.071
10.03.2011	14.5349	14.4600	-0.0749483	-0.198
11.03.2011	14.4606	14.4200	-0.0405946	-0.107
14.03.2011	14.4415	14.4900	0.0484837	0.128
15.03.2011	14.4951	14.5100	0.0149134	0.039
16.03.2011	14.4934	14.7000	0.206592	0.545
17.03.2011	14.7100	14.6900	-0.0200401	-0.053
18.03.2011	14.6723	14.8700	0.197656	0.522
21.03.2011	14.8942	14.8900	-0.00415165	-0.011
22.03.2011	14.8811	14.9800	0.0988793	0.261
23.03.2011	14.9917	14.8600	-0.131700	-0.347
24.03.2011	14.8536	14.8000	-0.0535797	-0.141
25.03.2011	14.8148	14.6600	-0.154768	-0.408
28.03.2011	14.6546	14.7100	0.0554114	0.146
29.03.2011	14.7149	14.8500	0.135106	0.356
30.03.2011	14.8377	14.9000	0.0623069	0.164
31.03.2011	14.8782	15.2000	0.321792	0.849
01.04.2011	15.2227	14.9900	-0.232685	-0.614

Mean (error) =	0.030265	**Root Mean Square Error =**	0.14146
SD (error)=	0.13818	**Mean Absolute % Error =**	0.78009

Table 21: Daily EUA forecasts, 21.01.2011-01.04.2011, based on daily prices 26.02.2008-20.01.2011.

The forecasts are based on a regression of EUA on itself with five lags using the data from 26.02.2008-21.01.2011, an AR(5) model. The model gives us a formula for what the price will be the next day based on the price of the previous five days, the estimates of which are presented below:

Variable	Coefficient	t-value
Constant	0.057	0.27
EUA Lag 1	1.061	28.8
EUA Lag 2	-0.171	-3.31
EUA Lag 3	0.178	3.31
EUA Lag 4	0.005	0.10
EUA Lag 5	-0.070	1.11
R^2	99.3 %	
N	737	

Table 22: AR(5) Regression estimates for daily EUA prices in observation period 26.02.2008-21.01.2011

From the regression results, we can see that the price from one day ago is relatively close to one, indicating that the price the next day will be relatively similar to the price one day before. The coefficients from two and five days ago have negative coefficients, meaning that a positive price these days will result in a negative movement in one day. We can see from the R^2-value that this model has relatively high explanatory factor for the future price one day ahead in time.

By looking at the root mean square error (RMSE) of 0.14146 and the mean absolute percentage error (MAPE) of 0.78009, we can see that the forecasts on a daily basis are relatively accurate. Further, we can look at the graphical representation of the forecasts vs. the actual prices, presented below.

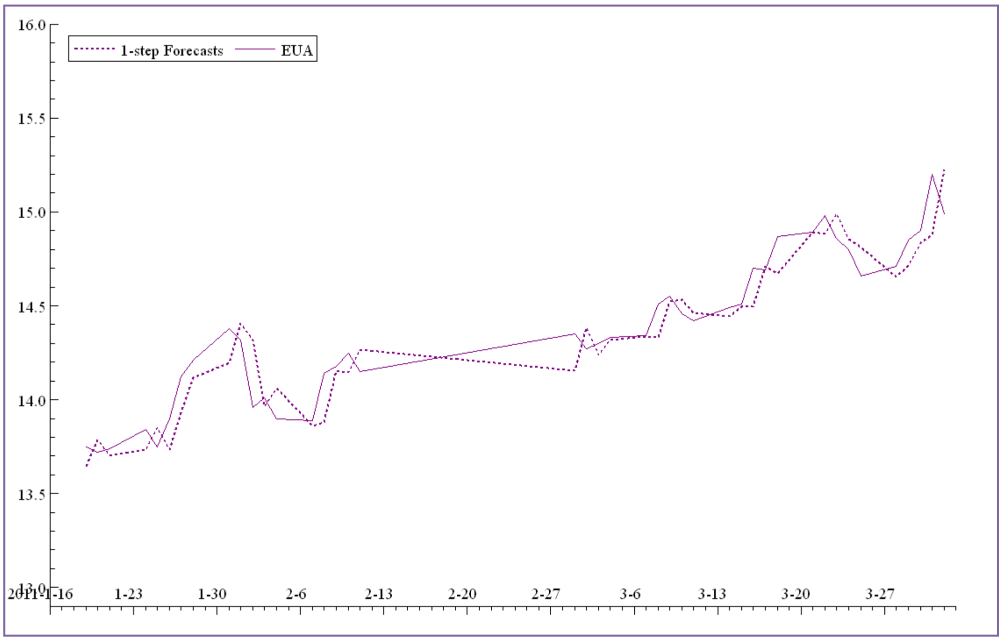


Figure 12: Daily EUA Prices and one-day Forecasts, 21.01.2011-01.04.2011.

The dotted line above represents the forecasted values, and the solid line represents the actual prices corresponding to the same date. We can clearly see that forecasts seem to react more slowly than the actual prices, reaching peaks and low points a day or so after the actual price.

Bringing other elements into the model may give more accurate forecasts. Using an ADL(3,3) model, forecasts were made for each combination of EUA and EEX, NordPool, oil and commodity prices with three lags each. Instead of presenting all forecasts for the last 40 days of data, a summary of mean and standard errors, RMSE and MAPE for all combinations with three lags are presented below:

	Mean Error	SD Error	RMSE	MAPE
EUA & EEX	0.020	0.158	0.159	0.881
EUA & NordPool	0.051	0.133	0.142	0.809
EUA & Oil	-0.062	0.136	0.150	0.842
EUA & GSCI	-0.099	0.138	0.170	0.954

Table 23: Mean errors, SD Errors, RMSE and MAPE from ADL(3,3) one-day forecasting between daily EUA prices and daily EEX, NordPool, oil and commodity prices, 40 forecasts 21.01.2011-01.04.2011, based on observation period 26.02.2008-01.01.2011.

Although the errors for the AR(3,3) model using NordPool are the smallest of the bunch, none of the errors in Table 23 are smaller than in the forecast using only EUA prices. Therefore, we can conclude that forecasting with five lags using only EUA prices is the most accurate.

Lastly, daily forecasts for the last 40 days of the data have been made using log prices of EUA. Regression estimates are presented below.

Variable	Coefficient	t-value
Constant	0.01398	0.14
Dlog EUA Lag 1	1.09053	0.00
Dlog EUA Lag 2	-0.22971	0.00
Dlog EUA Lag 3	0.21452	0.00
Dlog EUA Lag 4	-0.01577	0.77
Dlog EUA Lag 5	-0.06481	0.08
R^2	99.1 %	
N	737	

Table 24: AR(5) Regression estimates for daily log EUA prices in observation period 26.02.2008-21.01.2011

As seen with the actual price level, with log prices, the coefficient for the price one day earlier is relatively close to one. We can also see that a positive price from two, four and five days ago have a negative impact on today's price, because these have negative coefficients. Interestingly, the R^2-value is slightly lower than when using the actual price series rather than dlog prices.

The summary of errors is presented in Table 25. These are the lowest of all the one-day forecasts tested, implying relatively accurate forecasts of log prices for the one day ahead in time.

	Mean Error	SD Error	RMSE	MAPE
Dlog EUA	0.002	0.010	0.010	0.296

Table 25: Mean errors, SD Errors, RMSE and MAPE from AR(5) model for log EUA prices, 40 forecasts 21.01.2011-01.04.2011, based on observation period 26.02.2008-01.01.2011.

Graphically, the one-day forecasts of log EUA prices appear to be closer to the actual prices, as seen below:

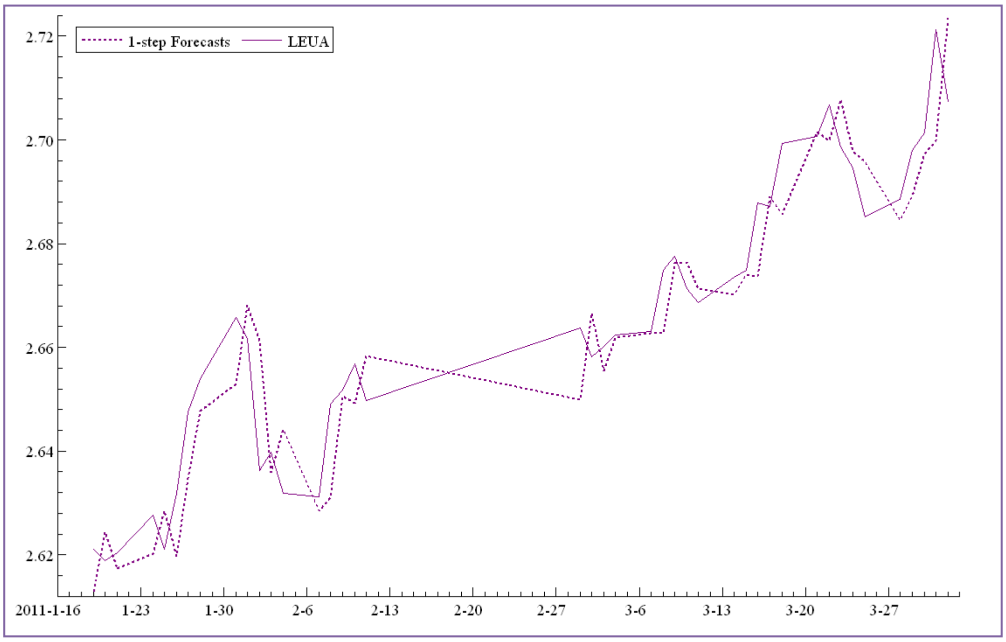


Figure 13: Daily log EUA Prices and one-day Forecasts, 21.01.2011-01.04.2011, based on observation period 26.02.2008-01.01.2011.

We can see in Figure 13 that the prices and forecasts seem to be moving more similarly than in the previous example, confirming that the forecast is more accurate when using log prices than actual prices. We can therefore assume that predicting price changes is more accurate than predicting prices.

7.2 One-Week EUA Forecasting

Although one-day ahead forecasting has proved relatively accurate in the previous section, being able to predict the price the next day does not have much use in practice. Therefore, a series of forecasts are made for one week ahead in time, using both an AR(5) model for lagged EUA prices, and ADL(3,3) models for a combination of EUA prices and each of EEX, NordPool, oil and commodity prices.

Forecasts are made for prices in five days (weekends are not included in the data), first using actual prices. The regressions are the same as above as it is the same regression, but the forecast is instead for the future price in five days based on the price the previous five days.

We can generally expect that the deviations will increase with longer forecast periods, as there tends to be more insecurity the longer into the future we attempt to estimate. Rather than presenting forecasts for each observation and its deviation, the errors for EUA price forecasts and log EUA price forecasts are summarized in the table below.

	Mean Error	SD Error	RMSE	MAPE
EUA	0.14642	0.24508	0.28549	1.6404
Dlog EUA	0.01000	0.01716	0.01987	0.6153

Table 26: Mean errors, SD Errors, RMSE and MAPE from AR(5) model of one-week forecasts of EUA and dlog EUA prices, 40 forecasts 21.01.2011-01.04.2011

We can see that the general level of the various errors is higher than with one-day forecasting, but again that the errors seem to be smaller when using log EUA prices rather than the actual price series. When examining the graphical representation of the forecasts versus actual prices during the period, shown in Figure 14, we again see a tendency towards forecasts reacting too slowly to price changes. At the same time, there may be periods where forecasts and actual prices move in opposite directions; the estimate moving downwards where the actual price increases.

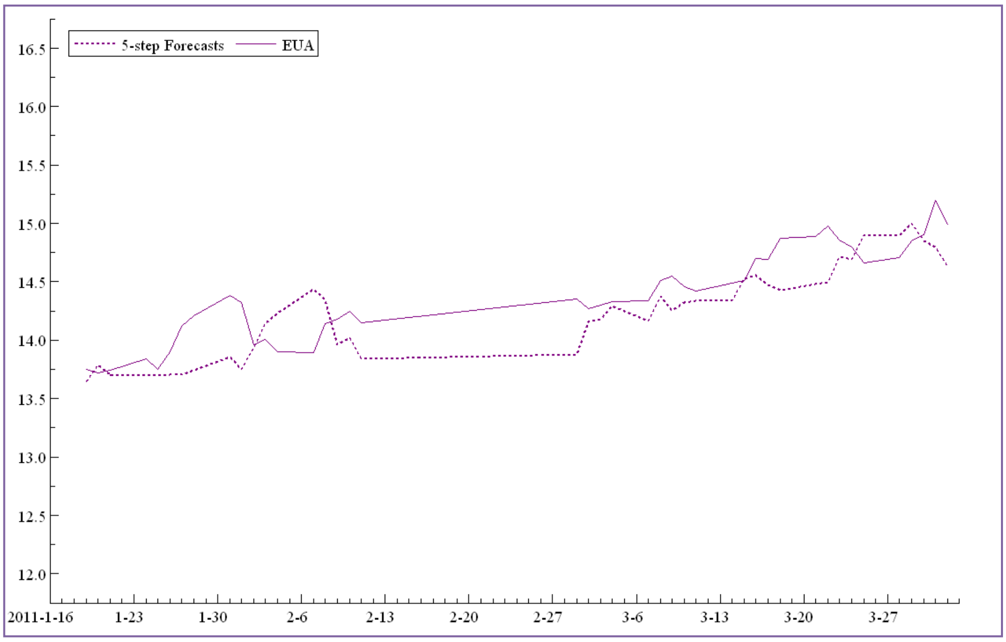


Figure 14: Daily EUA Prices one-week Forecasts, 21.01.2011-01.04.2011, based on observation period 26.02.2008-01.01.2011.

Compared to Figure 12 displaying the corresponding graph for one-day forecasts and EUA prices, one can clearly see that there is greater distance between estimates and actual prices for one-week forecasts. This illustrates the point of longer time horizons and corresponding more uncertainty resulting in larger discrepancies.

As above, forecasts have been made using ADL(3,3) models for each combination of EUA and EEX, NordPool, oil and commodity prices. These forecasts have been tested and the standard errors presented below. Again, we can see that the errors are larger when including longer forecast periods and other markets, and we can see that forecasts using only EUA prices and its own lags are more reliable.

	Mean Error	SD Error	RMSE	MAPE
EUA & EEX	0.09537	0.30058	0.31535	1.7365
EUA & NordPool	0.23807	0.22800	0.32964	1.9366
EUA & Oil	-0.26902	0.24434	0.36342	2.0940

EUA & GSCI	-0.43949	0.27921	0.52069	3.0961

Table 27:Mean errors, SD Errors, RMSE and MAPE from ADL(3,3) one-week forecasting between daily EUA prices and daily EEX, NordPool, oil and commodity prices, 40 forecasts 21.01.2011-01.04.2011, based on observation period 26.02.2008-01.01.2011.

Forecasting using log EUA prices has proven to be more reliable for one-day forecasts, and from the errors in Table 26 this seems to be the case for one-week forecasting as well. Although the errors are relatively small, they are notable higher for one-week forecasts than for one-day forecasts. When examining the graphical representation below and comparing it to the corresponding graph for one-day forecasts (Figure 13), the discrepancies are clearly larger.

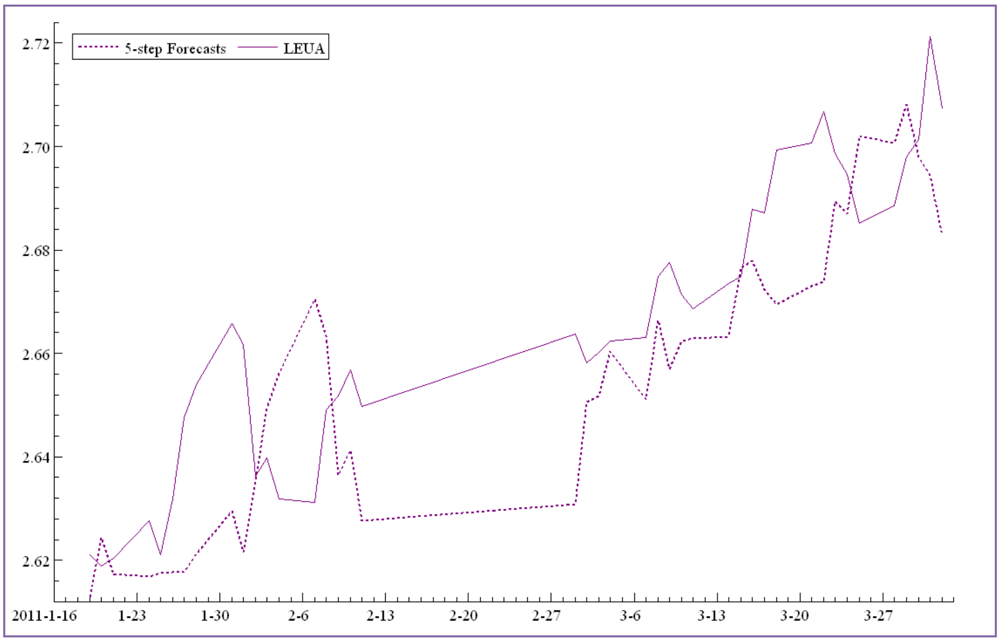


Figure 15: Daily log EUA Prices one-week Forecasts, 21.01.2011-01.04.2011, based on observation period 26.02.2008-01.01.2011.

Although the differences between forecasts and prices seem to be large in the figure above, it is important to keep in mind that the errors are in reality relatively small. One-day forecasting will naturally be more accurate because of the small time interval, but this one-week forecast is relatively reliable.

7.3 One-Month EUA Forecasting

This final section regarding forecasting considers a range of forecasts in an attempt to see whether the price one month in the future can be estimated with any accuracy. The observation period has been shortened in order to allow for a greater period for testing the forecast, and has been adjusted so that it ranges from 26.02.2008-21.12.2010.

Following the same structure as above, AR(5) regressions have been estimated for EUA and log EUA prices, because the observation period has been shortened by twenty days. The coefficients of this estimation are:

Variable	Coefficient	t-value
Constant	0.06131	2.24
EUA Lag 1	1.06136	27.6
EUA Lag 2	-0.18017	-0.72
EUA Lag 3	0.18046	0.62
EUA Lag 4	0.00398	0.06
EUA Lag 5	-0.06980	-0.54
R^2	99.3 %	
N	717	

Variable	Coefficient	t-value
Constant	0.01448	1.50
Dlog EUA Lag 1	1.09135	29.2
Dlog EUA Lag 2	-0.23275	-4.20
Dlog EUA Lag 3	0.21758	3.92
Dlog EUA Lag 4	-0.01787	-0.32
Dlog EUA Lag 5	-0.06369	-1.70
R^2	99.1 %	
N	717	

Table 28: AR(5) Regression estimates for daily EUA prices and log EUA prices in observation period 26.02.2008-21.01.2011

We can see the same pattern as with an observation period twenty days shorter. The first lag has a coefficient relatively close to one, meaning that the price the next day will be relatively similar to the price one day ago. On price level, we see that coefficients for two and five days ago have negative coefficients, and on dlog level the same can be said for the price two, four and five days ago.

Again, these models have been tested for accuracy of prediction thirty days ahead in the period 21.12.2010-01.04.2011, and the error values calculated:

	Mean Error	SD Error	RMSE	MAPE
EUA	-0.21814	0.69788	0.73118	4.5428
Dlog EUA	-0.01551	0.04748	0.04994	1.6616

Table 29: Mean errors, SD Errors, RMSE and MAPE from AR(5) model of one-month forecasts of EUA and dlog EUA prices, 60 forecasts 21.12.2010-01.04.2011

The errors for one-month predictions are, not surprisingly, higher than for both one-day and one-week forecasts. Usually, forecasting models become more reliable with longer observation periods, and as the EUA market is relatively young, it may swing more frequently and dramatically than most other more established markets, making forecasting more challenging.

The graph for one-month forecasts using EUA price levels is shown in Figure 16.

Figure 16: Daily EUA Prices one-month Forecasts, 21.12.2010-01.04.2011, based on observation period 26.02.2008-01.12.2011.

The degree of uncertainty in future prices thirty days into the future becomes more apparent when looking at the graphical representation, which displays large discrepancies between our predicted price and the actual price on the same day. At the most, there seems to be a price difference of about €1.25, which may seem marginal but becomes rather substantial when large numbers of quotas are traded.

Again, forecasting using other markets in conjunction with the EUA market has been explored in an attempt to obtain a more reliable model using more established and mature markets. The errors from these forecasts are presented below.

	Mean Error	SD Error	RMSE	MAPE
EUA & EEX	-0.41694	0.53813	0.68076	3.9371
EUA & NordPool	0.27793	0.65036	0.70726	3.8264
EUA & Oil	-1.6841	0.57236	1.7787	11.793
EUA & GSCI	-2.4775	0.84129	2.6164	17.300

Table 30: Mean errors, SD Errors, RMSE and MAPE from ADL(3,3) one-month forecasting between daily EUA prices and daily EEX, NordPool, oil and commodity prices, 60 forecasts 21.12.2010-01.04.2011, based on observation period 26.02.2008-21.12.2010.

Although the mean error and standard deviation errors for oil prices seem to be smaller than in the AR(5) model for lagged EUA prices, the RMSE and MAPE values are much larger, indicating larger discrepancies. In any case, none of these errors are smaller than forecasts using log EUA prices, which, although are large, seem to be the most reliable values to use in a one-month forecast. See Figure 17 for a graphical representation of this forecast.

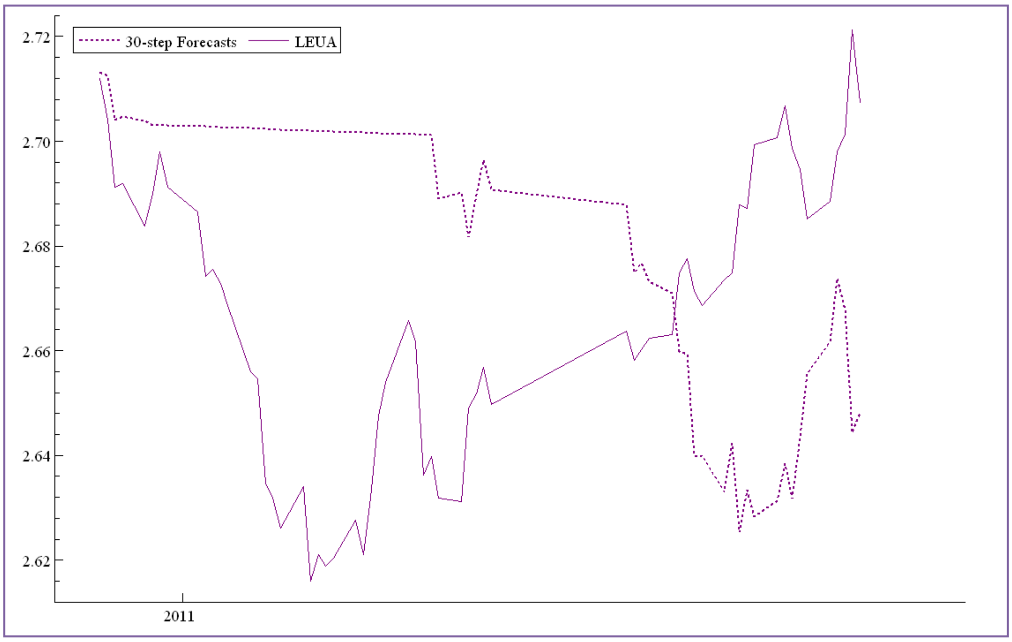


Figure 17: Daily log EUA Prices one-month Forecasts, 21.12.2010-01.04.2011, based on observation period 26.02.2008-01.12.2011.

Comparing this graph to those for one-day and one-week forecasts, it becomes apparent that the differences between forecasted values and actual values are rather large. Still, there may be some relevance in using this forecast for future prices as long as one takes into consideration there may be some differences between forecasted and actual log EUA prices.

For EUA prices, considering relevance and accuracy, it seems that one-week forecasts can be made with relative reliability. Although the errors for one-day forecasts imply fewer and less dramatic deviations, most traders will trade using a slightly longer time horizon.

7.4 Conclusions: Forecasting the EUA Price

When attempting to use historical EUA prices in order to predict future EUA prices, we can clearly see that the accuracy of such forecasts is highly dependent on how long into the future one is trying to forecast the price. Using other markets such as power or commodity prices to aid in forecasting the EUA price proved to be less accurate than only using the EUA price.

Although a relatively successful forecasting model has been found above, there seems to be a trade-off between accuracy and forecasting period. Generally, having the ability to forecast a price longer into the future is more beneficial to traders and players in the EUA market than being able to estimate the future price tomorrow. It is therefore important for this involved in EUA trade to approach this and other forecasting models with some caution as there tends to be rather large inaccuracies in a model based purely on historical prices. Generally, keeping up to date on world news and analyzing possible effects of this on the EUA price may well be more accurate than a statistical forecasting model.

8 Event Studies in the EUA Market

The EUA market is relatively young and immature market, having a history of only six years. One characteristic of immature markets such as this is that statistical structures tend to be inadequate for analysis and forecasting. Another is that these markets tend to react sharply to world events, and where more mature markets may absorb or adjust to new information, such underdeveloped markets may experience large and erratic shocks.

The purpose of this chapter is to uncover whether or not specific world events have had an effect on the EUA market. It will attempt to analyze specific price relationships around major events which have taken place in recent world news. The first of these events is the hacking scandal, where the central registries were hacked into and carbon units stolen. Next, the world saw a colossal price hike in the crude oil market. The final world event explored in this chapter is the aftermath of the earthquake in Japan on the 11th of March 2011, specifically the announcement by Germany's Prime Minister Angela Merkel that a number of the nuclear power plants in the countries would be shut down.

8.1 EUA Hacking Scandal and its effects on the price of EUAs

On the 19th of January 2011, BlueNext launched the "Safe Harbour Initiative" and suspended all spot trading of EUAs in order to counter the effect of stolen carbon registries. The central registries were hacked into and carbon units from Romania, Czech Republic, Greece, Italy and Austria were stolen. During the suspension, BlueNext received confirmed lists of contract serial numbers and put in place a filtration system to remove the stolen quotas from the market. Two weeks later, on February 4th, the market was opened again, and trading resumed (Financial Times, 2011).

To examine the effect of the cyber-theft of quotas, the daily EUA price is visually represented below. As there are no values for the no-trade period, this comes up as a straight line on the graph, and is represented by two vertical black lines. We can clearly see that the period following the reopening of trade saw a dramatic increase in price, and that the period directly before was subject to a price drop, assumingly as a result of the cyber-theft.

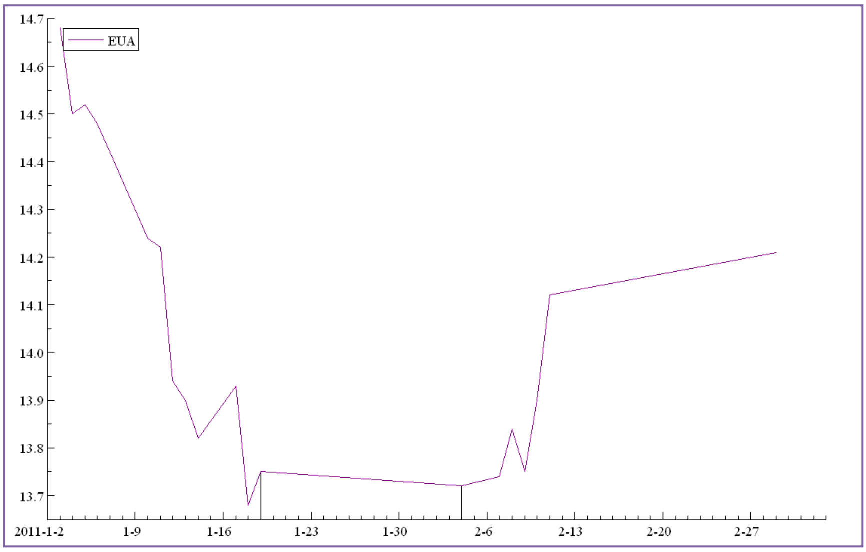


Figure 18: Daily EUA prices 15.01.2011-01.03.2011

Relating this event to the EEX market, we can see that the hacking scandal appears to have had similar effects on European electricity prices during the same period. Again, the no-trade period is between the vertical black lines.

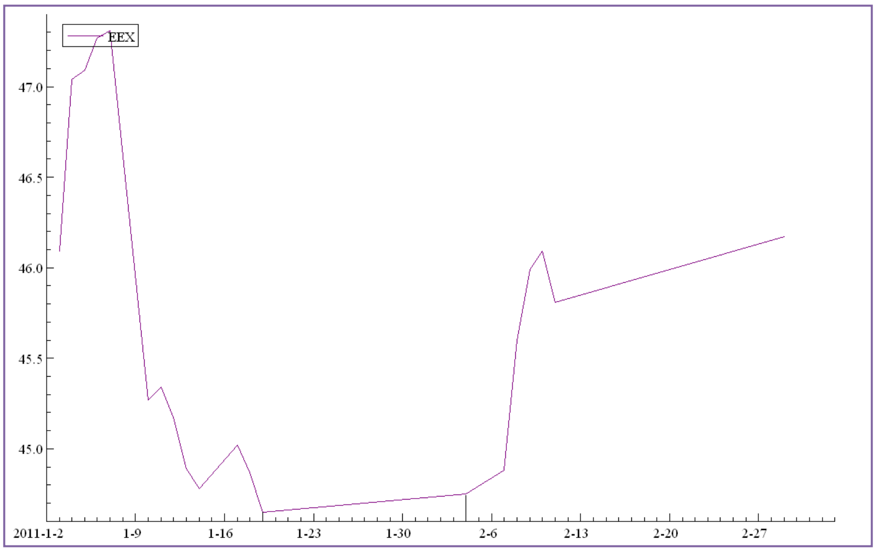


Figure 19: Daily EEX prices 15.01.2011-01.03.2011

What we can clearly see is that the electricity market in Europe seems to move in a similar pattern to EUA prices. Interestingly, on the date of the reopening of trade of EUAs, the price increase seems to be much more dramatic than for EUAs themselves.

Next, the $\left[\frac{EUA}{EEX}\right]$ relationship has been calculated and graphed in order to see how the interaction of prices has behaved during this period. This is to see whether they have moved in similar or opposite directions.

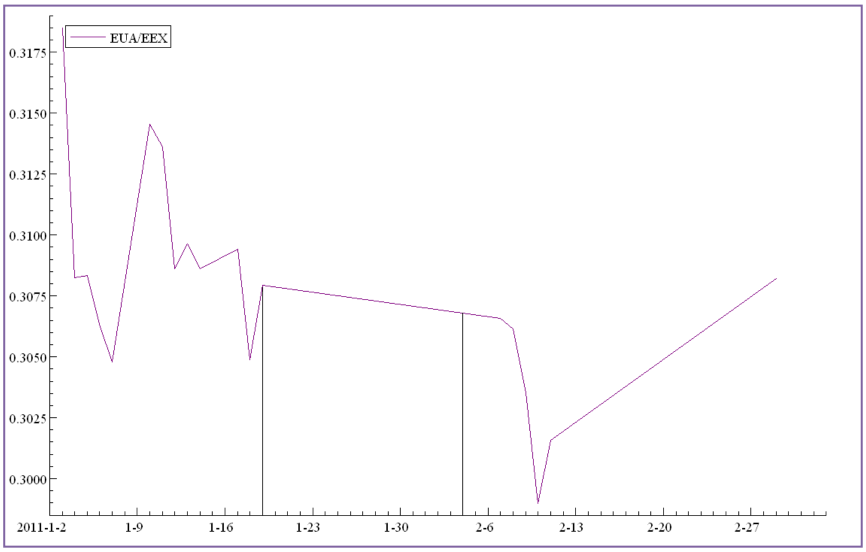


Figure 20: Daily $\frac{EUA}{EEX}$ prices, 15.01.2011-01.03.2011

The graph above shows us that there seems to be some disagreement between the two prices in the periods before and after the no-trade period. The downward pattern that seemed similar in Figure 19 and Figure 20 appears now to be quite different, and the prices seem to swing closer and further apart to a greater degree than previously thought. The price increase after the no-trade period seems to be timed differently for the two markets, but from around the 12th of March 2011, the prices seem to stabilize. This indicates that the hacking scandal and Safe Harbour Initiative only temporarily shocked the system, but that the prices have since stabilized until the next large event.

8.2 Crude Oil Price Hike and its effects on the price of EUAs

Early 2011 saw a great deal of instability worldwide, while some European nations, most notably Greece, still struggled with the aftermath of the financial crisis. At the same time, there was a great deal of unrest in the Middle Eastern area, namely in Libya, Egypt and Tunisia. The subsequent revolutions had a dramatic effect on oil prices, which globally experienced a sharp increase in a short time period around April 2011. Figure 21 below, from the US Energy Information Administration website, clearly shows the price increase around April-May, moving out of and above the average price range.

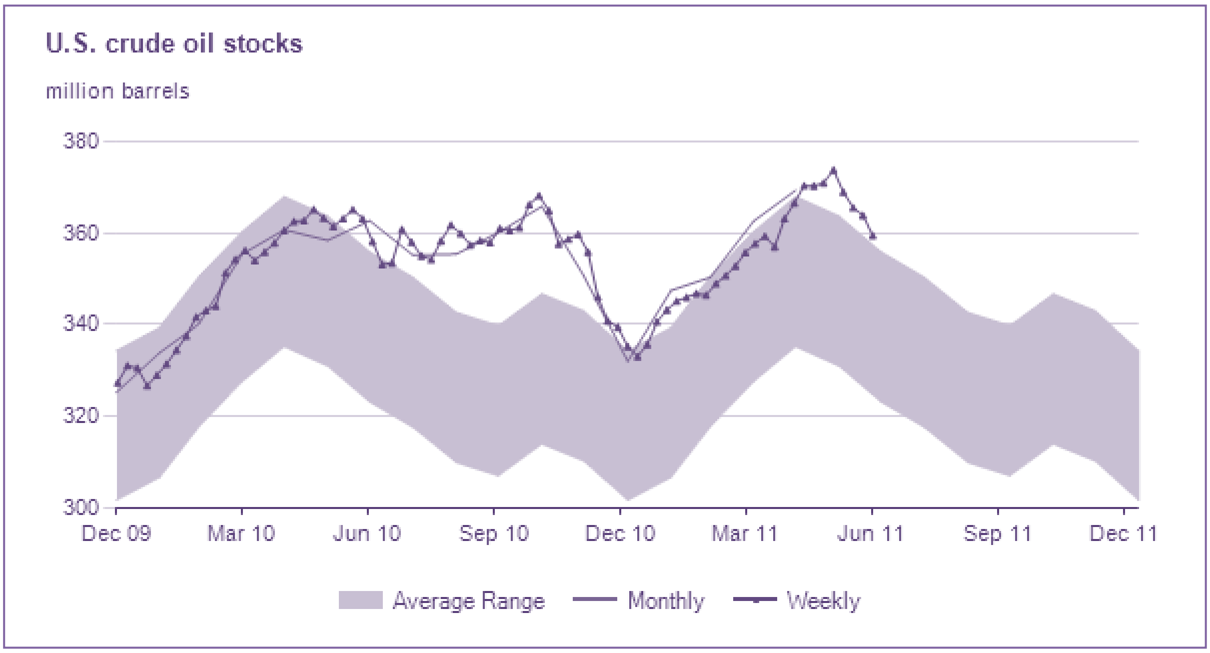


Figure 21: US Crude Oil Stock, Dec 09-June 11 (US Energy Information Administration, 2011)

Data from February 2011 to the end of June 2011 has been extracted, and below is a graphical representation of the period from 01.02.2011-21.06.2011. Particularly interesting is the period from early Februray until the beginning of March, where the oil price appears to have increased dramatically, from around 85 US Dollars to around 105 US Dollars in a matter of days.

A possible explanation of this development may be the resignation of President Mubarak of Egypt on February 11th 2011, as a result of what is now referred to as the Egyptian Revolution (BBC News, 2011). This was the first of a series of uprisings in the area, particularly in Libya, disrupting between a third and half of the nation's oil exports.

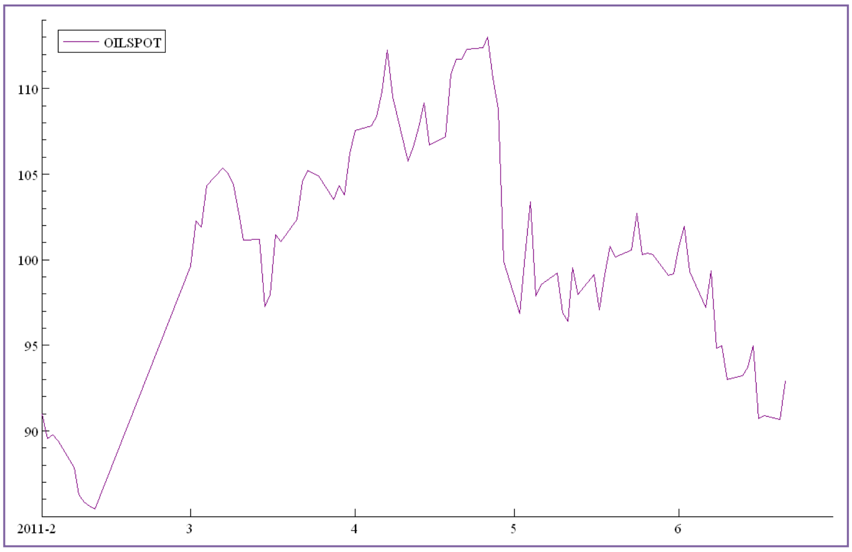


Figure 22: Daily oil spot prices, 01.02.2011-21.06-2011

What is interesting for this thesis is to see whether we can see this development reflected in the EUA price. Therefore, daily EUA prices are graphed for the same period as the oil price, and presented below.

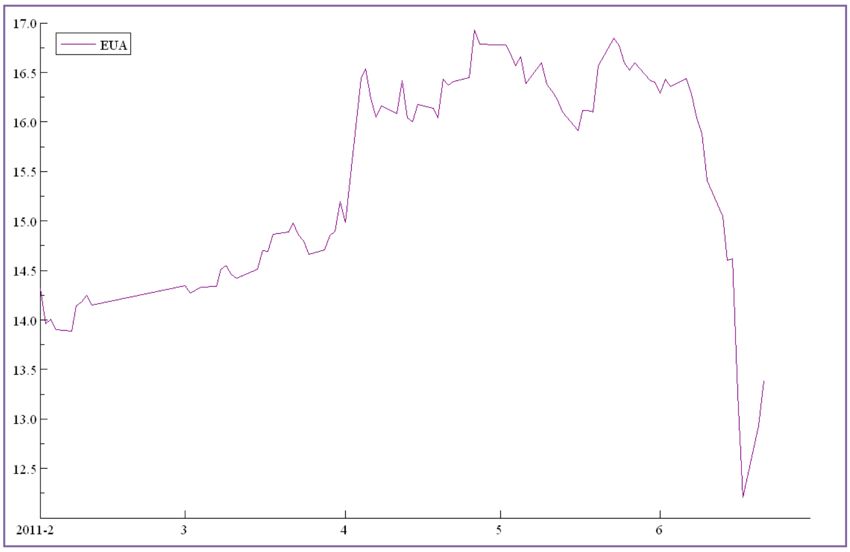


Figure 23: Daily EUA prices 01.02.2011-21.06-2011

Comparing the shape of the two graphs, appear to have different patterns. It seems that the price of EUAs took some time to react to the oil price increase, with a jump upwards in the beginning of April 2011. We can further see evidence of a delayed reaction to the oil price where the EUA price sees a dramatic decrease around early- to mid-May 2011, around a month after the oil price saw a similar decrease. Further, the drop in EUA prices seems to be more dramatic than the drop in oil prices, signaling that the EUA market is more sensitive to decreases in oil prices rather than increases in oil prices. This may signal skepticism in the EUA market, where anxious EUA traders react dramatically to even relatively small drops in oil prices.

Only looking at the graphical representations does not give us a satisfying picture of how these two price series interact during this period. Therefore, in order to get a more realistic picture of how the two relate to each other, the [OilSpot-EUA] and $\left[\frac{OilSpot}{EUA}\right]$ growth rates are plotted, and can be seen below.

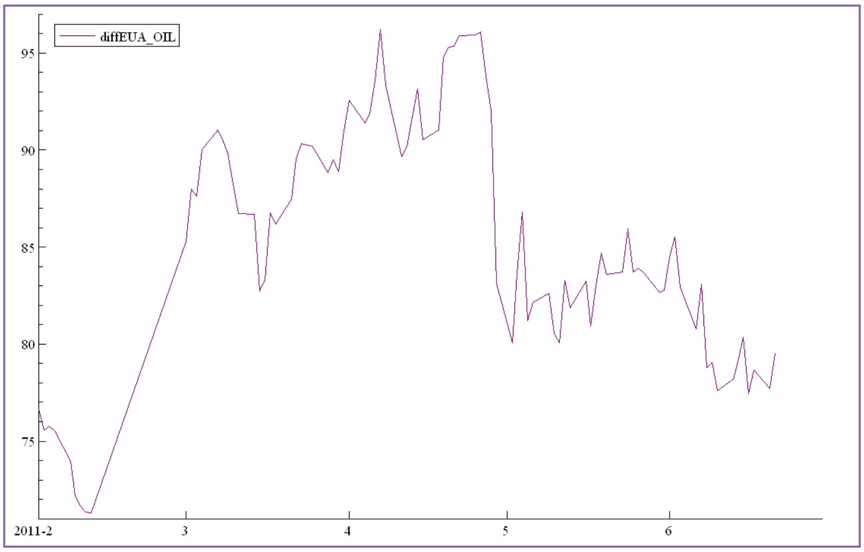


Figure 24: Daily EUA-OilSpot prices, 01.02.2011-21.06.2011

The purpose of plotting the differences is to determine whether the prices deviate more or less from each other in the period from mid-February to the beginning of March. Clearly, the differences between the two series are increasingly large in the period in question, again indicating that the oil price hike did not have a significant effect on the EUA price.

Lastly, the $\left[\frac{OilSpot}{EUA}\right]$ relationship is graphed for the same period, and we can see that Figure 25 tells the same story as Figure 24. The closer the relationship moves towards one, the more similar they are in that period. The price hike clearly shows that the prices move distinctly away from each other, indicating that the oil price hike was not significantly noticed on the EUA market.

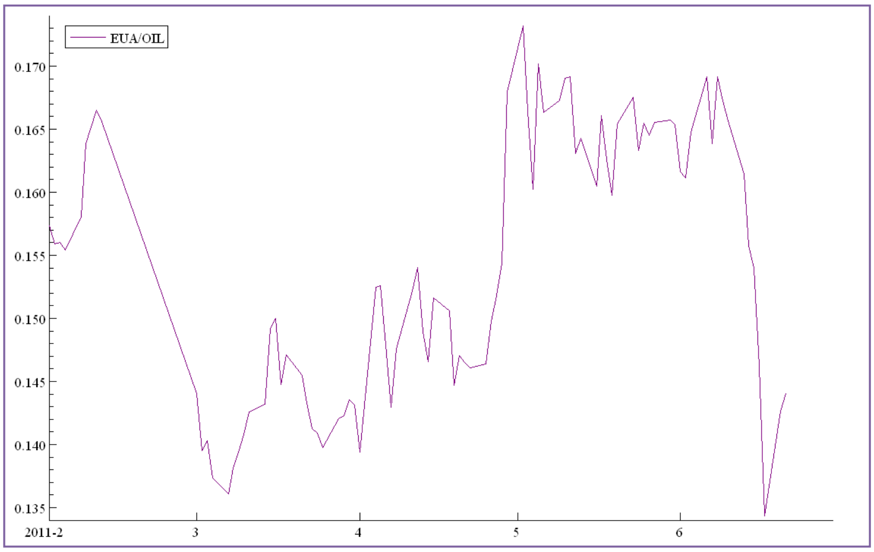


Figure 25: Daily $\frac{\text{OilSpot}}{\text{EUA}}$ prices, 01.02.2011-21.06.2011

8.3 The Aftermath of the Japan Earthquake and the Announcement of Suspension of Nuclear Power Plants in Germany and its effects on the price of EUAs

On Friday, the 11th of March 2011, an earthquake off the northeastern coast of Japan, measuring 9.9 on the Richter's scale, caused severe devastation to this island nation. A ten meter tall tsunami washed onto land and took with it an unknown number of casualties and causing massive destruction. In the days after the quake, it became clear that many of the country's nuclear facilities had been destroyed, and international media described the situation as a potential new Tschernobyl catastrophe. A few days later still, the country faced unusually late snow and low temperatures. With the main source of electricity out of order, the world grew anxious about the future of Japan and its people.

In the days after the earthquake, the Nikkei index experienced a drop in prices, along with most other Asian stock markets. Table 31 shows this trend, where most central Asian stock markets have experienced a decrease in prices (Dagens Næringsliv, 2011).On March 17th, the Japanese yen hit its strongest level against the US dollar since the end of World War 2 (BBC, 2011). At the same time, gas prices experienced a shock effect following the closing of four nuclear power plants in Japan and seven in Germany. This shock on gas prices is the result of Japan having to replace its nuclear power with gas (Dagens Næringsliv, 2011).

Central Market Indexes		
Nikkei 225 (Japan)	8 962,67	-1,44 %
Topix (Japan)	810,8	-0,83 %
Kospi (South Korea)	1 959,03	0,05 %
Taiex (Taiwan)	8 282,69	-0,50 %
Straits Times (Singapore)	2 940,18	-1,00 %
Shanghai Composite (China)	2 896,87	-1,16 %
Shenzhen Composite (China)	1 285,96	-1,65 %
Hang Seng (Hong Kong)	22 259,15	-1,90 %
Mumbai Sensex 30 (India)	18 282,42	-0,55 %
S&P/ASX 200 (Australia)	4 555,30	-0,06 %

Table 31: Central Market Indexes, data collected 07:54 17.03.2011

Applying this knowledge to this case, and particularly concentrating on how the market has reacted to Germany's announcement of shutting down its nuclear power plants, we can see whether and how the earthquake indirectly has affected the EEX and EUA markets. This analysis concentrates on the period around March 15th 2011, the date of the announcement and immediate shut-down of seven plants. The first graph shows the daily EEX prices from 1st of March 2011 until the 20th of April 2011. The black vertical line represents the 15th of March.

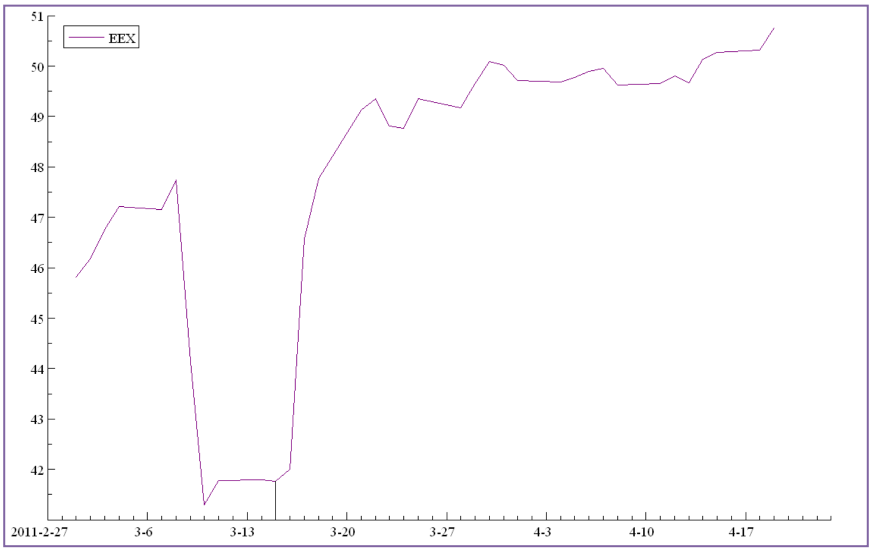


Figure 26: Daily EEX prices 01.03.2011-20.04.2011

Here, we can see a dramatic increase in EEX prices in the days following the announcement. It appears that the realization of the impact of this decision took about one day to set in, but after about four days of dramatic increase, it seems that the European electricity price stabilized at a new, higher price.

Below is the graph for the same period for EUAs. Again, March 15th is indicated with a black vertical line. We can see that the price of EUAs increased in the days following the announcement, but it appears to have taken longer to fully react to the announcement. This is evident from the fact that a dramatic increase in price is not seen before around the 20th of April.

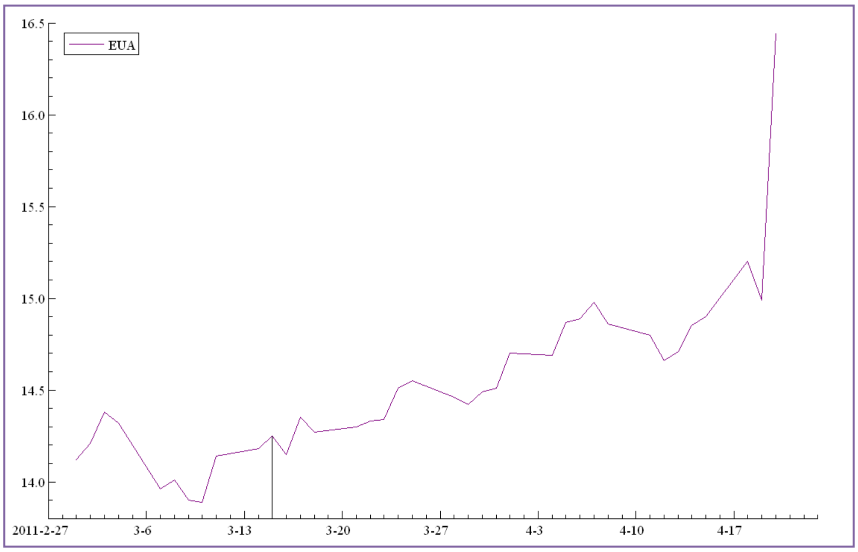


Figure 27: Daily EUA prices 01.03.2011-20.04.2011

Lastly, the $\left[\frac{EUA}{EEX}\right]$ relationship is also graphed in order to see whether the combination of the two prices show signs of dramatic change during this period.

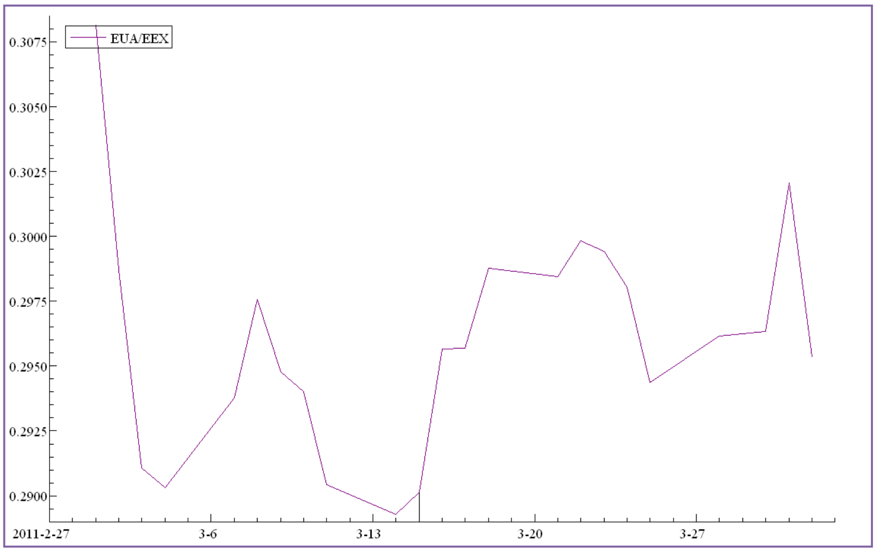


Figure 28: Daily $\frac{EUA}{EEX}$ prices, 01.03.2011-20.04.2011

Although there is an increase after the 15th of March, it seems that this is not out of the ordinary for this relationship, as it is neither the largest nor sharpest change in this period. Therefore, it may seem that although both prices appear to have been affected by the closing of seven nuclear power plants in Germany, they seem to have reacted at different paces. Where the EEX market experienced a sharp increase, the EUA price only gradually increased, until the sharp increase in April.

Although the EEX market seems to be largely affected by world events, it is unclear exactly how and how quickly it responds. It seems to follow electricity and oil price jumps, but at a slightly delayed pace. This reflects the relative immaturity of the EUA market and indicates that it is not as efficient as the more developed electricity and oil markets.

9 Discussion and Conclusions

Although the empirical analyses in this thesis do not uncover any significant relationships between European or Scandinavian electricity markets, oil or commodity markets on one hand and EUA prices on the other, there are nevertheless a number of conclusions to draw around the results. First, we can say that there are other factors than the ones explored here that have a deciding effect on EUA prices. Second, the event study in this thesis has uncovered that although relationships between electricity, oil and commodity markets and the CO_2 market cannot be confirmed on a general basis, there is still some evidence that shocks in the European electricity market and the oil market may have an effect on the EUA market.

An empirical analysis such as the one presented in this thesis is limited in the sense that it only tests for a few specific quantitative factors. Although the results from these tests are very clear and give specific yes or no answers, it does not give a full impression of how the EUA market behaves, because in reality the factors affecting this market are more dynamic and often of a more qualitative and complicated nature. For instance, an exploration of the largest traders in this market may uncover who are the key players, and how their behavior and actions affect EUA trade as a whole. One or a few major companies in the EU ETS may control trade in how they trade, the volume in which they purchase or sell quotas, and the timing of these purchases and sales. Other, smaller, players may then react to these actions, pressing the price up or down in accordance with interpretations of these actions, and predictions of future actions.

Further, a qualitative analysis can uncover the effects of the structure of the market itself on price movements. What effect do the policies in place have on movements? Do they inspire growth or place limitations on the development of the market? Considering this in conjunction with the degree of achievement of the goals outlined in the Kyoto protocol may well uncover explanatory factors in the price development of EUAs. Another factor may be the attitudes of traders of CO_2 quotas. It is possible that the opinions of those responsible for the purchase and sale of emissions quotas have an effect on their trade patterns, as well as the overall attitude of a company towards environmental questions and emissions. For instance, a company very motivated to reduce emissions may do so instead of participating heavily in trade, and if this company happens to be a key player this may have a major effect on how related and competing companies trade emissions quotas.

The event analysis found in Chapter 6 gives more opportunities to draw conclusions about the nature of the EUA market. We can, for instance, see that the EEX and EUA markets must be more related than previously found, because they quite clearly are affected by each other during turbulent periods. This was seen for both the period before, during and after the hacking scandal, as well as the time after the announcement of the shut-down of nuclear power plants specifically in Germany. The hacking scandal, an event only directly affecting the EUA market, appears to have had a similar effect on the EEX market as a result of the no-trade period of EUAs. The opposite effect can be seen following Angela Merkel's announcement to close nuclear power plants, directly affecting European electricity prices as a source of electricity production disappeared, which in turn affected the price of EUAs. Similarly, the increase in oil prices seems to also have had an effect on the price of EUAs. This, however, only becomes evident after some time, indicating that the EUA market reacts more slowly to the announcement of new information on various markets. As the CO_2 market increases in maturity and size, we may see more evidence of its reactions to movements in different markets, and an expansion of the above analyses to include more factors may prove that the EUA price does, in fact, depend on prices on other markets. Further, as the market grows and becomes more efficient, it may well start reacting quicker to information, meaning that an empirical analysis can show clearer evidence of any relationships.

Future explorations of the EU ETS are likely to uncover more significant relationships as the market matures and stabilizes, finding its place in the world market. As more companies join the system, the purpose of the system becomes more apparent to them, and confidence grows within them to actively trade quotas, we can assume more stability and therefore more grounds for conclusions.

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