

Carbon Emissions Markets

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Master Thesis in International Business

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ADMINISTRATION

This thesis was written as a part of the Master of Science in Economics and Business Administration program - Major in International Business. Neither the institution, nor the advisor is responsible for the theories and methods used, or the results and conclusions drawn, through the approval of this thesis.

Abstract

The purpose of this thesis is to explain the carbon emissions markets; what they are, how they work and what determines the carbon price. With a focal point on the EU ETS, the thesis deals with these problems with thorough explanations built on a large reference base together with economic and financial analysis. A distinct line has to be drawn between compliance and voluntary markets, with the EU ETS as the compliance powerhouse. Several carbon emissions products are currently available for trading with EUA futures being the most commonly traded. Major price drivers for the EU ETS allowances are political decisions, fuel/power prices, CDM supply and weather. In the analysis of Chapter 4.3, CAPM Beta for EUA Dec08 was set to be around 0.20 with only explaining ~2% of the asset's total risk. From the regression analysis we can infer that no linear relationship exists between returns on EUA Dec08 futures and the rate of return on the overall European stock market.

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1. Introduction

The purpose of this thesis is to examine the carbon emissions market by providing thorough explanations of the marketplaces and trading with a focus on the European Union Emissions Trading Scheme (EU ETS). The main analysis consists of CAPM Beta estimation and a regression analysis of the relationship between the EU ETS carbon price and main European stock markets.

1.1 Interest in the topic

At NHH and other institutions as well as other arenas, carbon markets are often known to the masses but not very much understood from a theoretical point of view. This leads to myths and unanswered questions about a heavily growing asset market and one of the most interesting measures taken to combat climate change. Compliance and voluntary markets, products traded and the economics behind them can often be confused, and it is thus difficult for individuals and businesses to follow the developing carbon emissions market. Hence, the background and motivation for the thesis was this feeling of a lack a good carbon emissions market overview at NHH. In addition, upcoming markets' developments are exciting and challenging to explore. After having taken several master courses in finance, the financial aspects of the trading and the relation to the stock markets variation has been an area of interest as well. This background and motivation has contributed to the structure of the master thesis. The word 'carbon' is used for both CO₂ (Carbon Dioxide) and other greenhouse gas emissions (GHGs). This is more thoroughly explained in Figure 2.1 on page 13.

It should be clarified that the author of this thesis has not taken a political standpoint about climate change and it is just the thrill and interesting economic and financial aspects of a new emerging market that has caught the interest. Broadly speaking, two main schools of thought on how best to address the threats posed by climate change exist:

- 1) The IPCC/UNFCCC/Kyoto position, which is that mitigation of climate change is essential;
- 2) The position of those skeptical that Kyoto can deliver meaningful benefits, who argue that, wherever possible, adaptation is a more practical response.

Critics and those skeptical often argue that the economic costs of implementing carbon dioxide emissions cuts would by far exceed the benefits and that the reasons for a global climate change is far more complicated and influenced by other mechanisms than man-made carbon emissions.¹ Olav Kårstad, the author of “Keeping the lights on” (Universitetsforlaget 2007) and leader of StatoilHydro’s carbon capture and storage (CCS) think tank, supports the first school of thought and has provided the following equation of the options the world have to reduce emissions:²

$$\text{CO}_2 \text{ Emissions} = \text{Population} \times (\text{GDP/Population}) \times (\text{Energy/GDP}) \times (\text{Emissions/Energy})$$

Everyone uses energy and the number of people on the planet is an important determinant of the total energy used and hence the level of emissions. Their wealth, expressed as average GDP per capita, explains that generally a higher GDP per capita implies a higher use of energy. The energy intensity of the population’s activities is reflection the fact that different individuals or countries use more or less energy than others and is expressed in the equation as the amount of energy use per unit of GDP. The emissions produced by their energy technologies explain that each and every means of using or supplying energy can be associated with a certain amount of CO₂ emissions, which is expressed as the emissions per unit of energy supplied or used in the equation. Since global population is still increasing and most countries are striving for and expect higher standards of living in the future, reducing the left-hand side of the equation is proven rather complicated. Consequently, energy intensity and technology shifts will have to drive the development. As one of many means for this, carbon emissions trading is believed to help cutting emissions in the most cost efficient manner. This thesis will thus work on this stand point.

1.2 Perspective and statement of the thesis problem

The perspective taken in order to write this thesis has been rational explanation and analyses. Although very difficult, political agendas and other emotional influences about climate change and the global warming debate that usually flourish in reports about the carbon market have been locked out. Other political themes such as the successfulness of carbon

¹ Newsnight 7/4/08 - Nigel Lawson & Chis Rapley; <http://www.youtube.com/watch?v=74E2D6oNSHc>

² Freund, P., Kaarstad, O (2007): Keeping the Lights on. (In Chapter 5: p86-86). Universitetsforlaget

trading will not be dealt with. This thesis' goal has simply been to explore the fact of rising carbon emissions trading based on as good facts as possible and rational economic analysis. The following full thesis title and statement of the problem has thus been developed:

Carbon Emissions Markets

–

What are they? How do they work? And what determines the carbon price?

Chapter 2 about the Marketplace explains what they are and where they come from by using broad and thorough explanations built on a large reference base and economics textbook examples. Chapter 3 about the Trading explains how they work by presenting structured carbon trading information on a financial and economic theoretical basis. The focus in Chapter 3 is turned more and more towards the EU ETS and in Chapter 4 about A Price for CO₂ in the EU, the main carbon price drivers will be presented assisted by professional research from Point Carbon. Furthermore, Chapter 4 presents the main analyses of price developments with CAPM Beta estimation and regression analyses of the relationship between EU ETS allowances and the main European stock markets. Chapter 5 will provide a short summary of the chapters and suggestions for further studies by presenting interesting aspects of carbon emissions trading worth to follow in the future. Full references list, appendices and a glossary of abbreviations are attached at the end.

This thesis is international business in the highest sense. Carbon emissions trading requires international markets in order to work in its most efficient way, and trading of carbon allowances in the EU has risen sharply since the introduction of the EU ETS in 2005. Capitalization, instead of amounts of emissions traded is used in this thesis in order to explain the size of the market, Euro (€/EUR) is the main currency, and the language used is US English. The average CO₂-price in the EU in 2008 (January 1st – June 18th) was €23.30.³

1.3 Limitations and general remarks

The very comprehensive nature of this thesis has led to many constraints and limitations. Concessions were made and general explanations of broad areas had to be

³ European Climate Exchange website, Market Data, ECX Historical Data, EUA08 Futures: <http://www.ecxeurope.com/>

preferred to more thorough financial and economic analysis of smaller areas. This is a limitation of the thesis and one may argue that it is far too general. However, the wide range of the thesis has been a serious challenge for the author and necessary to provide good explanations of the set of themes in order to explain the statement of the problem. This sets the thesis apart from other more technical and analytical theses. Writing alone on such a comprehensive thesis about a relatively new area of study has also been a challenge and has contributed to limitations in the discussions and analyses. The changing political climate of carbon emissions markets throughout the process has also been a challenge. This is another limitation of the thesis since some of the information provided might become outdated in short time. It has however been an interesting journey and this thesis will add some interesting new information to the NHH knowledge base, and hopefully spark a deeper interest in the fast-changing sphere of carbon emissions markets.

Sincerely,

Kristian A. Fosslund

June 18th, 2008

2. The marketplace

2.1 Emergence of emissions markets

This part of the thesis will examine the history behind emissions trading and the emergence of the well-known Kyoto Protocol and the only existent emissions market, the European Union Emissions Trading Scheme. The analysis will also discuss the different systems of carbon markets and the economic rationale behind emissions trading.

2.1.1 History

The emergence of a carbon emissions market is not the sole example of emissions trading. But to be able to understand the emergence of this market, a brief of the fundamental thoughts behind it will create an essential background. Emission trading has a long theoretical history, and this paragraph will show that there are examples of well-functioning emissions trading markets already.

The antecedents of emissions trading can be traced back to the theories of “Ecological Economics”, “Free-market environmentalist” and the newer term “Eco-capitalism”. Ecological Economics started with the Romantics of the 1800s and its ideas dealing with the social and ecological costs of an uncontrolled industrial expansion and how to operate an economy within the ecological constraints of the biosphere.⁴ Ecological Economists have, among others, advocated the view that the market is unable to correct the negative externalities of industrial production and excessive depletion of non-renewable resources. For example, a firm may receive the full benefit of producing pollutant waste if it is not required to pay the full social costs of contaminating the environment. In this situation, the firm keeps all the benefits of an activity itself but shifts responsibility for the costs to all citizens and future generations.

Free-market environmentalist does however oppose this by arguing that the free market, property rights, and tort law provide the best tools to preserve the health and sustainability of the environment.⁵ Such a free market is in sharp contrast with a *controlled*

⁴ Common, M. and Stagl, S. 2005. Ecological Economics: An Introduction. New York: Cambridge University Press.

⁵ Anderson, T L & Leal, D R (2001) Free-market environmentalism. Palgrave Macmillan

market of emissions set up by governments, although not all aspects of the public domain are believed to be easily privatized. It might thus be impossible to establish property rights on things like air and water that circulate the globe. A lot of free-market environmentalists as well as “Eco-capitalists”⁶ therefore often support emissions trading schemes for polluting gases, although it compromises free-market thoughts of many economists. One of the world’s most influential environmentalists isn’t an environmentalist at all. He is not an activist, conservationist or politician. Richard L. Sandor⁷, the founder, chairman and CEO of the Chicago Climate Exchange, more than anyone else invented the idea of emissions trading. Sandor turned his attention to air pollution in the late 80s, when acid rain, caused by pollutants from coal plants, factories and cars, was fast becoming one of the biggest environmental threats facing the industrialized world. Because of his expertise, he also contributed to mapping out the direction of international emissions trading on the Earth Summit in Rio de Janeiro in 1992.⁸

2.1.2 US Acid Rain Program

The sulfur dioxide (SO₂) and nitrogen oxides (NO_x) trading system under the framework of the Acid Rain Program of the 1990 Clean Air Act in the USA is a leading example of an emission trading system brought to life. This market-based mechanism was initiated by the United States Environmental Protection Agency⁹ in order to reduce the overall atmospheric level of the two chemicals above, which cause acid rain. The system would allow power plant operators, especially the coal industry and utilities, to buy, sell and trade credits to pollute as long as they cut overall emissions in half from the 1980 levels. Plants that missed the target faced stiff fines.¹⁰

⁶ The term Eco-Capitalists or Blue Greens is applied to those who espouse eco-capitalism. This can either be greens who accept or favor free market principles to achieve environmental aims or conservatives or liberals who espouse Green policies or, more generally, environmental concerns.

⁷ Chicago Climate Exchange homepage, Staff - Richard L. Sandor, Ph.D., Dr. Sc.h.c.; <http://www.chicagoclimatex.com/content.jsf?id=122>

⁸ How to Save the Planet and Make Money Doing It; Time Magazine online 20.04.2008: <http://www.time.com/time/health/article/0,8599,1732518,00.html> (20 April 2008)

⁹ US Environmental Protection Agency homepage: <http://www.epa.gov/>

¹⁰ US Environmental Protection Agency, Acid Rain Program, <http://www.epa.gov/airmarkets/progsregs/arp/index.html>

Trading of SO₂ started in 1995 and NO_x in 1999, and most of the investments are made in futures at The New York Mercantile Exchange (NYMEX). The emissions trading are now sourced out to “The Green Exchange”¹¹ which was set up by the NYMEX and had its first trade in March 2008. The flexibility of the system has proven itself a success by lowering technological abatement costs compared to imposing strict regulations, and reducing SO₂ and NO_x emissions by 40% since 1990 levels and acid rain levels with 65% since 1976. Of that reason, the Acid Rain Program has emerged as a model for the EU Emissions Trading Scheme of greenhouse gases and the California and other states’ carbon trading rules are based on the same principles. The problematic part is that the technology did exist to control the components of acid rain without a huge cost. At this time, the author of this thesis cannot see that this is the case in the same magnitudes when it comes to greenhouse gases.

On the other hand, one big lesson learned from the US Acid Rain Program is that stability and predictability are key factors in creating a successful emissions trading program, helping electric utilities and other emitters to prepare for the future. Another is that the rate of technological advance is indeed affected by public policy.¹² This will be further discussed in chapter 5.

2.1.3 Carbon emissions and energy sources

Leaving the Acid Rain Program and its politics aside, this chapter’s focus will be greenhouse gases and the main industrial emitters of them.

Greenhouse gases (GHGs) are simply said to be the gases present in the atmosphere which reduce the loss of heat into space and therefore contribute to global temperatures through the greenhouse effect. GHGs are fundamentally different from most other pollutants (SO₂ for example) in that their effect on the Earth and its atmosphere is identical, regardless of where the emission takes place. The allegedly main GHG contributor, CO₂, is also hard to categorize as a pollutant since it is fundamentally important and necessary for all organic life on Earth. Hence, this thesis will be cautious with the usage of the word “pollution” when it comes to GHGs.

¹¹ The Green Exchange powered by NYMEX: <http://www.greenfutures.com/>

¹² 'Cap-and-trade' model eyed for cutting greenhouse gases, San Francisco Chronicle online 2007-12-03, <http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2007/12/03/MNMMTJUS1.DTL&hw>. (December 3, 2007)

Some of the technicalities behind GHGs like radiative forcing¹³ are complex and often raises controversy between research communities. A brief overview can be found at the official US Energy Information Administration (EIA)¹⁴. Hence, this thesis will not discuss this further but simply introduce some of the fundamentals behind the EU Emissions Trading Scheme which is the IPCC/UNFCCC/Kyoto position presented in the introduction part of this thesis. The UNFCCC identified six GHGs and these gases are ranked in terms of an index that measures their global warming potential (GWP) relative to carbon dioxide. 1 GWP is also called 1 CO₂ equivalent unit (CO₂e):¹⁵

Figure 2.1: Global Warming Potential of the six GHGs addressed by UNFCCC	
Greenhouse gas	Global Warming Potential (GWP)
Carbon dioxide (CO ₂)	1
Methane (CH ₄)	23
Nitrous Oxide (N ₂ O)	296
Hydrofluorcarbons (HFCs)	12-12,000
Perfluorcarbons (PFCs)	5,700-11,900
Sulphur hexafluoride (SF ₆)	22,200

Furthermore, Figure 2.2¹⁶ below shows an overview of the annual GHG emissions by sector and the main GHGs in 2000. The top panel shows the percentage sum of all man-made greenhouse gases, weighted by their global warming potential. This consists of 72% carbon dioxide, 18% methane, 9% nitrous oxide and 1% other gases. The lower panels show the comparable information for each of these three primary greenhouse gases, with the same coloring of sectors as used in the top chart. Segments with less than 1% are not labeled. The largest emitters of GHGs are power stations (21.3%), industrial processes (16.8%) and transportation fuels (14%).

¹³ In climate science, radiative forcing is loosely defined as the change in net irradiance at the tropopause. "Net irradiance" is the difference between the incoming radiation energy and the outgoing radiation energy in a given climate system and is thus measured in Watts per square meter. Source: Myhre et al., New estimates of radiative forcing due to well mixed greenhouse gases, Geophysical Research Letters, Vol 25, No. 14, 1998

¹⁴ What Are Greenhouse Gases?, Energy Information Administration, Official Energy Statistics from the U.S. Government, <http://www.eia.doe.gov/oiaf/1605/gccebrc/chapter1.html>

¹⁵ United Nations Environment Programme (UNEP/GRID-Arendal), 6.12.2 Direct GWPs, http://www.grida.no/climate/ipcc_tar/wg1/248.htm

¹⁶ Figure: <http://www.globalwarmingart.com/>; Original data citation: [Emission Database for Global Atmospheric Research](http://www.mnp.nl/edgar/model/v32ft2000edgar/) version 3.2, fast track 2000 project, <http://www.mnp.nl/edgar/model/v32ft2000edgar/>

Figure 2.2:

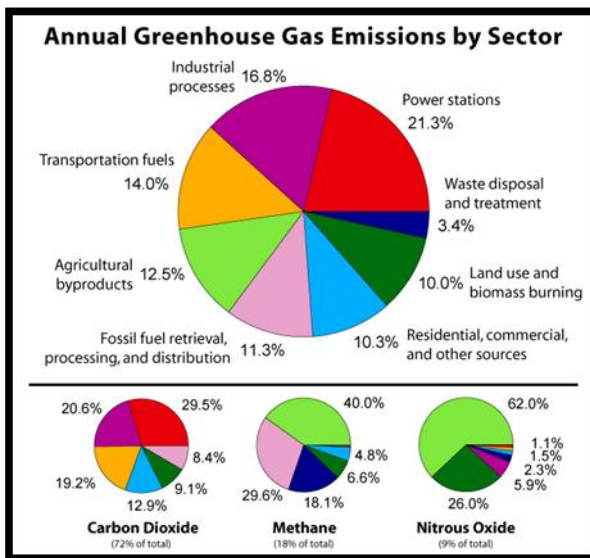


Figure 2.3:

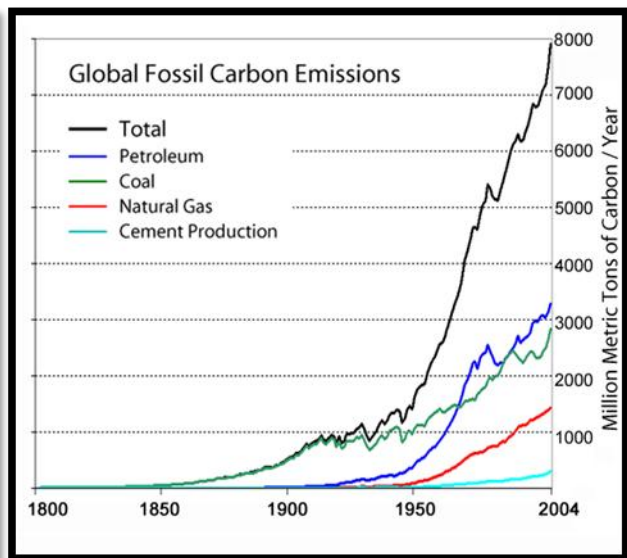


Figure 2.3¹⁷ shows the global annual fossil fuel carbon emissions through year 2004, in million metric tons of carbon, as reported by the Carbon Dioxide Information Analysis Center¹⁸. Note that it is carbon (C) and not carbon dioxide (CO₂) emissions that are denoted in this figure. The general picture is however the same and current man-made GHG emissions are believed to be around 30 billion tons CO₂e per year¹⁹, mainly from the combustion of fossil fuels. Natural sources of carbon dioxide include the respiration (breathing) of animals and plants, and evaporation from the oceans. Together, these natural sources release about 150 billion tons of carbon dioxide each year.²⁰ The rationale behind all this is that natural removal processes, such as photosynthesis by land and ocean-dwelling plant species, cannot keep pace with this extra input of man-made carbon dioxide, and consequently the gas is building up in the atmosphere. The increased concentration of GHGs will by complex measures not further discussed in this thesis lead to global warming and

¹⁷ Figure: <http://www.globalwarmingart.com/>; Original Data citation: "Marland, G., T.A. Boden, and R. J. Andres. 2007. Global, Regional, and National CO₂ Emissions. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, United States Department of Energy, Oak Ridge, Tenn., U.S.A."

¹⁸ Carbon Dioxide Information Analysis Center homepage: <http://cdiac.esd.ornl.gov/home.html>

¹⁹ Envisat makes first ever observation of regionally elevated CO₂ from manmade emissions, The European Space Agency (ESA) news 2008-03-18, http://www.esa.int/esaEO/SEMZHVM5NDF_index_0.html (March 18, 2008)

²⁰ Manchester Metropolitan University. The Atmosphere, Climate & Environment (ACE) Information Programme homepage, "Greenhouse gas emissions": http://www.ace.mmu.ac.uk/eae/Global_Warming/Older/Emissions.html

climate change in the longer run.²¹ By volume, the Earth's atmosphere contains roughly 78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.0383% (383 ppm²²) carbon dioxide, ~1% water vapor and 0.002% other gases. Although gases such as carbon dioxide and methane are minor constituents, the rationale behind the standpoint of the United Nations Framework Convention on Climate Change (UNFCCC) is that they are responsible for the greenhouse effect and thus exert a large influence on Earth's temperature.²³

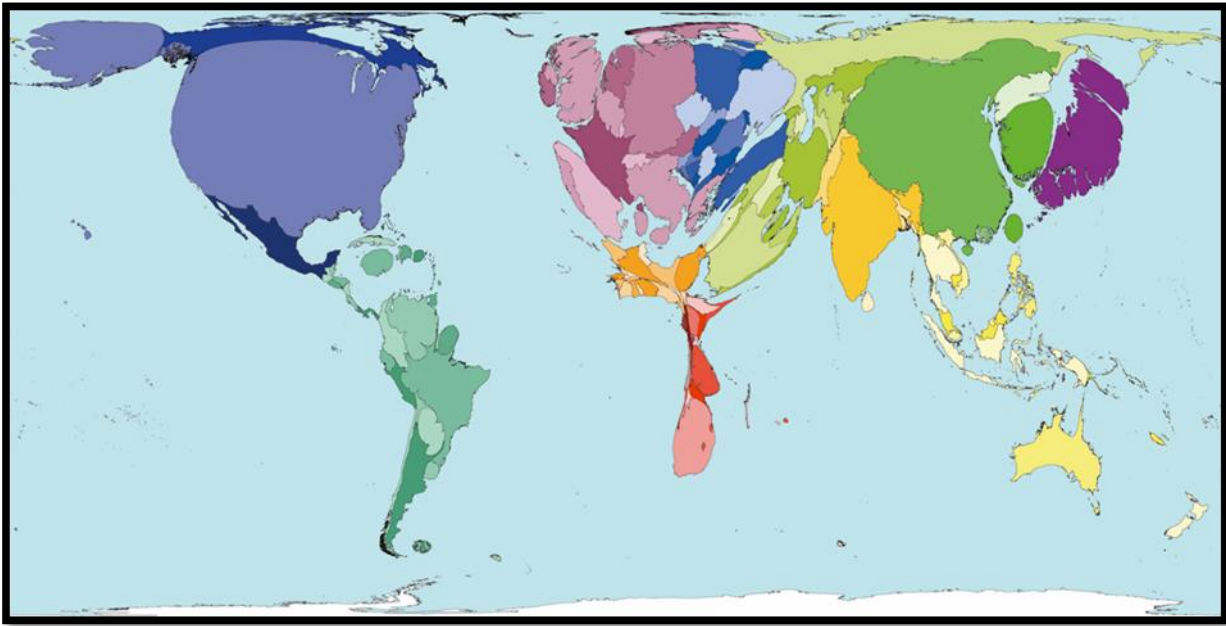
Before finishing up this part, Figure 2.4²⁴ on the next page presents a country-wise overview of where the GHG-emissions occur worldwide, where the areal proportions of the country reflects their total GHG-emissions. Depicting the figure, emissions of carbon dioxide vary hugely between places, due to differences in lifestyle and ways of producing energy. The picture shows estimation that developed countries accounted for 52% of emissions, and the developing world for 48%.

²¹ CICERO, Bjerknessenteret and met.no, "Myter om klima" 2008-05-05:
<http://www.cicero.uio.no/webnews/index.aspx?id=10961> (Norwegian only)

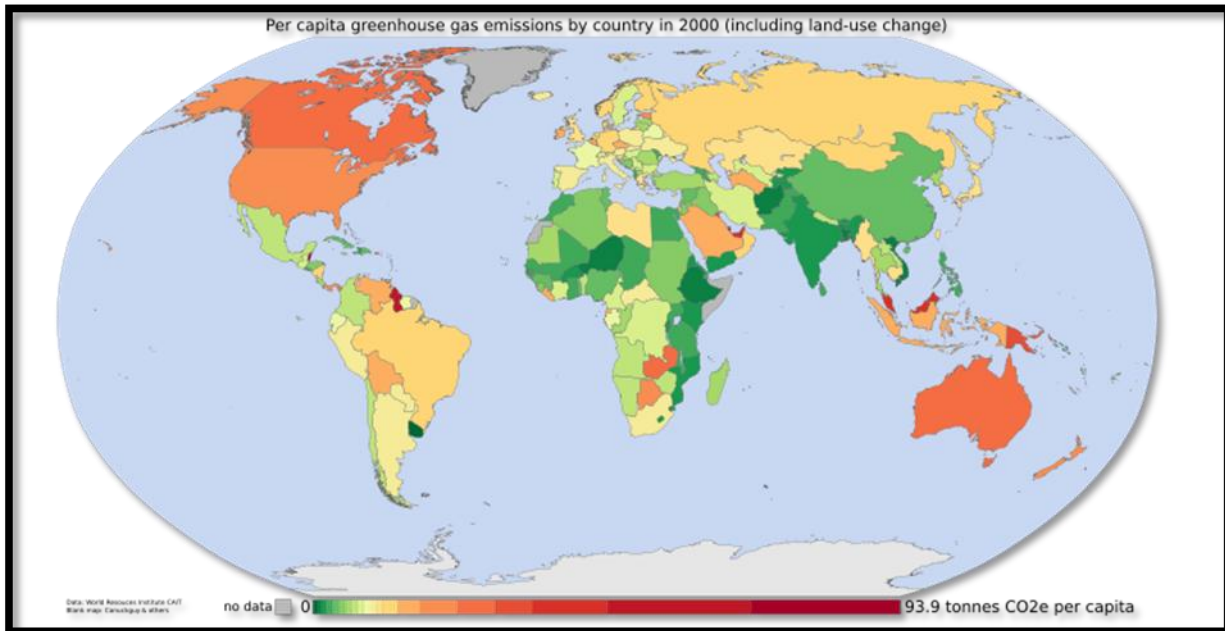
²² ppm: parts per million

²³ Window to the Universe website:
http://www.windows.ucar.edu/tour/link=/earth/Atmosphere/chemistry_troposphere.html&edu=high

²⁴ Carbon Emissions 2000, Worldmapper.org, <http://www.worldmapper.org/display.php?selected=295>

Figure 2.4: Carbon Emissions 2000

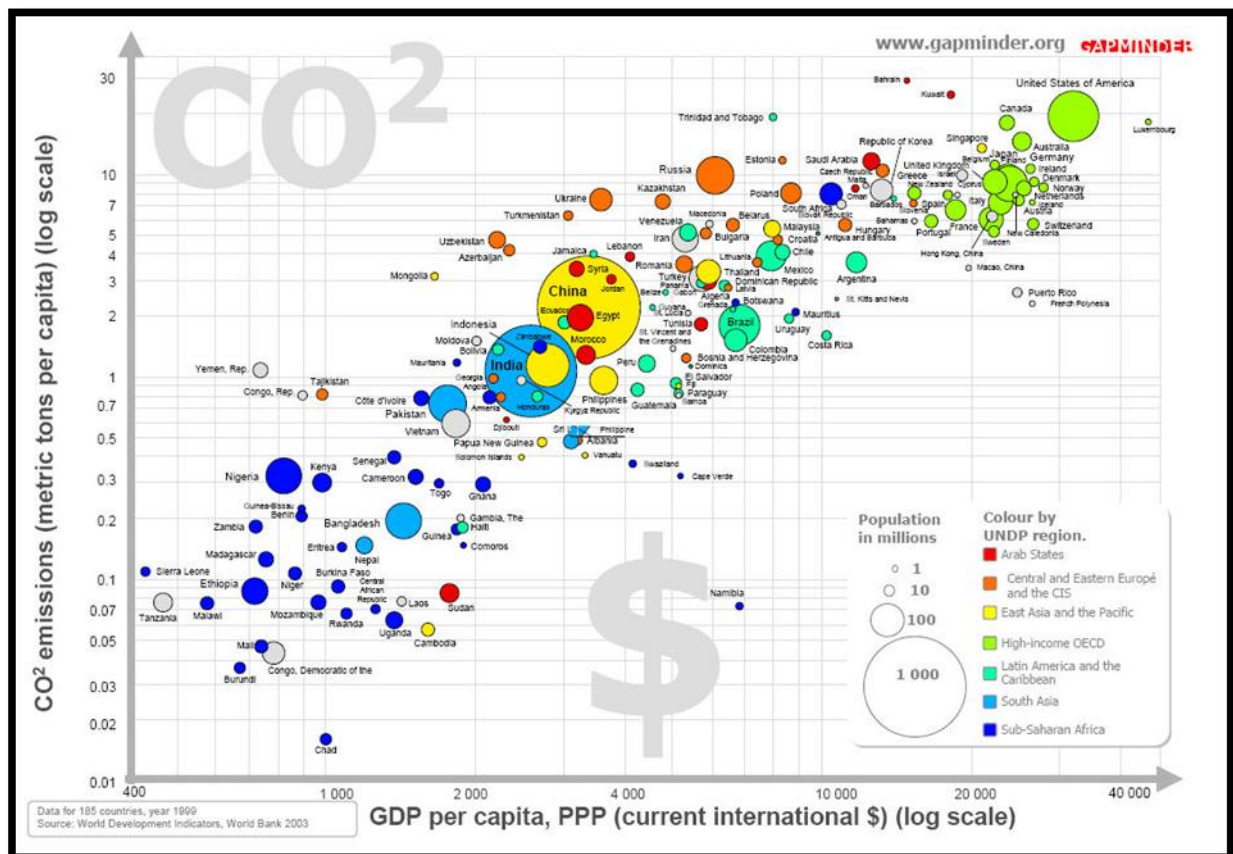
This is further illustrated by Figure 2.5²⁵ which illustrates the per capita greenhouse gas emissions by country in 2000.

Figure 2.5: Per capita GHG emissions by country in 2000

²⁵ Made by Vinny Burgoo 2007-09-03, Data from the World Resources Institute's CAIT 4.0 database, <http://cait.wri.org/>

Given their respective populations, there is a much higher carbon intensity in the developed world which reflects the strong correlation of emissions with levels of industrialization and hence GDP. This is because of the energy usage a high GDP requires, which can be seen in Figure 2.6²⁶ where GDP per capita, adjusted for purchasing price parity (PPP), together with CO₂ emissions per capita for 185 countries is plotted along an upward sloping line.

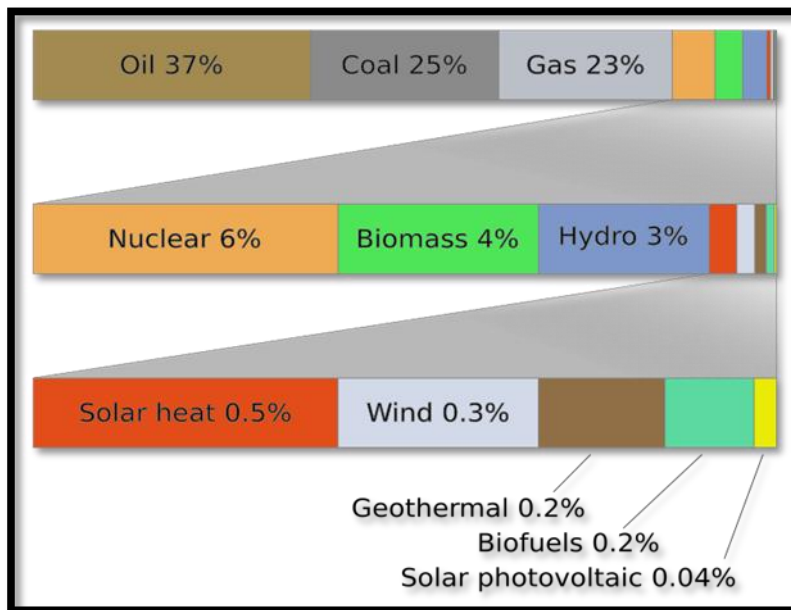
Figure 2.6: Link between GDP (PPP) and CO₂ emissions per capita, 1999



The last central insight in this section will be given by a world energy usage types bar graph depicted in Figure 2.7²⁷ on the next page which presents a view of world energy sources in 2006.

²⁶ World Development Indicators, World Bank 2003, Data for 185 countries, year 1999. Taken from publicly available Gapminder World Environment Chart: <http://www.gapminder.org/downloads/handouts/world-environment-chart.html>

²⁷ Data from REN21, “2006 Global Status Report on Renewables”, http://www.ren21.net/globalstatusreport/download/RE_GSR_2006_Update.pdf

Figure 2.7: World energy usage 2006

An interesting fact (given 2 % worldwide annual energy increase):

A 20% renewable energy sources (Bio, hydro, solar, wind, geo) goal worldwide in 2020 requires an 9 % annual renewable energy sources increase, 12% when excluding hydro and 24% when excluding biomass as well.

2.1.4 UN, IPCC, UNFCCC & Kyoto Protocol

The carbon market in the EU is a direct consequence of the Kyoto Protocol. The carbon market's sole mission is to place a cost on carbon emissions, a value on emission reductions, and to enable trade of the resulting allowances or credits. Simply put, the idea of carbon emissions trading through these establishments is that firms can either cut emissions or buy the right to keep polluting. There are four main mechanisms at play:

- I. International Emission Trading
- II. Clean Development Mechanism
- III. Joint Implementation
- IV. Regional/Domestic Emission Trading

This section will discuss the essential background and establishment of the UN (United Nations) backed scientific body IPCC (The Intergovernmental Panel on Climate Change), the international environmental treaty UNFCCC (The United Nations Framework Convention on Climate Change) which led to the basis of today's compliance carbon markets – The Kyoto Protocol.

IPCC

The Intergovernmental Panel on Climate Change (IPCC) is a scientific intergovernmental body and was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The motive was to provide decision-makers and others interested in climate change with an objective source of information about the causes of climate change, its potential environmental and socio-economic consequences and the adaptation and mitigation options to respond to it. It is important to notice that the IPCC does not carry out research or monitor climate or related phenomena. The IPCC homepage states that the main activity of the IPCC is to publishing special reports on topics relevant to the implementation of the UN Framework Convention on Climate Change (UNFCCC) which will be more thoroughly discussed in the next paragraphs. The IPCC's constituency is made of the governments, the scientists and the people. Governments are all member countries of WMO and UNEP, the scientists are hundreds of scientists all over the world that contribute as authors, contributors and reviewers, and the people since it is a UN body working to promote the United Nations human development goals.²⁸

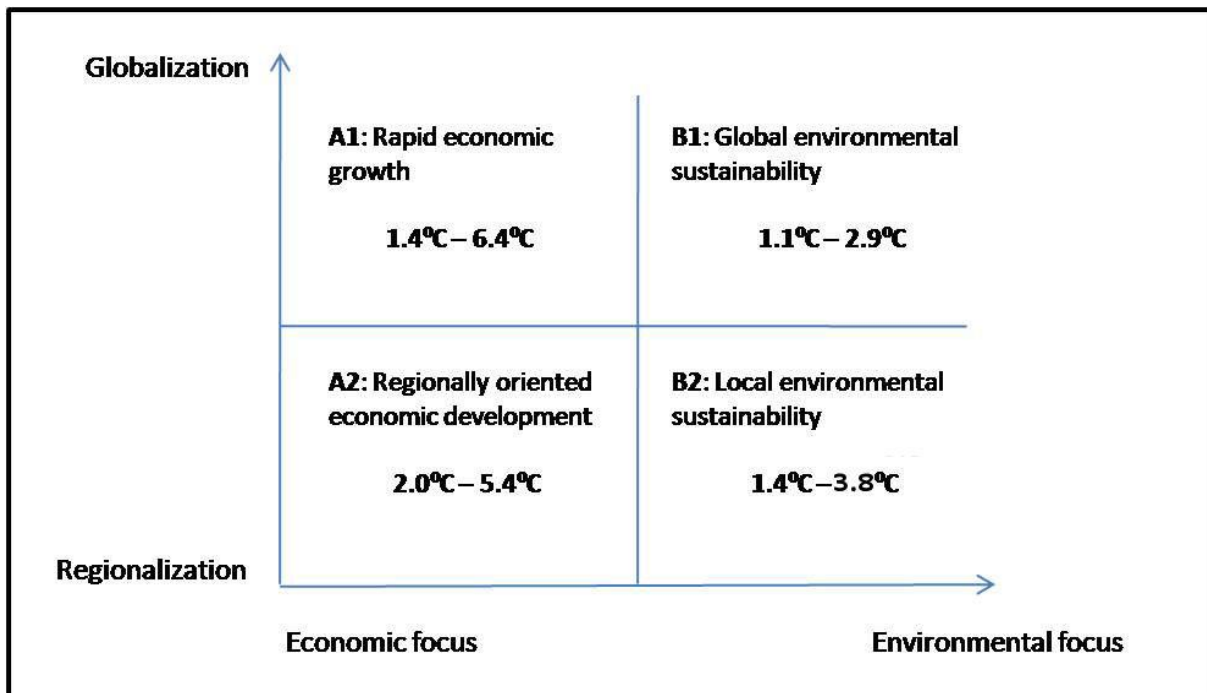
The IPCC published its first assessment report in 1990, a supplementary report in 1992, a second assessment report (SAR) in 1995, a third assessment report (TAR) in 2001, and a fourth assessment report (AR4) was released in 2007. This thesis will not discuss all the findings of these reports since it is not required to understand the basis of this thesis. They are very often cited in popular literature and can easily be found on the IPCC homepage²⁹. The most interesting insights from the AR4, and thus maybe also the future grounds for existing and future emissions markets, are the Special Report on Emissions Scenarios (SRES) which divides the associated changes in global-mean temperature until 2100 in four main scenarios. In Figure 2.8, an economic focus implies a business-as-usual scenario with absence of any GHG abatement measures, while an environmental focus will divert economic growth into costly GHG abatement measures. The future world is furthermore split into a more globalized world or a more regionalized world.³⁰

²⁸ IPCC homepage, About IPCC: <http://www.ipcc.ch/about/index.htm>

²⁹ IPCC homepage, Reports: <http://www.ipcc.ch/ipccreports/index.htm>

³⁰ IPCC Special Report on Emissions Scenarios, 4.2. SRES Scenario Taxonomy, 4.2.1. Storylines: <http://www.grida.no/climate/ipcc/emission/091.htm#4.2.1>

Figure 2.8: The four SRES in AR4 together with changes in global mean temperature at 2090-99 relative to 1980-1999



The AR4 suggests that in absence of any abatement of GHGs (A1 or A2 in Figure 2.8), the projected concentration of carbon dioxide in the atmosphere will be from 700 to 1,500ppm (from today's ~380ppm) by the end of the 21st century. According to the IPCC, this would lead to the potential global warming of 1.4°C – 6.4°C.³¹ Nevertheless, given the numerous uncertainties inherent in all attempts to model the future, it can never be clear from this what the 'right' target for CO₂ emissions reductions should be, either scientifically or economically. From this thesis' point of view, this would mean that any attempt to reach international agreements on how to best tackle the threats caused by climate change has to take account of these uncertainties and their political implications. This will not be further discussed at this point but serves as a guideline and introduction to the political difficulties that this topic comprises.

The IPCC was awarded the Nobel Peace Prize in 2007 for "their efforts to build up and disseminate greater knowledge about man-made climate change and to lay the foundations for the measures that are needed to counteract such change".³²

³¹ IPCC, AR4 - Climate Change Synthesis report, p45: <http://www.ipcc.ch/ipccreports/ar4-syr.htm>

³² IPCC homepage press release: <http://www.ipcc.ch/press/index.htm#nobel>

UNFCCC

The United Nations Framework Convention on Climate Change (UNFCCC or FCCC) is an international environmental treaty produced and opened for signature at the 1992 United Nations Conference on Environment and Development (UNCED) conference in Rio de Janeiro (a.k.a. the Earth Summit). Its stated objective is “to achieve (...) stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” Initially, the treaty set no further goals but a voluntary "non-binding aim" to reduce atmospheric concentrations of greenhouse gases that moreover should “be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.”³³ 154 nations signed the treaty on June 12, 1992. Signatories to the UNFCCC are split in three groups and have different missions under the treaty. Annex I countries represent 40 of the world’s industrialized countries and economies in transition, and the intention of the treaty was to stabilize their emissions of greenhouse gases at 1990 levels by the year 2000. Annex II countries’ which are developed countries which pay for costs of developing countries, are a sub-group of Annex I that consists of all original OECD member countries plus the European Union.³⁴ Developing countries have no immediate restrictions under the UNFCCC. The main initial reason for this was to avoid restrictions on growth because carbon emissions are strongly linked to industrial growth. Under the treaty, developing countries may volunteer to become Annex I countries when they are sufficiently developed. The signatory states of the UNFCCC were also split up into Annex B Countries which are the 39 emission-capped countries of the Protocol, and Annex II Countries which includes all original OECD member countries plus the EU. Lists of Annex I, II, B and Non-Annex I parties can be found in Appendix 1.

Since the UNFCCC entered into force in 1994, there have been held 13 UNFCCC annual Conferences of the Parties (COP) to assess progress in dealing with climate change. The COP-2 in Geneva, Switzerland (July, 1996) accepted the findings on climate change published by the IPCC and called for “legally binding mid-term targets”, and the definite

³³ Article 2. The United Nations Framework Convention on Climate Change; http://unfccc.int/essential_background/convention/background/items/1353.php

³⁴ UNFCCC homepage: http://unfccc.int/not_assigned/b/items/1417.php

breakthrough came in Kyoto, Japan (December, 1997) when the Kyoto Protocol on Climate Change was adopted by COP-3 after intensive negotiations. Furthermore, the following Conferences of the Parties also negotiated the Kyoto Protocol (“the Protocol”) to establish legally binding obligations for developed countries to reduce their greenhouse gas emissions.

This thesis will not deal with all the complex issues of the Protocol, but introduce some of the fundamentals that also served as the basis of the EU ETS. The major leap was that whereas the FCCC encouraged developed countries to stabilize GHG emissions, the Kyoto Protocol committed them to do so. And because it affects virtually all major sectors of the economy, the Protocol is considered to be the most far-reaching agreement on environment and sustainable development ever adopted. Most of the world’s countries ratified the Protocol, but some nations as the United States chose not to. After the ratification by Russia, the Protocol entered into force on 16 February 2005.

The Protocol requires developed countries to reduce their GHG emissions and that these targets must be met within a five-year time frame between 2008 and 2012. This should add up to a total cut in GHG emissions of at least 5% against the baseline of 1990. As already mentioned, the parties of the Protocol are given a certain degree of flexibility in order to meet their emissions reduction targets. These mechanisms in the Protocol were developed on the COP-6 and COP-7 in 2001 and are Emissions Trading (International and regional/domestic), Joint Implementation (JI) and Clean Development Mechanism (CDM).³⁵ The reason for this is that if Annex I countries cannot meet their emissions reduction target locally they must buy emission credits or invest in conservation so that the worldwide GHG reductions will be the same. JI is set forth in Article 6 of the Kyoto Protocol where any Annex I country can invest in emission reduction projects in any other Annex I country as an alternative to reducing emissions domestically and thus generate credits to cope with their Kyoto targets more cheaply. The CDM is a mechanism for similar project-based emission reduction activities in developing countries. The JI, unlike the CDM, takes place in countries which have an emission reduction requirement. The process of receiving credit from CDM and JI projects is somewhat complex and these mechanisms will be further discussed in chapter 2.2.4 about the EU ETS. The COP-13 in Bali, Indonesia (2007) agreed on a time lined negotiation on the post-2012 framework which is to be the Kyoto Protocol’s

³⁵ UNFCCC homepage, Kyoto Protocol: http://unfccc.int/kyoto_protocol/items/2830.php

successor.³⁶ As an overarching goal, the UNFCCC concludes that since a stabilization of atmospheric concentration below 500ppm would be very difficult to achieve and would require abrupt abatement before 2020, the right balance should be around 550ppm as this should avoid the worst impacts of the high concentrations and is achievable over a reasonable time period. IPCC AR4 describes modeling studies that shows stabilization around 550ppm by 2100 is consistent with a global carbon price around €15-56/tCO₂^e by 2030.³⁷

2.1.5 Basic economics of emissions control

Given that man-made GHG emissions can be seen as a negative impact on planet Earth in the long run and have to be mitigated, governments and other institutions in power can do this by a command-and-control approach of direct cuts or impose an emissions tax. In a command-and-control system with direct emission caps, carbon markets can be established in order to favor the most cost efficient abatement solutions. The effect of GHG emissions is a classic example of negative externalities, which is explained by the negative effects of production and consumption activities not directly reflected in the market price.³⁸ Since the debate has mostly been circulating around the relative advantages on price versus quantity instruments, this part of the thesis will now introduce some of the economics behind the ways of correcting this market failure and putting a market price on the social costs caused by a damage-causing emission. The inspiration of the following textbook examples is taken from *Microeconomics*, 5th ed. (2001) by Pindyck and Rubinfeld.³⁹ Necessary assumptions and adjustments for the sake of the topic in question will be made. GHGs will throughout this chapter be referred to as carbon emissions which can be interpreted as a carbon dioxide equivalent (CO₂e) as introduced in Chapter 2.1.3.

To remedy the externalities caused by production if the firm that generates the externality has a fixed-proportions production technology, one simply has to encourage the

³⁶ UNFCCC homepage, The United Nations Climate Change Conference in Bali, http://unfccc.int/meetings/cop_13/items/4049.php

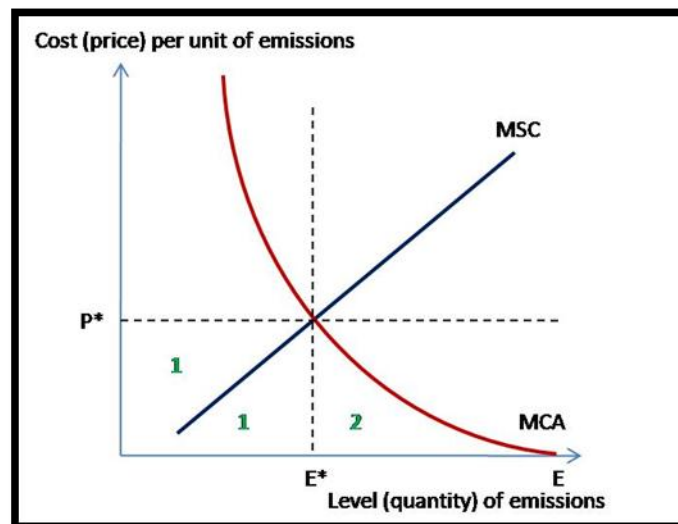
³⁷ IPCC, AR4 - Climate Change Synthesis report, p59: <http://www.ipcc.ch/ipccreports/ar4-syr.htm>

³⁸ Pindyck, Robert S. and Rubinfeld, Daniel L (2001); *Microeconomics*. 5th ed. (In Chapter 18: Information, Market Failure and the Role of Government, p621-634). Prentice Hall International, Inc.

³⁹ Pindyck, Robert S. and Rubinfeld, Daniel L (2001); *Microeconomics*. 5th ed. (In Chapter 18.2: Ways of Correcting Market Failure, p625-634). Prentice Hall International, Inc.

firm to produce less. This is a standpoint of many environmental institutions when it comes to carbon emissions because e.g. less energy usage causes less carbon emissions. However, most utilities can substitute among inputs in the production process by altering their choices of technology either in the short or the long run. In these examples, Marginal Social Cost (MSC) is the sum of the marginal cost of production and the marginal external cost, while the Marginal Cost of Abatement (MCA) measures the additional cost to the firm of installing pollution control equipment. The MSC curve is upward sloping because the marginal cost of more carbon emissions (i.e. production) is believed to be higher the more extensive it is. This is nevertheless a widely debated topic because the social costs of carbon emissions lies in the future and is not yet known. In addition, since these are the social costs of future generations, we have to consider the future generations' adaptation of a changed climate and their increased wealth caused by industrial development and thus more carbon emissions. This has also been one of the main criticisms of the Stern Review⁴⁰, especially by William Nordhaus in his article addressing the Economics of Climate Change.⁴¹ This will not be further discussed here, and an assumption of an upward sloping and constant MSC curve will be made.

Figure 2.9: The efficient level of emissions, standard and fees (tax)



⁴⁰ HM Treasury homepage: Stern Review on the economics of climate change. http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

⁴¹ Nordhaus, W. (2007); The Stern Review on the Economics of Climate Change, May 3, 2007.

The MCA curve is downwards sloping because the marginal cost of reducing emissions is low when the reduction has been slight and high when it has been substantial. A slight reduction can be made from smaller efficiency improvements and fuel switching e.g. from lignite to cleaner coal in power stations. Large reductions will require costly changes in the production process and the technology used. No emissions will require no production and is has thus an unlimited unknown cost, e.g. bankruptcy.

Because emissions reduction is costly and offers no direct benefit to the firm, the firm's profit-maximizing level of emissions in Figure 2.9, is E, the level at which the marginal cost of abatement is zero and level of emissions are high. The efficient level of emissions is at point E* where the marginal social cost of emissions, P*, is equal to the marginal cost of abating emissions. If emissions are lower than E*, the marginal cost of abating emissions is greater than the marginal social cost and emissions are too low relative to the social optimum. On the other hand, if the level of emissions is larger than E*, the marginal social cost is greater than the marginal benefit and emissions are then too high. From the theory, the firm can be encouraged to reduce emissions to E* by setting emissions standards (a cap) or introducing emissions fees (a tax). It is also possible to introduce transferable emissions permits which are tradable units similar to emissions trading. To get a good introduction of the theory, the two first ones will be dealt with in this section, while the economics behind emissions trading will be discussed in the next sub-chapter.

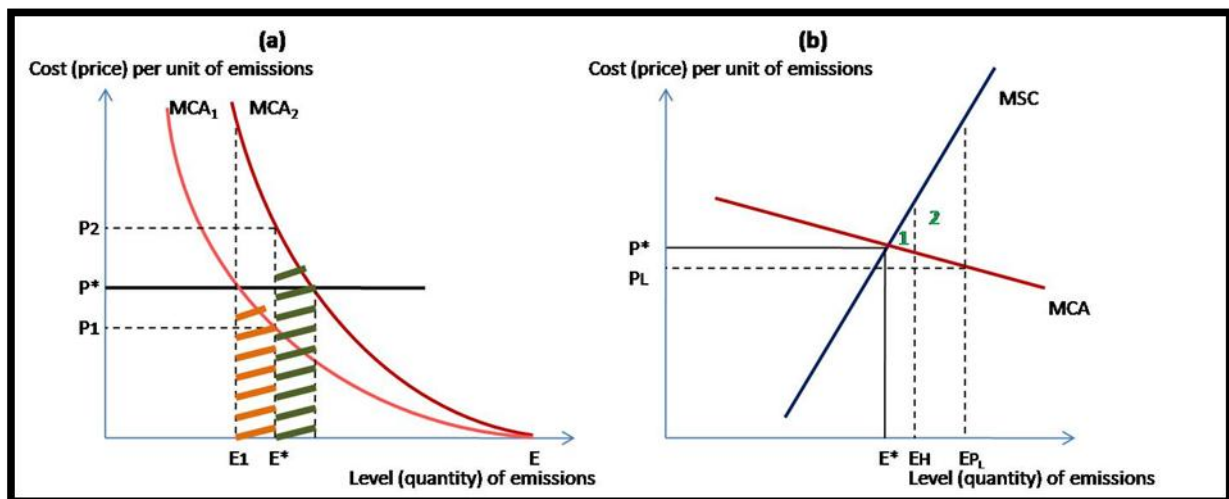
An emissions standard, or a cap, is a legal limit on how much emissions a firm can emit. If the firm exceeds the limit, it can face monetary and even criminal penalties. In Figure 2.9, the efficient emission standard is at point E*, and the firm will be heavily penalized for emissions exceeding this level. If the firm meets the standard by shifting production or installing abatement equipment, the total costs will be area 2 under the MCA line in Figure 2.9. In this isolated world, the firm's average cost curve will rise by the average cost of abatement and firms will find it profitable to enter the industry only if the price of the product is greater than the average cost of production plus abatement. The increase is believed to be equal to the average cost of abatement in the EU which is the carbon emissions price.

An emissions fee, or a tax, is a charge levied on each unit of a firm's emissions. In Figure 2.9, a tax of P* will generate efficient behavior by the firm. The firm will pay a total

fee given by area 1 in Figure 2.9 and incur a total abatement cost given by area 2. This cost is less than the fee the firm would pay if it did not reduce emissions at all.

It is evident that it is impossible for the policymaker to have perfect information about the MSC and MCA curves. There are important differences between standards and fees when the policymaker has incomplete information and when it is costly to regulate firms' emissions. The next paragraphs will explore these differences with two examples, so let us suppose that the institution in power must charge the same fee or set the same standard for all firms.

Figure 2.10: Examples of standards (caps) and fees (tax)



Firstly, consider the two firms in Figure 2.10 (a) that have different abatement costs and thus different MCA curves. The MSC curves are the same and left out from this graph since carbon emissions is causing the same problems wherever they are occurring. MCA_1 and MCA_2 represent the marginal cost of abatement curves for the two firms. Each firm initially generates E emissions, and the government wants to reduce total emissions to E^* in total for both firms. Figure 2.10 (a) shows that the cheapest way to do this would be to have Firm 2 to reduce its emissions to E_2 and Firm 1 to E_1 which would add up to a total of E^* for both firms. If the government was to impose a cap on both firms to E^* , the MCA of Firm 2 increases from P^* to P_2 and the MCA of Firm 1 decreases from P^* to P_1 . Because $P_2 - P^* > P^* - P_1$, this cannot be cost-minimizing when the first firm can reduce emissions more cheaply than the first. This can be seen from the green and yellow areas in Figure 2.10 (a) where Firm 2 incurs additional abatement costs given by the green-dashed area and Firm 1 enjoys reduced abatement costs given by the yellow-dashed area. The added abatement costs

to Firm 2 are clearly larger than the reduced costs of Firm 1. A fee or a tax of P^* might thus be preferable to a standard of E^* because we will get the efficient outcome given above.

Secondly, consider Figure 2.10 (b) where the MSC curve is set very steep and the MCA curve relatively flat for the sake of the example. The efficient emission fee is P^* , but because of limited information a lower fee of P_L is set by the institution in power. Because the MCA curve is flat, the firm's emissions will be increased from E^* to E_{P_L} units. The increase in social costs less the decrease in the firm's abatement costs is given by area 1 + 2. If a similar percentage error is made when setting a cap, i.e. a higher level of emissions allowed from E^* to E_H , the increase in social costs less the decrease in abatement costs will be the triangle given by area 1, which is far smaller than the one before. Hence, a standard might be preferable in this situation.

To conclude, when no emissions units are traded, taxes offer certainty about the costs of abatement but leave the reduction of emissions levels uncertain. Taxes also give a certain flexibility since it can be imposed directly on the producer or indirectly on the consumer. With incomplete information, caps offer more certainty about emissions levels but leave the costs of abatement uncertain. The preferable policy will depend on the shapes of the cost curves and hence the amount of information available.

A third system, and the core of this thesis, is mentioned in the theory from Pindyck and Rubinfeld: Transferable Emissions Permits which is a system of marketable permits, allocated among firms, specifying the maximum level of emissions that can be generated. This is very much like the "cap-and-trade" system we have seen in chapter 2.1.2 about the US Acid Rain Program and the EU ETS, or a "baseline-and-credit" system used in e.g. the New South Wales Abatement Scheme in Australia presented in Ch. 2.2.4.2 or the Joint Implementation (JI) and Clean Development Mechanism (CDM) of the Kyoto Protocol. The system works so that each firm must have permits or carbon credits to generate emissions and the credits can be bought and sold on a market. In Figure 2.10 (a), Firm 2 could buy carbon credits from Firm 1 for a price up to P_2 and thus make the allocation more efficient. If there are enough firms and credits, a competitive market for credits will develop, and in market equilibrium, the price of a credit equals the marginal cost of abatement for all firms. In this way, marketable emissions credits create a market for externalities. The institution(s) in power determines the total number of credits available and thus the total amount of emissions. This reflects the system with standards (caps), but the marketability of the credits

allows pollution abatement to be achieved at a minimum cost, just as a system of fees (taxes) would do.

Some parties in the debate between taxes or an emissions trading program are concerned with the cost of the cap-and-trade policy, and have thus introduced an additional “safety valve” instrument which can be seen as a hybrid between the price and quantity instruments. The system provides a guaranteed emissions allowance price and the government will print new credits for sale at this specified price to companies in need, potentially in an unlimited quantity. Emitters have the choice of either obtaining permits in the marketplace or purchasing them from the government at a specified trigger price which can be adjusted over time. By setting the trigger price high enough, or the number of allowances low enough, the safety valve can be used to mimic either a pure quantity or a pure price mechanism since it gives the governments to tame an overly stringent emissions target or control unreasonable price volatility. The way of implementing this all comes down to the new information in hand.⁴²

As mentioned above, a distinction is generally drawn between regulated command-and-control as cap-and-trade systems and baseline-and-credits systems. Both trade with emission permits or allowances and consist of an absolute level of emissions which can increase or decrease over time. Thus, the emissions baseline in a credit scheme can be identical to the emissions cap in an allowance scheme. However, a baseline-and-credit program can also exist of baselines that are not emission limits but simply GHG per capita or GDP. Any emissions reductions below an agreed baseline are referred to as emissions credits and only those emissions credits can be traded. Furthermore, a set of emission producers that are not under an aggregate cap can create credits by reducing their emissions below a baseline level of emissions so that these credits can be purchased by polluters that do have a regulatory limit. Cap-and-trade schemes require an extensive regulatory involvement and hence effort at the beginning to set them up, while baseline-and-credit schemes require less initial design effort, but baselines need to be determined on a project-by-project basis and individual trades must be certified by the regulator. Both approaches have their advantages and disadvantages, and there is considerable dispute about which system is more efficient

⁴² Jacoby, D.H. & Ellerman, A.D., The safety valve and climate policy. (In: Energy Policy, Vol 32, Issue 4, March 2004, p 481-491)

and hence more desirable.⁴³ Generally, the cap-and-trade system has been viewed as more efficient and effective and many of the criticisms of emissions trading seem to be targeted at baseline-and-credit rather than cap-and-trade schemes. The next chapter will thus introduce an economics example of the rationale behind emissions trading with cap-and-trade without a safety valve, e.g. the EU ETS.

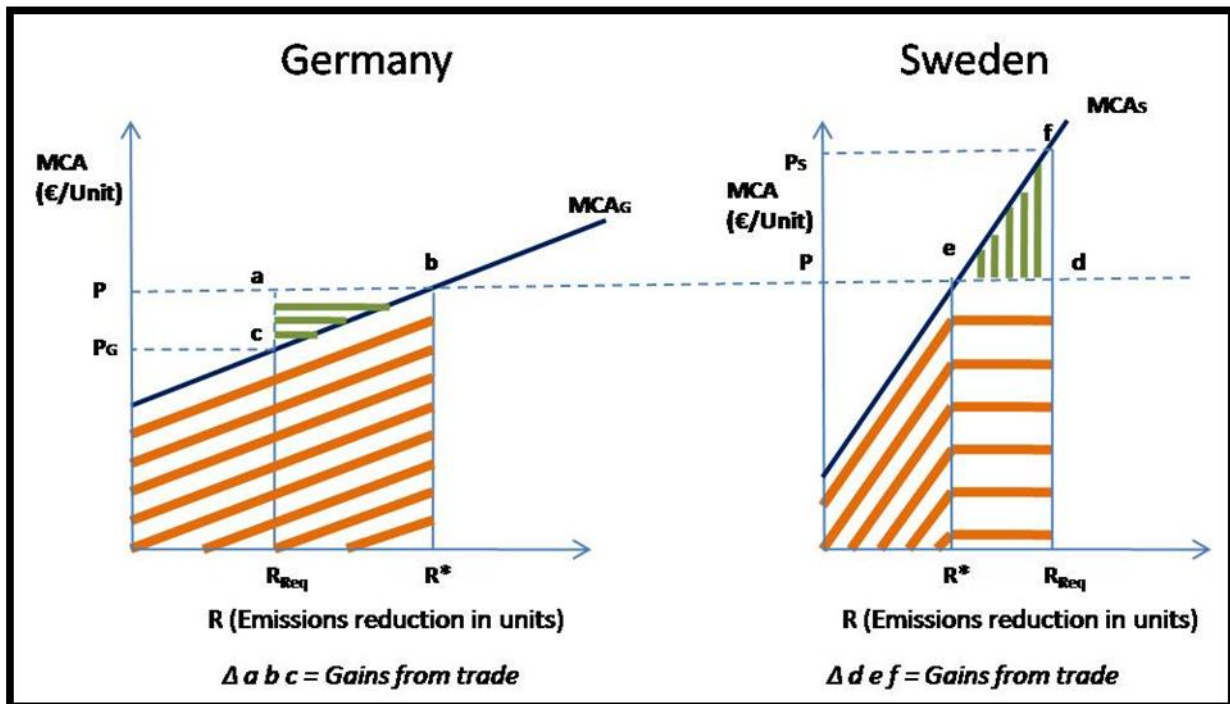
2.1.6 Economics of international emissions trading

This section will elaborate on the last section and present a straightforward example of the economics of emissions trading where two countries are participating in a cap-and-trade scheme such as the EU ETS. The rationale behind the emissions trading called cap-and-trade is that the institutional power sets a limit on the economic area's total carbon output and then issues permits or allowances to companies. Companies that emit more than they have allowances for have to buy more or face stiff fines. Companies that emit less could sell the extras. In theory, the market would find the most efficient way to meet emissions standards, which the government would tighten over time. Another big question in relation to this is the distribution method of allowances, i.e. if they should be given away or auctioned to firms. This will be addressed in Chapter 2.2.1.1 about the EU ETS.

The following example is popular and constitutes a simple overview of the economics of international emissions trading. This example is not only valid on a national level, but it could be between two firms or even two subsidiaries in the same company as well. Consider two countries in Figure 2.11 below, Germany and Sweden, where the marginal cost of abatement (MCA) is higher in Sweden (MCA_S) than in Germany (MCA_G). The X-axis is inverted from the previous two figures in last chapter and is now showing the emissions reductions and not total emissions. Hence, the MCA curve is upward sloping because the marginal cost of reducing emissions assumed to be low when the reduction has been slight and high when it has been substantial.

⁴³ Environmental Finance homepage, Features, April 2000 – Kyoto Protocol: <http://www.environmental-finance.com/2000/featapr2.htm>

Figure 2.11: International emissions trading example



The required cap and reduction R_{Req} for each country is set by the institution in power, e.g. the EU, and each country can either reduce all the required amount of emissions by itself or it can choose to buy or sell in the market. P is the market price for carbon allowances. Germany can however abate its required amount at a marginal price of $P_G < P$, and it has the potential to profit if it abates more emissions than required internally. On the other side, Sweden can abate the required amount only at a price of P_S which is quite higher than the market price P . Thus, Sweden has the potential to profit if it abates fewer emissions than required internally and instead buys allowances for abatements elsewhere.

Through international emissions trading, created precisely to exploit different MCAs, Sweden would abate emissions until MCA_S intersects with P at R^* and buy emissions allowances from Germany for the price of P to fill up its required reduction quota. Sweden will have total abatement costs equal to the yellow-dashed area and its gains from trade would be the green-dashed area (d, e, f), reflecting the cost of purchasing $R_{Req} - R^*$ at a price (R^*, R_{Req}, d, e) from Germany and saving the costs of internal abatement in area (R^*, R_{Req}, f, e) at the same time. Germany sells $R^* - R_{Req}$ to Sweden at a unit price P while spending less than P on abatement. Germany's gains from trade will be the green-dashed area (a, b, c) since it spends less (R_{Req}, R^*, b, c) on internal abatements and earns more (R_{Req}, R^*, b, a) on selling. The two R^* represent the efficient allocations that arise from participating in emissions trading.

2.2 Existing markets of carbon emissions

This chapter will present the application of the economic theory presented in the previous section in today's existing carbon emissions markets. It is however not clear-cut for policy makers to utilize this theory because of the massive lack of perfect information about abatement costs and when it comes to political values and interests such as how to address the threats posed by climate change, and the rationality behind the cost of mitigating GHGs worldwide. One GHG can for example be far cheaper to mitigate than another both with regards to technology and geographical location. Today, various emission trading schemes exist inside and outside the scope of the Kyoto Protocol. This thesis finds it paramount to distinguish between compliance or regulated markets like the European Union Emissions Trading Scheme (EU ETS) and the various voluntary markets like the California Climate Change Register (CCCR). Basically, compliance markets are governed by an institutional power to generate demand, while voluntary markets are made for philanthropic and marketing reasons with currently no legally mandated reduction to guarantee demand.⁴⁴ This chapter will firstly introduce the existing and planned compliance markets, with focus on EU ETS, and secondly give a brief introduction to the various voluntary markets.

2.2.1 Compliance (regulated) markets

As previously stated, the only existent functioning cap-and-trade compliance carbon emissions market at the time of writing is the European Union GHG Emissions Trading Scheme. All together, the following compliance schemes have been/are effective or are being developed, using either cap-and-trade, baseline-and-credit or a mix⁴⁵:

Name	Type	Periods
European Union Emission Trading Scheme (EU ETS)	Cap-and-trade	2005-7 2008-12, 2013- ?
New South Wales (NSW) GHG Abatement Scheme (GGAS) in Australia	Baseline-and-credit	2003-?
New Zealand Emissions Trading Scheme (NZITS)	Cap-and-trade & Baseline-and-credit	2013-?
Canadian Emissions Trading Scheme (C ETS)	Baseline-and-credit	2010-?

⁴⁴ Bayon, Ricardo et.al. (2007): Voluntary Carbon Markets: A Business Guide to What They Are and How They Work. Earthscan Publications Ltd.

⁴⁵ IETA homepage, Introduction to Domestic Emission Trading Schemes: <http://www.ieta.org/ieta/www/pages/index.php?IdSiteTree=85>

2.2.1.1 *European Union Emission Trading Scheme (EU ETS)*

The European Union Greenhouse Gas Emission Trading Scheme (EU ETS) commenced operation in January 2005 as the largest multi-country, multi-sector carbon emission trading scheme world-wide in conjunction with the Kyoto Protocol.⁴⁶ The first phase was a “mandatory warm-up” and ran from January 2005 to December 2007, while the second phase is the mandatory Kyoto phase lasting five years from 2008-12. A third one, Phase III, will start in 2013 and allegedly last until 2020. The background for the third phase is The Integrated Energy and Climate change package from January 2007⁴⁷, endorsed by the European Council in March 2007, where Member States agreed to reduce the EU's greenhouse gas (GHG) emissions by 20% in 2020 compared to 1990 levels by increasing energy efficiency by 20% and increase the share of renewable energy to at least 20% by 2020.⁴⁸

In phase I and II, the scheme is mandatory for sectors listed in Annex I and covers almost half of the CO₂ emissions in the 27 Member States of the EU plus Iceland, Liechtenstein and Norway, from over 11,500 energy-intensive installations such as combustion and power plants, oil refineries and other carbon intensive factories.⁴⁹ The scheme may however be expanded to include other gases than CO₂ in the future.⁵⁰

The EU ETS is a cap-and-trade system, and National Allocation Plans (NAPs) are central in the determination of the number of allowances available. The NAPs fix the total quantity of CO₂ emissions that Member States grant to their companies, which can then be sold or bought internationally by the companies themselves. As the theory presented, by placing a cap on the total number of emission allowances, NAPs create the scarcity needed for a functioning market in allowances to develop, and in turn enables companies to limit or

⁴⁶ European Commission homepage, Environment, Climate Change: Emission Trading Scheme (EU ETS), <http://ec.europa.eu/environment/climat/emission.htm>

⁴⁷ European Commission homepage, Environment, Climate Change: The EU's Contribution to Shaping A Future Global Climate Change Regime, http://ec.europa.eu/environment/climat/future_action.htm

⁴⁸ European Commission homepage, Environment, Climate Change: EU ETS post 2012, http://ec.europa.eu/environment/climat/emission/ets_post2012_en.htm

⁴⁹ European Commission homepage, Press releases: Q&A on Emissions Trading and National Allocation Plans, <http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/05/84&format=HTML&aged=1&language=EN&guiLanguage=en>

⁵⁰ IETA homepage, EU ETS: <http://www.ieta.org/ieta/www/pages/index.php?IdSitePage=389>

reduce their emissions at least cost. Member States must ex-ante decide on how many allowances to allocate in total for the trading period and how many to grant to their installations. It is also mandatory for each Member State to have a national registry to ensure accurate accounting of all units available and traded.⁵¹ NAPs can be checked, rejected, adjusted and confirmed by the European Commission in dialogue with the Member States. The European Commission has the final say and is required to assess each NAP for compatibility with the criteria set out in the directives and with the EC Treaty.⁵² The companies are responsible for monitoring and reporting emissions and reports to Member States and the Commission, which keeps electronic registries to track allowances and where emissions reports will be subject to independent verification. The CO₂-producing installations in the Member States are required annually to surrender emission allowances equal to their emissions in the previous year before April 30th. So before April 30th, 2008 a company has to surrender the allowances that match the emissions for the year 2007 and so on.⁵³ This is called ‘surrendering’ of allowances, and for every ton of emissions that is not covered by an allowance a company will have to pay a penalty of €40 in the first phase and €100 thereafter. Borrowing or banking of allowances within the years of the period is allowed.⁵⁴

Free allocation vs. auctioning of allowances

Since the EU Member States are in charge of allocating allowances to installations, the allocation methods will be and have been a serious question of debate. There are two practices; whether to allocate them directly by giving them away, also called grandfathering, or to allocate them by auctioning. This is an important, albeit not dominant, theme of this thesis because the political decision of the choice of mix between these two will affect the pricing and volatility of EU allowances. There could have been written an entire thesis on this topic alone, and the following discussion is brief and will only reflect the theory and debate headlines.

⁵¹ European Commission homepage, EU ETS, CITL: http://ec.europa.eu/environment/climat/emission/citl_en.htm

⁵² European Commission homepage, Press releases: Q&A on national allocation plans for 2008-2012, <http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/06/2&format=HTML&aged=0&language=EN&guiLanguage=en>

⁵³ CAN Europe, “Emissions Trading in the EU”: <http://www.climnet.org/EUenergy/ET.html>

⁵⁴ European Commission homepage, Linking JI and CDM: Slide presentation summarising the proposal, <http://ec.europa.eu/environment/climat/pdf/linkingprojectcredits.pdf>

Grandfathering comes from the “grandfather clause” which is an exception that allows an old rule to continue to apply to some existing situations, when a new rule will apply to all future situations. When a new regime with emissions allowances comes into practice in the EU, the old power plants and industrial factories will be exempted and granted them for free. Since firms can abate emissions and sell allowances at market price or use them, the price of their products, e.g. electrical power, increases with the average market price for allowances. The market price is settled by the supply (number of allowances available in the system) and demand (cost of average CO₂ abatement). This has been the practice in most Member States and led to a windfall of firm profits, because giving allowances out for free rather than selling them does not change the underlying dynamics of price increases for consumers. This was also acknowledged by the European Commission in their statement that “...an allocation approach that gives all allowances for free to directly affected industries will have the overall effect of transferring some wealth from the broad public (in this case consumers) to those industries.”⁵⁵

Auctioning of allowances was adopted during phase I by four EU countries; Denmark, Ireland, Hungary and Lithuania. From the original EU ETS Directive, governments could auction up to 5% in phase I and up to 10% in phase II. A research article by Hepburn et al.⁵⁶ regarding the auctioning of EU ETS phase II allowances provides several points about the pros and cons of auctioning allowances. The technicalities of the auctioning itself are also thoroughly discussed, but will not be addressed here. One main insight is since abatement measures might increase the operating costs of companies, free allocation is essentially a one-off subsidy that helps companies maintain a good profit in the face of the higher operating costs in the short term. Auctioning, on the other hand, reduces the scale of that subsidy. However, free allocation or auctioning is concluded to not change competitiveness in the longer term. Another main insight is that auctioning of allowances can be used to dampen price volatility and offers the prospect of supporting a long-term price signal to aid investor confidence. It is also argued that auctioning will provide funds which the allocator can use for efficiency, rebates or other related subsidies.

⁵⁵ Williams-Derry, C., de Place, E., Why Free Allocation of Carbon Allowances Means Windfall Profits for Energy Companies at the Expense of Consumers (February 2008), Sightline Institute: http://www.sightline.org/research/energy/res_pubs/windfalls/windfalls

⁵⁶ Hepburn, Cameron et al., Auctioning of EU ETS phase II allowances: how and why?: www.climatepolicy.com

Linking with the market mechanisms of the Kyoto Protocol

The EU ETS is linked with the Kyoto Protocol's flexible mechanisms Joint Implementation (JI) and Clean Development Mechanism (CDM). These were briefly introduced under "UNFCCC" in Chapter 2.1.4, and will be further presented in this section. Linking EU ETS with the Kyoto Protocol implies a bridge between two different frameworks. The EU ETS is a cap-and-trade system while the JI/CDM of the Kyoto Protocol can be seen as a baseline-and-credit system where you generate credits from the emissions abated through a project. The most common projects are within energy efficiency, fuel switches, renewables and reduction of gases with a high GWP (see Figure 2.1) in factories. Furthermore, the units traded (this will be addressed in Chapter 3.2) and the regulatory context and institutions involved are different. While JI-projects can be within the EU (Annex I) countries, the CDM is only for projects in developing countries.

The CDM is considerably larger than the JI with 1,510 million units expected to be issued and available to trade until 2012 compared to JI's 250 million today's date.⁵⁷ While the global carbon market was worth €40 billion in 2007, the CDM market alone was worth €12 billion – an astounding 200% increase in value terms from 2006 and thus the secondary trading of CDM credits became the fastest growing segment within the carbon markets.⁵⁸ The largest host country for CDM-projects in 2007 was by far China with 62% of the relative share, followed by Indonesia, Brazil, India and Mexico together accounting for a relative share of 27%. The largest buyers in 2007 were UK (48%), Japan (15%) and Luxembourg (11%).⁵⁹ The reason for UK and Luxembourg's share is that the largest CDM buyers are private firms or banks in these locations that are willing to take on uncertainty and invest in these relatively risky projects. Eager Western bankers have spent billions of dollars capturing GHG gases, improving energy efficiency and building wind farms in developing countries to gain a first-mover advantage of this increasing market. The EU ETS is believed to account for 80% of all international GHG emissions trading, while Japan is believed to account for almost 10% through its investments in CDM-projects.⁶⁰ All CDM-projects have

⁵⁷ UNEP Risø Centre homepage: <http://cdmpipeline.org/>

⁵⁸ Point Carbon, "Carbon 2008 – Post-2012 is now", 2008-03-11. www.pointcarbon.com

⁵⁹ UNEP Risø Centre homepage, CDM pipeline analysis: <http://cdmpipeline.org/publications/CDMpipeline.xls>

⁶⁰ TSE Eyes Carbon Trading from 2009: Japan Corporate News online 2008-05-19: http://www.japancorp.net/Article.Asp?Art_ID=18254

to be carefully planned, registered and scrutinized by an independent firm, the local governments and finally the UNFCCC. This can require substantial upfront investments in a developing country. The supervising power, CDM Executive Board of the UNFCCC, is responsible for finally issuing the certified emissions reductions. The issuance of credits from CDM-projects first started to pick up in early 2006.⁶¹

A condition for the issue of credits in these projects in respect of the reductions achieved is that the projects result in real, measurable and long-term climate change benefits. All CDM projects must meet three key criteria. Firstly, the project must satisfy the criterion of encouraging *sustainable development*, whereby the host developing country gets access to more efficient technology than it otherwise would have. Secondly, the project must be *additional* to best practice in the relevant industry sector of the host country so that the emissions reductions are additional to those that otherwise would occur. I.e. the planned reductions would not occur without the additional monetary incentive provided by emission reductions credits. Thirdly, the project must be *supplemental* to that developing country's existing policy measures.⁶² Although the CDM is widely debated, the reason for these criteria is to give developing countries the opportunity to benefit from the transfer of technology, knowledge and expertise in accordance with the concept of sustainable development. Nonetheless, some critics argue that the scale of the investment has remained grossly insufficient and that the scheme gives poor countries a reason to avoid any sort of 'climate-friendly' regulation. Why spend money when someone else will pay you to do it?⁶³ These are of course huge challenges that could be argued to create a 'false market' for these credits. This is thus another important aspect of the political challenge this market faces.

The linking itself works through a conversion of JI/CDM credits into EU ETS allowances in order to maintain a single currency within the EU ETS. Participants in EU ETS can buy JI/CDM credits, deliver them to the national authority and get issued an allowance in exchange of it. This increases supply and is an important price signal. Hence, there will be a limit of the amount of JI/CDM credits that can be allowed into the EU ETS: As soon as JI/CDM credits amounting to 6% of initially allocated allowances for the trading

⁶¹ UNFCCC homepage of the Clean Development Mechanism (CDM): <http://cdm.unfccc.int/>

⁶² The Kyoto Protocol, Article 12: http://unfccc.int/essential_background/kyoto_protocol/items/1678.php

⁶³ The Economist 2008-06-07, "Climate change: A convenient truth, sadly ignored", p14-15

period have been converted, the European Commission must undertake a review and consider placing a limit on the credits that can be converted during the remainder of the trading period. Appendix 1 provides a Member State overview of the already set JI/CDM targets. Problems with linking the UNFCCC's International Transaction Log (ITL) with the EU counterpart, Community Independent Transaction Log (CITL) have however caused some delays in the availability of credits from the CDM system.⁶⁴ Furthermore, the EU has indicated willingness to link the EU ETS to trading schemes in other countries that have ratified the Kyoto protocol as well, but the results of this is still too early to say something about since the regulations and compliance of other schemes vary too much. The EU ETS and Kyoto Protocol do for example not allow credits from nuclear projects or "carbon sinks" such as planting forests to absorb CO₂.⁶⁵

2.2.1.2 Other compliance emissions trading schemes

There are a number of other compliance schemes already working and under way around the world. Some of them are still at the idea and planning stage, but might very well be operational within a few years. Some of the most recognized ones are the Regional Greenhouse Gas Initiative (RGGI) in the US, New South Wales Greenhouse Gas Abatement Scheme (NSW GGAS) in Australia, New Zealand Emissions Trading Scheme (NZETS) and the Canadian Emissions Trading Scheme.⁶⁶

The Regional Greenhouse Gas Initiative (RGGI) was established in April 2003 as a cooperative effort by a number of Northeast and Mid-Atlantic US states⁶⁷ to reduce carbon dioxide emissions in the region. The RGGI's goal is the design of a regional, multi-state cap-and-trade program initially covering carbon dioxide emissions from power plants in the region and then expanding the program to other kinds of sources. The scheme will commence with its initial features in 2009 and it will be the first compliance cap-and-trade

⁶⁴ UNFCCC website, ITL: http://unfccc.int/kyoto_protocol/registry_systems/itl/items/4065.php

⁶⁵ European Commission homepage, Press releases: Q&A Kyoto Protocol: <http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/03/154&format=HTML&aged=0&language=EN&guiLanguage=en>

⁶⁶ IETA homepage, Introduction to Domestic Emission Trading Schemes: <http://www.ieta.org/ieta/www/pages/index.php?IdSiteTree=85>

⁶⁷ The eight currently participating states are Connecticut, Delaware, Maine, Maryland, New Hampshire, New Jersey, New York, and Vermont. District of Columbia, Massachusetts, Pennsylvania, Rhode Island, the Eastern Canadian Provinces, and New Brunswick are observers in the process. <http://www.rggi.org/states.htm>

scheme in the US.⁶⁸ Most states have pledged full or close to full auctioning of the allowances, and a secondary market in which allowances are traded between compliance buyers, financials, and others are expected to emerge after the auctions.⁶⁹

The **NSW GGAS** commenced on January 1st, 2003 and was one of the first mandatory GHG emissions trading schemes in the world. Although not universal or close to the industrial coverage of the EU ETS, the scheme aims to reduce GHG emissions associated with the production and use of electricity and all the six GHGs in Figure 2.1 are covered. This is a baseline-and-credit scheme and electricity producers have a benchmark obligation assigned to their operation and can achieve their targets by offsetting their liability with credits created from renewable energy and low emission generation, tree planting and energy efficiency. Although the fines of not complying have been AU\$12.00 (~€7.30) and only a fraction of the GHG emissions of the area is covered, the scheme has been considered such a success that the NSW government announced it would extend the program from its current end date of 2012 to 2020. If the national politics change, however, NSW GGAS is planned to end and join the proposed National Emissions Trading Scheme of Australia of 2010.⁷⁰

Meanwhile, New Zealand and Canada are working on compliance emissions trading schemes as well. The **NZITS** early stages started with a Climate Change Response Act in 2002 and The Climate Change (Emissions Trading and Renewable Preference) Bill of the NZ parliament in December 2007.⁷¹ The plan is to introduce a cap-and-trade greenhouse gas emissions trading scheme in 2013 covering all sectors and all gases, linking it with baseline-and-credit schemes such as the CDM and no absolute limit on domestic emissions. Carbon sinks will also be allowed.⁷² **The Canadian Government** is working towards tough goals such as an emission-intensity reduction of 33% from 2006 levels in 2020. The period should start in 2010 and a variety of compliance mechanisms are put forward. Although not stated,

⁶⁸ RGGI homepage: <http://www.rggi.org/>

⁶⁹ Point Carbon report, "Carbon 2008 – Post-2012 is now":
<http://www.pointcarbon.com/research/carbonmarketresearch/analyst/1.912721>

⁷⁰ NSW GGAS homepage info: <http://www.greenhousegas.nsw.gov.au/>

⁷¹ Report: NZ "Climate Change (Emissions Trading and Renewable Preference) Bill":
<http://www.climatechange.govt.nz/nz-solutions/trading-scheme-reports.shtml>

⁷² Report: "How a New Zealand emissions trading scheme will work": <http://www.climatechange.govt.nz/nz-solutions/fast-facts.shtml>

it is looking like a baseline-and-credit system where firms can obtain credits by domestic abatement and trading, investing in technology funds that are promoting GHG reducing technologies, offset systems from other projects such as carbon sinks, being rewarded a one-time credit for early action and use the CDM with 10% of total target.⁷³

2.2.2 Voluntary markets

The ideas behind voluntary markets are mainly those behind compliance markets and the markets have a lot of the same characters when it comes to functionality and products traded. It can be argued that the voluntary markets try to resemble the compliance markets. Still, where compliance markets are strictly run by the government or other institutional powers and can protect the system with fines, voluntary carbon markets are largely unregulated and made for philanthropic and marketing reasons with currently no legally mandated reduction to guarantee demand. There are however situations where governments are interfering in voluntary markets, providing subsidies and even setting them up.⁷⁴ A good site of information about voluntary carbon markets is “Ecosystem Marketplace” by The Katoomba Group.⁷⁵ The site has gathered information from a number of clearing houses and valued the international over-the-counter (OTC) market at €210 million in 2007. The voluntary carbon markets are therefore dwarfed to 0.5% of the compliance markets’ capitalization of €40 billion in 2007. One of the reasons is the average voluntary CO₂e offset price of about €4.00 compared to the average price of 2008-12 EU allowances of €19.60 during the same year.⁷⁶ At the same time, the range of voluntary carbon credits was €1.10 - €190 while the EU allowances were €12.25 – €25.15 in 2007. This explains the less mature and stable nature of the voluntary markets. Because of the relatively small, uncertain and immature market for voluntary carbon credits, albeit argued as important by market players, this thesis will not discuss the background further. The next section will shortly introduce some of the most famous voluntary carbon emissions schemes and collaborations in order to get a sense of the way they work. The quantitative reduction targets and other numbers are will be avoided.

⁷³ Environment Canada: “Regulatory Framework for Industrial Greenhouse Gas Emissions”: http://www.ec.gc.ca/doc/virage-corner/2008-03/541_eng.htm

⁷⁴ Bayon, Ricardo et.al. (2007): Voluntary Carbon Markets: A Business Guide to What They Are and How They Work. Earthscan Publications Ltd.

⁷⁵ Katoomba Group’s Ecosystem Marketplace: <http://ecosystemmarketplace.com/>

⁷⁶ Ecosystem Marketplace, “State of the Voluntary Carbon Markets 2008”, 2008-05-08: http://ecosystemmarketplace.com/documents/cms_documents/2008_StateofVoluntaryCarbonMarket2.pdf

The United Kingdom Emissions Trading Scheme (UK ETS) was a pilot project prior to the EU ETS and a voluntary emissions trading system which started in April 2002 and closed in 2006. It was the first cross-industry, national GHG ETS in the world. Companies could choose to enter the scheme through a timed auction as a direct participant with absolute targets or caps, or through the Climate Change Levy Agreement which was an energy tax where companies could get a discount on the tax if they chose to make reductions through participation in the trading scheme.⁷⁷ The UK ETS thus allowed government and corporate early movers and to gain experience in the auction process and the trading system that the later schemes such as the EU ETS have entailed.

Japan commenced their voluntary emissions trading scheme in April 2006 with a CO₂ emissions quota trading system for 34 selected companies and corporate groups with national reduction targets similar to those in the Kyoto Protocol.⁷⁸ The system works more like a fund where the ministry subsidizes the installation cost of GHG emissions reduction equipment to help businesses that are actively attempting to reduce GHG emissions. In exchange for the subsidy, the participants are required to commit to a certain reduction in their GHG emissions. The scheme also allows them to trade GHG emission quotas to meet their reduction targets, e.g. through the CDM.⁷⁹ Today, the Tokyo Stock Exchange Group Inc is exploring the possibilities of establishing a carbon emissions trading market in Japan by 2009.⁸⁰

The US has some of the most complex and well-established voluntary markets and collaborations for GHG reductions. **The Chicago Climate Exchange® (CCX®)** is a self-regulatory exchange that administers the world's first multi-national and multi-sector marketplace for reducing and trading GHG emissions.⁸¹ It commenced in 2003 with a legally binding integrated trading system to reduce emissions of all six major GHGs with offset

⁷⁷ IETA homepage, UK ETS: <http://www.ieta.org/ieta/www/pages/index.php?IdSitePage=388>

⁷⁸ Ecosystem Marketplace, "Japan Carbon Finance": http://ecosystemmarketplace.com/pages/article.news.php?component_id=2346&component_version_id=3811&language_id=12

⁷⁹ IETA homepage, "Japan Launches Voluntary Emissions Trading Scheme", 2005-09-28: <http://www.ieta.org/ieta/www/pages/index.php?IdSitePage=962>

⁸⁰ TSE Eyes Carbon Trading from 2009: Japan Corporate News online 2008-05-19: http://www.japancorp.net/Article.Asp?Art_ID=18254

⁸¹ IETA homepage, Chicago Climate Exchange: <http://www.ieta.org/ieta/www/pages/index.php?IdSitePage=441>

projects worldwide. The CCX members make a voluntary but legally binding commitment to meet annual GHG emission reduction targets. The founder, chairman and CEO of CCX is Richard L. Sandor who previously in this thesis was introduced as the “father of emissions trading”. The CCX provides independent, third party verifications of reductions and offers their members to gain leadership recognition for taking early, credible and binding action to address climate change.⁸²

The Western Climate Initiative (WCI) is a collaboration between states or provinces of the western US, Canada and Mexico established in order to develop regional strategies to address climate change. WCI is identifying, evaluating and implementing collective and cooperative ways to reduce greenhouse gases in the region such as to develop a market-based, multi-sector mechanism to help achieve a GHG reduction goal. The partners will complete a design of a voluntary market-based mechanism in August 2008.⁸³

The California Climate Action Registry was established in 2001 by California statute as a non-profit voluntary registry which tracks and registers voluntary projects that reduce GHG emissions. The purpose is help companies and organizations with operations in the state to establish GHG emissions baselines against which any future GHG emission reduction requirements may be applied. The registry basically encourages voluntary actions to increase energy efficiency and reduce GHG emissions.⁸⁴ The sister organization, **The Climate Registry**, was set up in 2007 as a non-profit partnership that serves all of North America in the same way.⁸⁵ The Climate Registry for example manages **The Midwestern Greenhouse Gas Accord**, which is a regional agreement by six governors of states of the US Midwest. The Accord’s goals are to reduce GHG emissions, to develop a market-based and multi-sector cap-and-trade mechanism to help achieve those reduction targets and to create a regional transportation and storage infrastructure for CO₂ emissions.⁸⁶

⁸² CCX homepage, Overview: <http://www.chicagoclimatex.com/content.jsf?id=821>

⁸³ WCI homepage: <http://www.westernclimateinitiative.org/>

⁸⁴ California Climate Action Registry homepage: <http://www.climateregistry.org/>

⁸⁵ The Climate Registry homepage: <http://www.theclimateregistry.org/>

⁸⁶ Midwestern Governors Association news: <http://www.midwesterngovernors.org/govenergynov.htm>

3. The trading

This part of the thesis will move on to more practical parts of carbon emissions markets, namely the trading, with a main focus on the EU ETS. This part will move away from the fundamental economics behind emissions trading and turn to a more financial and investor specific view. The chapter will start off with introducing the types of products traded, move on to the exchanges where they are traded and the participants in the market and end with some facts and overview about the size of the market. Price developments and other analyses of the products will be kept on hold until the next chapter – Chapter 4.

3.1 Trading allowances

There are a number of different allowances and credits available for trading today. The line is usually drawn between baseline-and-credit voluntary offset credits products and compliance cap-and-trade allowances products.

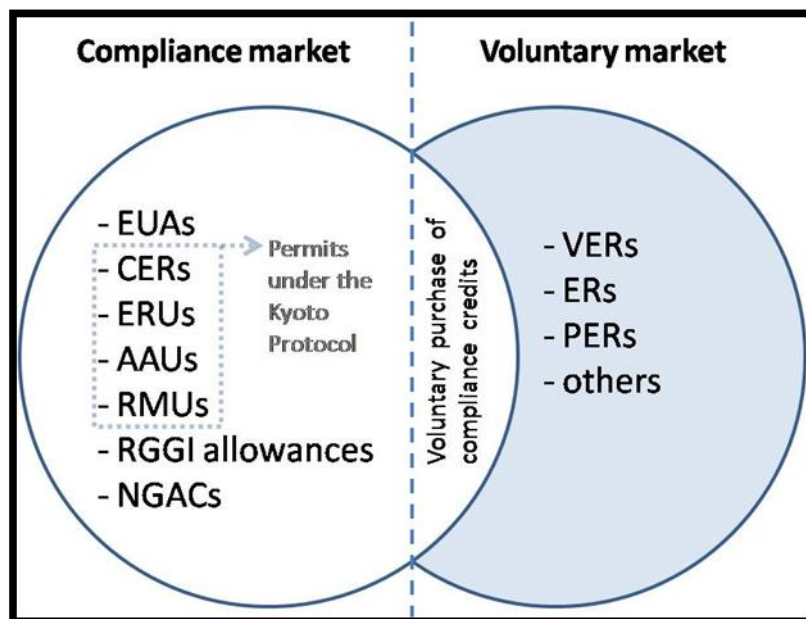
Basically, CO₂ equivalent units (CO₂e) as presented in Chapter 2.1.3 and Figure 2.1 are the ones that are being traded. Common for all underlying credits and allowances is that, whatever the name, they give the holder within the scheme a right to emit one ton CO₂e. The features of the right are dependent on the different products. GHGs are thus being commoditized and bought and sold as if they were barrels of oil or a ton of coal. The underlying commodities traded within the EU ETS are the European Union Allowances (EUAs) as issued under the scheme, and the allocation of EU allowances was introduced and discussed in Chapter 2.2.4.1 about the EU ETS. In addition, Certified Emission Reductions (CERs) from CDM-projects are tradable and can be converted into EUAs within the EU ETS in order to link with the flexible mechanisms of the Kyoto Protocol and maintain a single currency within the EU. The EUAs and CERs have slightly different prices in the market, because of the higher uncertainty of CERs and other reasons which will be discussed in Chapter 4. Today, EUAs and CERs are traded at spot price, as futures and futures options.⁸⁷

Before moving on with the EU ETS trading, there are a number of other products being traded in today's carbon emissions market world as well. Figure 3.1 is inspired by Point Carbon's report "Carbon 2008 – Post-2012 is now" and gives a good overview of the

⁸⁷ European Climate Exchange website, Products & Services, "ECX Products": <http://www.ecxeurope.com/>

underlying products that are being traded in today's compliance and voluntary markets. Note that the largely unregulated voluntary markets are allowed to buy compliance market allowances, but compliance markets participants are more constrained and cannot buy voluntary market credits. This will increase demand in the compliance market and decrease supply for its participants and could be an important price signal if the voluntary market's share were big enough. We know from the discussion in 2.2.5 that the voluntary carbon markets were dwarfed to 0.5% of the compliance markets' capitalization in 2007 and the scales in the figure can thus be a bit misleading.

Figure 3.1: Overview of carbon credits available



On the compliance market side, the following permits are dealt with in this thesis. (EUAs and CERs were presented in the previous paragraph.):

- **Emission Reduction Units (ERUs)** are Kyoto Protocol permits achieved through a Joint Implementation (JI) project as described in Chapter 2.2.4.1. The market created for the JI mechanism within Annex I countries has been active for years, with projects mainly started in New Zealand, Ukraine and Russia. However, no ERUs have so far been issued.⁸⁸

⁸⁸ UNFCCC website, Joint Implementation (JI): <http://ji.unfccc.int/index.html>

- **Assigned Amount Units (AAUs)** are Kyoto Protocol permits which the emissions-capped countries, Annex B, are allowed to buy and sell of their permitted emissions volumes. Since there currently is no international emissions trading based solely on the Kyoto Protocol, no known trades have yet taken place.⁸⁹ However, the market is potentially very large with nations as Ukraine, Latvia, Hungary and Russia expected to perform the first trades in 2008 or 2009.⁹⁰
- **Removal units (RMUs)** are Kyoto Protocol permits on the basis of land use, land-use change and forestry (LULUCF) activities such as reforestation. There are yet no registered trades of RMUs.⁹¹
- **RGGI allowances** are permits eligible for trading under the cap-and-trade scheme of The Regional Greenhouse Gas Initiative in the US described in Chapter 2.2.4.2.
- **NSW Greenhouse Abatement Certificates (NGACs)** are permits eligible for trading under the New South Wales GHG Abatement Scheme in Australia described in Chapter 2.2.4.2. NGACs are generated from Landfill Gas projects by organizations accredited by the scheme's Administrator. The market is however small and prices have fluctuated widely over the last years.⁹²

On the voluntary market side, the following permits are recognized in/by this thesis:

- **Verified Emission Reductions (VERs)** are the biggest group of voluntary market credits and are generated by small scale projects, sometimes village-level activities, which are assessed and verified by third party organizations rather than through the more costly and regulated UNFCCC that generates CERs. In order to ensure that buyers are purchasing a real emission reduction, VERs must be calculated according to a VER Standard. There are many types of VERs and several VER Standards around the world which each set out different rules and the way emission reductions

⁸⁹ UNFCCC website, Emissions Trading: http://unfccc.int/kyoto_protocol/mechanisms/emissions_trading/items/2731.php

⁹⁰ Point Carbon, "Carbon 2008 – Post-2012 is now":
<http://www.pointcarbon.com/research/carbonmarketresearch/analyst/1.912721>

⁹¹ UNFCCC website, Emissions Trading: http://unfccc.int/kyoto_protocol/mechanisms/emissions_trading/items/2731.php

⁹² "Is the GHG Laden Sky Falling Down?", The Demand Manager - News Focus 2007-11-01:
<http://www.demandmanager.com.au/News%20Focus%20-%20Edition%201.htm>

are measured.⁹³ This can illustrate the instability of this market, but a higher quality standard will thus be believed to decrease risk of failure and thus increase the price. A new Voluntary Carbon Standard⁹⁴ is now emerging as a leading standard.

- **Emissions Reductions (ERs)** are non-verified emissions reductions generated by projects that have not undergone a validation or verification process, but are contracted for purchase. The credits have been generated but not yet verified.⁹⁵
- **Prospective Emissions Reductions (PERs)** are transactions settled before ERs are delivered and typically used for forestry projects.⁹⁶

The products of the underlying EUAs and CERs are mostly the same. Futures are far most common, and an options market is under development. Swaps trading where one can bet on the price difference between CERs and EUAs are also possible. Spot trading with CERs will be available when the UNFCCC's International Transaction Log (ITL) is fully connected with the EU's CITL.⁹⁷ EUAs, as the world's most traded carbon emission commodity, will now be the focus of attention through the rest of this chapter.

The EUA contracts can be traded at spot price, but a much more significant derivatives market with futures and futures options have developed throughout Europe since trading started in 2005. Allowances traded in the EU ETS are not printed but held in accounts in electronic registries set up by the Member States. These registries are furthermore supervised by the EU's Community Independent Transaction Log (CITL) which checks each transaction for irregularities. The installations covered by the EU ETS need to have an "operator holding account" in its national registry while any individual or organization wishing to participate in the market will be able to open a "person holding account" in any of the registries.⁹⁸ In this way, the registries system keeps track of the ownership of allowances

⁹³ EcoSecurities website, Buying VERs:

http://www.ecosecurities.com/Home/Buying_from_our_portfolio/Buying_VERs/default.aspx

⁹⁴ The Voluntary Standard homepage: <http://www.v-c-s.org/>

⁹⁵ Barry, Dan. "The State and Trends in the Voluntary Carbon Market" 2007-11-19, Arreon Carbon (www.arreon.com): <http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File1566.ppt>

⁹⁶ Barry, Dan. "The State and Trends in the Voluntary Carbon Market" 2007-11-19, Arreon Carbon (www.arreon.com): <http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File1566.ppt>

⁹⁷ UNFCCC website, ITL: http://unfccc.int/kyoto_protocol/registry_systems/itl/items/4065.php

⁹⁸ EU ETS website, CITL: <http://ec.europa.eu/environment/ets/>

in the same way as a banking system keeps track of the ownership of money. According to the NAP of the Member States, each installation will receive its assigned amount at the beginning of the year, presumably February 28th although delays have and will happen, and the deadline for installations to submit its verified emissions report for the previous year is March 31st. Before April 30th the installation will have to surrender the number of allowances according to its previous year emissions.⁹⁹

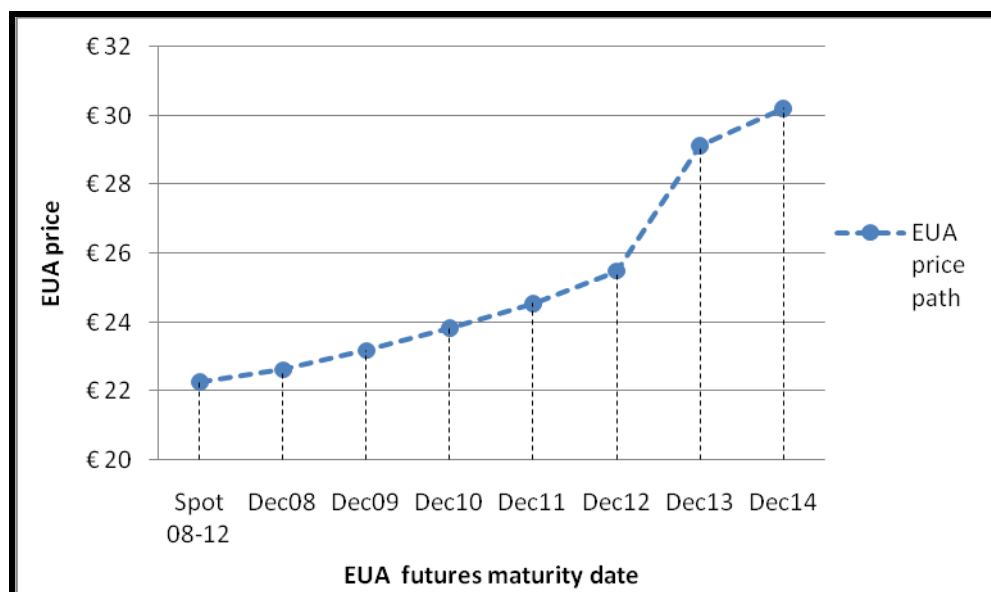
Although EUA contracts can be traded as spot price with immediately delivery, the standardized futures contracts with maturity in December each year are the ones most commonly traded. This is in order to be certain that all installations will have received their allowances for the year from the Member State.¹⁰⁰ A futures contract calls for delivery of a commodity at a specified delivery or maturity date, for an agreed-upon price, called the futures price, to be paid at contract maturity. Because the futures exchange specifies all the terms of the contract, the traders need bargain only over the futures price. The trader can take a long position which commits to purchasing the commodity on the delivery date, or a short position which commits to delivering the commodity at a contract maturity. To exit the commitment, the holder of a futures position has to sell his long position or buy back his short position, effectively closing out the futures position and its contract obligations.¹⁰¹ The various EUA products are named “EUA Dec08”, “EUA Dec09” et cetera with the front year, currently being “EUA Dec08”, as the most traded. Figure 3.2¹⁰² on the following page shows the average daily EUA second phase spot and futures price from January 2nd to May 22nd, 2008 plotted on a line.

⁹⁹ EU ETS website, about CITL, “Animated presentation on how the CITL works”:
http://ec.europa.eu/environment/climat/emission/citl_en.htm

¹⁰⁰ Climate Corporation, The EU Allowance market: <http://www.climatecorp.com/>

¹⁰¹ Bodie, Zvi et al. (2005): Investments. 6th Ed. (In Chapter 22: Futures Markets, p791-814). McGraw-Hill

¹⁰² Figure made by the author with official public price data from ECX website: Market Data, ECX Historical Data, EUA Futures: <http://www.ecxeurope.com/> . Spot prices from BlueNext: <http://www.blunext.eu>

Figure 3.2: EUA futures average price path, Jan-May 2008

The trajectory is upward sloping with a kink from the Dec12 to the Dec13 maturities. The upward or downward slope of this curve depends on who is most interested in security against future price movements, buyers or sellers, and this is likely to be related to the direction in which prices are generally expected to move.¹⁰³ This theoretical point of view implies that market players anticipate an increasing EUA price in the coming years e.g. due to a scarcity of allowances and credits available in the market. Buyers are thus willing to pay a higher price today for a future delivery than a spot delivery and sellers are less interested in this. The situation when futures prices are larger than the spot price is called a normal futures curve. A normal futures curve occurs when the market price is expected to increase and the holders of the front year or spot contract does not have clear benefits because of dividends, the convenience yield¹⁰⁴, low storage costs and cost of carry. An inverted market is the opposite of a normal futures curve.¹⁰⁵ Furthermore, EUAs can be seen as both an investment asset for speculators, hedgers, as well as a consumption asset for power plants. Carbon emissions do however differ a lot from physical commodities often linked with these trends because of a non-existent storage cost, cost of carry and convenience yield due to the strict regulatory nature of the EU ETS market. The reason for

¹⁰³ Hannesson, Rögnvaldur. (1998): Petroleum Economics. (In Chapter 1: Oil and oil prices, p11). Quorum Books

¹⁰⁴ Convenience yield is the monetary benefit from holding the physical asset and having it available when you need it.

¹⁰⁵ Bodie, Zvi et al. (2005): Investments. 6th Ed. (In Chapter 5: Futures Markets, p791-814). McGraw-Hill

the normal futures curve can be the ambitious EU 2020 environmental goals as explained in Chapter 2.2.4.1 and increased EU emissions over the last year.¹⁰⁶ Large uncertainties and rumors of a tighter cap in relation to the structure of a third EU ETS phase from 2013 can explain the leap from the 2012 contract to the 2013 contract.

In addition to futures themselves, a futures options market for EUAs has developed and standardized futures options contracts on the underlying EUA futures can be bought on various exchanges. An option is a financial derivative that represents a contract sold by one party, called the option writer, to another party, called the option holder. A call option gives the holder the right to purchase a futures contract for a specified price, called the exercise or strike price, on or before some specified expiration date. A put option gives the holder the right to sell a futures contract for a specified strike price on or before some expiration date. American options allow exercise before the specified expiration date, while European options only allow exercise on the expiry date.¹⁰⁷ European-style options are in most cases easier to value and are thus mostly used in the options derived from EUAs.¹⁰⁸ This thesis will not go into a valuation of EUA futures options, but assume that the price of EUAs are unknown in the future or at least not known with certainty, and thus non-stationary which is explained in Chapter 4. Nevertheless, the value of EUA futures options are dependent on the nature of the option, call or put, the underlying price of EUA futures, the strike price, life of the option, the volatility of the EUAs and the type of risk-free rate used.¹⁰⁹ Since the option gives the buyer a right and the seller an obligation, the buyer has received something of value. The amount the buyer pays the seller for the option is called the option premium and is far less than the strike or exercise price. Option contracts are thus far more volatile and risky than simple futures and their prices vary widely.

Since EUA futures contracts are the underlying commodity, options are believed to be most commonly used in connection with other derivatives or instruments in order to hedge risk and reduce risk from potential futures market movements. A liquid options

¹⁰⁶ “Industry emissions rise in carbon price boost”, Reuters:
<http://www.reuters.com/article/environmentNews/idUSL2383160120080523>

¹⁰⁷ Bodie, Zvi et al. (2005): Investments. 6th Ed. (In Chapter 20: Options Markets, p697-705). McGraw-Hill

¹⁰⁸ European Climate Exchange website, Products and Services, “What are Options? – Key points about Options”:
<http://www.ecxeurope.com/>

¹⁰⁹ Bodie, Zvi et al. (2005): Investments. 6th Ed. (In Chapter 21: Option Valuation, p748). McGraw-Hill

market is needed in order to hedge effectively. By doing this, it is possible for advanced speculators to earn on certain price movements or simply volatility of the underlying commodity itself. Four alternative trading strategies involving futures options are recognized:

1. A position in the futures option;
2. A position in the futures option and the underlying future;
3. A position in two or more future options of the same type (spread);
4. A position in a mixture of calls & puts (combination).¹¹⁰

Additionally, both futures and option futures of EUAs can be used in more sophisticated instruments by installations and speculators in connection with other commodity derivatives. In this way, one can for example hedge the price of coal futures with EUA futures since the demand for EUAs is believed to decrease when the price of carbon emission intensive coal increases relative to gas. As already discussed, this will force power plants substitution from coal to gas or other less carbon intensive fuels. Like this, the EUAs can be used to hedge power plants' and other installations' input costs as well as providing a market for speculators with diverse portfolios that bet on the future direction of the market. The strategy and products traded will often be influenced by the relative liquidity and size of the respective market. To this date, the EUA futures with maturity in December same year are by far the most important product on the various exchanges with typically 90% of the overall carbon trading.¹¹¹

¹¹⁰ Hull, John C. (2007): Fundamentals of Futures and Options markets. 6th Ed. (In Chapter 10: Trading Strategies Involving Options), Prentice Hall

¹¹¹ "EU member states not ready to issue EU allowances" 2008-02-06, Montel Powernews: <http://www.montelpowernews.com/> . Needs login to access news search.

3.2 Exchanges and their participants

In 2006 and 2007 the carbon trading market witnessed unprecedented growth in this asset class, not only from mayor CO₂-emitting industrial companies, but also from newer participants like commercial firms, banks and financial institutions that recognize the attractiveness of this market for managing risks and earning returns on capital. The exchanges trading EUAs are marketplaces that manage the marketing and product development of the underlying commodity. In addition, a clearinghouse acts as an intermediary between each pair of traders, acting as the short position for each long and as the long position for each short. In this way traders need not be concerned about the performance of the trader on the opposite side of the contract. On the exchange, gains and losses on a futures position are settled daily, called “marking to market”. This, together with the maintenance margin which is a critical value amount of equity that must be maintained in an account, is determined by the exchange’s clearinghouse and reviewed based on historical price fluctuations of the contract. This is in order to reduce credit risk to the exchange and the clearinghouse.¹¹²

As one of the goals of this thesis, some research of the emissions trading exchanges where products eligible for trading under the EU ETS has been done. All the exchanges trade electronically and provide standardized versions of the products on the underlying allowances or credits traded. A spot sample with data gathered from the different exchange’s websites on the settle prices has been conducted in Figure 3.3

Figure 3.3: Spot sample of settle prices gathered May 27th, 2008

	EUA-Dec08
European Climate Exchange	€ 26.34
Nord Pool	€ 26.30
European Energy Exchange	€ 26.37
BlueNext	€ 26.10
Energy Exchange Austria	N/A
Climex	N/A
The Green Exchange (NYMEX)	€ 26.40

and shows no or close to none arbitrage opportunities. The minor price differences observed can be caused by the opening hours of the exchange, its liquidity at closing time or simply sampling error of the spot test. Figure 3.4 gives an overview of the seven leading emissions trading exchanges recognized by this thesis:

¹¹² European Climate Exchange website: “What Are Futures? – Margin”: <http://www.ecxeurope.com/>

Figure 3.4: Seven leading emissions trading exchanges trading EU ETS related products

Exchange name	Allowances/credits traded	Products	HQ location
European Climate Exchange	EUAs; CERs	Futures; Options	London, UK
Nord Pool	EUAs; CERs	Futures; Spot	Oslo, Norway
BlueNext	EUAs; CERs	Futures; Spot	Paris, France
European Energy Exchange	EUAs; CERs	Futures; Spot	Leipzig, Germany
The Green Exchange (NYMEX)	EUAs; CERs	Futures; Options	New York, US
Climex	EUAs; CERs; VERs	Futures; Spot; Auctions	The Netherlands
Energy Exchange Austria	EUAs	Spot; Auctions	Vienna, Austria

The European Climate Exchange (ECX) is owned by The Chicago Climate Exchange (CCX), which is the world's largest and North America's only voluntary and legally binding carbon credit exchange.¹¹³ The CCX commenced in December 2003, and the subsidiary ECX was launched in April 2005 and was listed and admitted to trading on the ICE Futures Europe's electronic platform. ECX is currently known as the most liquid, pan-European platform for carbon emissions trading, attracting over 85 % of the exchange-traded volume in the market.¹¹⁴ They are thus the biggest player in the market and offer futures and futures option contracts on both EUAs and CERs.

Nord Pool was the first exchange in the world to list EUA and CER contracts, in February 2005 and June 2007 respectively. It is Europe's largest and most liquid marketplace for physical and financial power contracts, and the second largest exchange in EUA and CER trading, offering day-ahead spot contracts on EUAs and futures.¹¹⁵

BlueNext is the EU's leading spot exchange for EUAs and took over the carbon trading business of Powernext, which was launched in June 2005. It was established in

¹¹³ CCX website, Overview: <http://www.chicagoclimatex.com/content.jsf?id=821>

¹¹⁴ European Climate Exchange website, About ECX: <http://www.ecxeurope.com/>

¹¹⁵ Nord Pool website, Emissions derivatives: <http://www.nordpool.com/en/asa/Services/Emissions/>

December 2007 when NYSE Euronext¹¹⁶ and Caisse des Dépôt¹¹⁷ joined forces with a goal to become the world's largest exchange for environmental-related products.¹¹⁸

European Energy Exchange (EEX) is the leading energy exchange in Central Europe and has, together with Eurex¹¹⁹, been trading in the carbon emissions market since December 2007. They offer trading in EUA and CER futures and options on EUA futures.

The Green Exchange, as explained in Chapter 2.1.2, is the emissions trading part of the New York Mercantile Exchange (NYMEX), which is the world's largest physical commodities exchange. It was initially trading in NO_x and SO₂ contracts in relation to the US Acid Rain Program. The Green Exchange brands itself as the world's most comprehensive environmental marketplace and commenced trading with futures and futures options on EUAs and CERs in March 2008.¹²⁰

Climex is a relatively small exchange and commenced trading in 2008 with spot trading and auctioning of EUAs.¹²¹ **Energy Exchange Austria** is another small emissions trading exchange where auctions on EUA spot contracts are taking place.¹²²

These seven exchanges account for close to all trading of allowances and credits under the EU ETS. As the market matures, there has been a trend that international investors and speculators enter the increasing carbon emissions market of the EU. Other exchanges such as the National Commodity & Derivatives Exchange in Mumbai, India which started CERs trading in April 2008¹²³ and Japan's Tokyo Stock Exchange¹²⁴ are also positioning

¹¹⁶ NYSE Euronext is a holding company owning, among others, the world's largest stock exchange New York Stock Exchange (NYSE) and Euronext in Paris: <http://www.nyse.com/about/1088808971270.html>

¹¹⁷ Caisse des Dépôts is a public financial institution that performs public-interest missions on behalf of France's central, regional and local governments: <http://www.caissedesdepots.fr/spip.php?article57>

¹¹⁸ BlueNext website, About BlueNext: <http://www.bluenext.eu/>

¹¹⁹ Eurex is one of the world's largest derivatives exchanges and the leading clearing house in Europe: <http://www.eurexchange.com/>

¹²⁰ The Green Exchange powered by NYMEX, Overview: <http://www.greenfutures.com/overview/>

¹²¹ Climex website: <http://www.climex.com/about-climex.aspx>

¹²² Energy Exchange Austria, "Trading Concept": http://en.exaa.at/spotmarket_CO2/marketplace/trading_concept.html

¹²³ NCDEX website, "Carbon Credits": <http://www.ncdex.com/product/CER.aspx?comm=CERCC>

¹²⁴ Tokyo Stock Exchange website, "Carbon Market (Emissions Trading)": <http://www.tse.or.jp/english/rules/carbon-m/>

themselves to trade EU allowances in the future. Banks, hedge funds, pension funds and energy trading shops are beginning to seek products in order to trade actively in carbon emissions products, diversity portfolios or simply gain experience within the potentially huge market. Because of this, the next chapter will provide some analysis and interesting aspects of the liquid size of the global market compared to the more commonly traded stock markets around the world.

3.3 Size of market

This chapter will deal with the relative size of the global carbon market compared to stock markets and can be seen as a preface to Chapter 4, which will compare EUA price developments with the European stock markets. In order to define the size of the market, this thesis finds it most worthwhile to compare the total value of trading. Popular markets have more traders and products available which both are fundamental contributors to the overall total value. Note that the global carbon market also includes the voluntary markets although their share is believed to be relative small compared to the compliance markets.

Figure 3.5: Global carbon market size

		Increase:
2005:	€ 9.4 bn	
2006:	€ 22.5 bn	163 %
2007:	€ 40 bn	90 %
2008 (pred):	€ 63 bn	58 %

Figure 3.5 provides an overview of the total value of the global carbon market from 2005. The data are gathered from Point Carbon's¹²⁵ annual public carbon market reports¹²⁶, and shows an unprecedented growth of the asset class over the last few years. In order to add depth to the

predicted numbers, another carbon market firm, Rabo India Finance Ltd¹²⁷ in Mumbai, India, has estimated the global carbon market to be in the range of €60-70 billion in 2008.¹²⁸ The EU ETS alone (EUAs) is by Point Carbon expected to account for 75% of the global value in 2008 while it had over 80% in 2006 and around 70% in 2007. Increased allowance auctions and a surge in the options market are believed to be important factors to boost volumes of the market. Furthermore, the market for CERs from CDM projects is believed to account for 20% of this while ERUs from JI projects and other markets such as the RGGI, AAUs of the Kyoto Protocol and voluntary carbon offsets are believed to account for the rest.¹²⁹

¹²⁵ Point Carbon is a world-leading provider of independent news, analysis and consulting services for European and global power, gas and carbon markets: <http://www.pointcarbon.com/aboutus>

¹²⁶ Point Carbon's annual public carbon market reports: <http://www.pointcarbon.com/research/carbonmarketresearch/>

¹²⁷ Rabo IndiaFinance (RIF) website: http://www.rabobank.com/content/global/office_pages/Asia/India/Mumbai/mumbai.jsp

¹²⁸ "Carbon trading market likely to be €60-70 billion", The Hindu BusinessLine online news 2008-16-05: <http://www.thehindubusinessline.com/blnus/14161820.htm>

¹²⁹ Environmental Finance news, "Carbon market to be worth €63 billion in 2008 – Point Carbon" 2008-02-28: <http://www.environmental-finance.com/online/0228car.html>

To put things in perspective, the figure found in Appendix 3 shows the results from an analysis of the total value of the world's different stock markets in 2007 compared to the projected size of the carbon market in 2008. Data from the total value of share trading from the world's 51 reporting stock exchanges was gathered from The World Federation of Stock Exchanges, which is the global trade association for the exchange industry. Its exchanges account for over 97% of world stock market capitalization, and most of its exchange-traded futures, options, listed investment funds, and bonds.¹³⁰ The data was gathered in US Dollars and converted to Euros using the average 2007 EUR/USD exchange rate of 0.73.¹³¹ Figure 3.5 gives an interesting overview of the relative size of the stock markets and the carbon market's projected size in 2008 is merely 0.09% of the total capitalization of the world's stock exchanges in 2007. This discovery is an interesting fact and when comparing Figure 3.5 to 3.6, the 2008 global carbon emissions market is projected to be as large as the Warsaw Stock Exchange in Poland was in 2007.

¹³⁰ World Federation of Stock Exchanges website: <http://www.world-exchanges.org>

¹³¹ Using data from Yahoo! Finance: <http://finance.yahoo.com/q?s=USDEUR=X>

4. A price for CO₂ in the EU

This part deals with the price for carbon emission allowances. As previously presented, the largest and only existent compliance cap-and-trade market for carbon emissions is the EU ETS. This part will thus deal with the most traded products which are the Emissions Union Allowance (EUA) futures. The first section will introduce and discuss the main demand drivers of the EUA price, while the second will go through the historic price path and try to explain some of the central shifts that have occurred since April 22nd, 2005. The third section will present a financial analysis of the connection between the stock market and the price of carbon emissions allowances. This is an interesting area of study and maybe one of the most neglected factors when it comes to explaining what drives the EUA price. The moderately simple regression analysis used is not without controversy as the analysis' concluding discussion will reveal.

4.1 What determines the carbon price

The EUA price is, as in any other market, set by supply and demand. The EU created the ETS market, and supply is thus determined by the amount of allowances and carbon credits available to the market. Demand is set by the amount of emissions in relation to the overall allocation. The main fundamentals influencing the demand for EUAs are the weather, fuel and power prices, CDM/JI supply, political decisions as well as multiple other more or less recognizable factors. The interpretation of these fundamentals has become crucial in maturing carbon trading markets and requires complex models and comprehensive understanding by participants.

Weather is influential, as temperatures determine power demand and consumption. Precipitation increases the potential for hydropower production and wind the potential for wind turbines, causing shifts in dependence on fossil fuels for power generation. Fuel prices are important as the relative price differential between coal and gas will determine which of the fuels that will be used for power production, called substitution. Since gas prices are highly correlated with the price of oil because of substitution between them in certain sectors¹³² a soaring oil price is believed to boost carbon prices as well. Relatively cheaper

¹³² Hannesson, Rögnvaldur. (1998): Petroleum Economics. Quorum Books

coal compared to gas will increase GHG emissions, as more power production will be based on coal, which emits more GHGs per unit of output than gas. Higher CO₂ emissions will hence increase the carbon price.¹³³

Figure 4.1¹³⁴ on next page is based a web-survey conducted by Point Carbon and illustrates the short-term price drivers in the EU ETS. We do however have to differentiate between the short and long term in this instance. The industrial companies and utilities that are regulated by the market often operate project planning horizons of 30-50 years due to large investment costs. Hence, the long-term price signals are important in order to get a decent picture of how the market works and the market players are positioning themselves. Figure 4.2¹³⁵ illustrates the long-term price drivers in the EU-ETS.

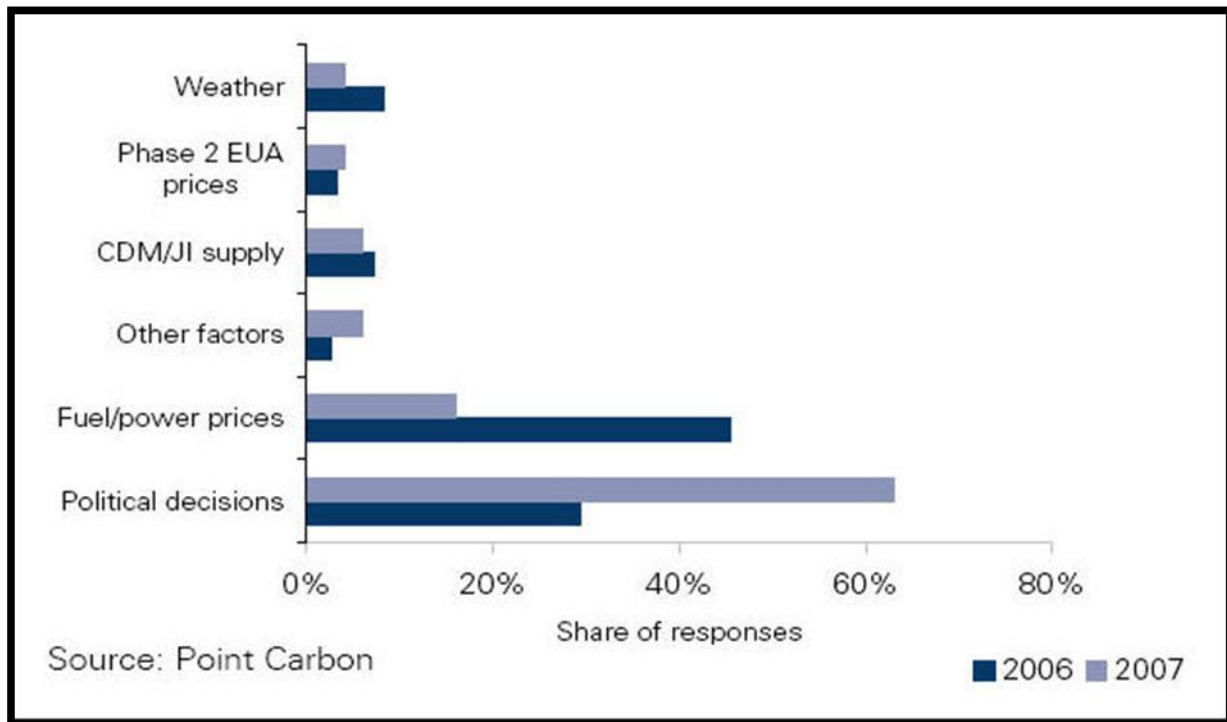
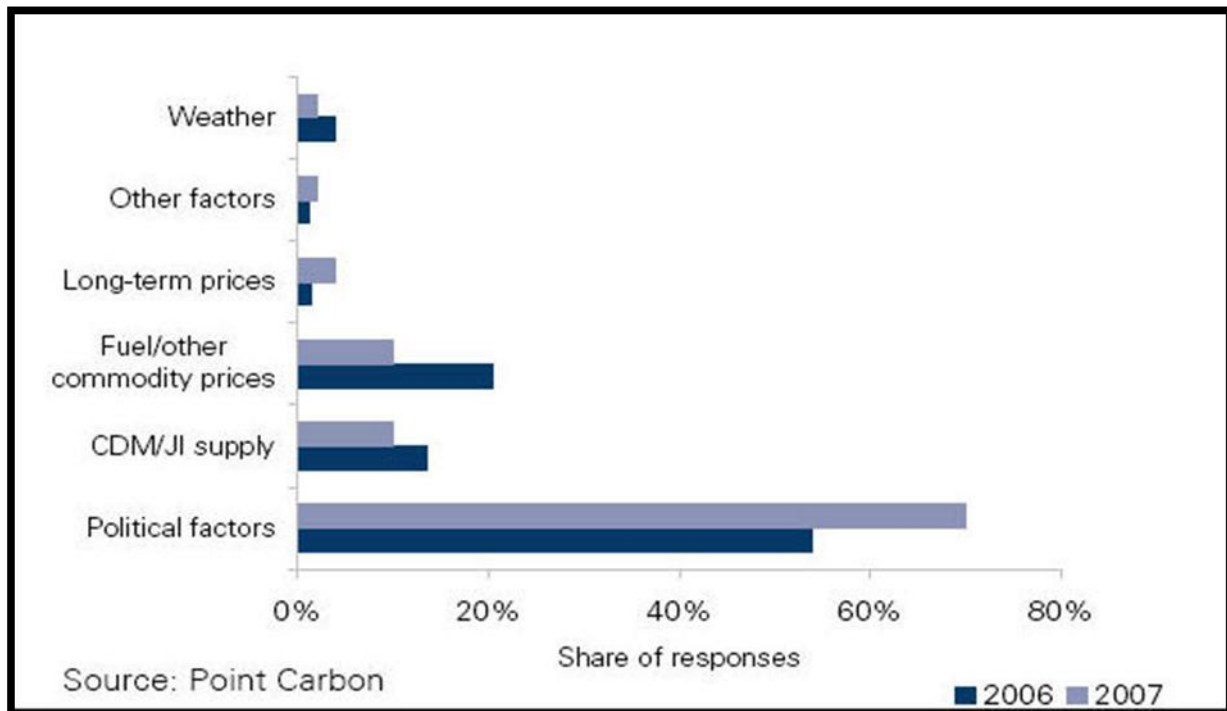
The underlying responses in this Point Carbon survey© was given from trading sectors such as finance and banking investors, CDM/JI project developers, academics, governments and carbon investment funds, and permission to use it in this thesis was granted by editor Kjetil Røine at Point Carbon. It becomes evident from Figure 4.1 that the carbon market is still, and will remain, a politically driven market, as supply and demand for allowances and credits are determined to a significant degree by political decisions - both in the short and long term.

Other factors are believed by this thesis to be overall economic conditions in the EU and liquidity factors in the carbon market itself. The overall economic conditions in the EU can be explained by the performance of stock markets where financial institutions are the biggest players. To make ends meet, financial institutions are showing a growing interest in the carbon markets and it would thus be instructive to look at the performance of the EU stock markets compared to the EUA futures price. This analysis will be performed in Chapter 4.3.

¹³³ "Carbon 2007 – A new climate for carbon trading", Point Carbon, 2007-03-13, www.pointcarbon.com

¹³⁴ "Carbon 2007 – A new climate for carbon trading", Point Carbon, 2007-03-13, p12, www.pointcarbon.com, (Copyrighted by Point Carbon, permission to use granted by editor Kjetil Røine)

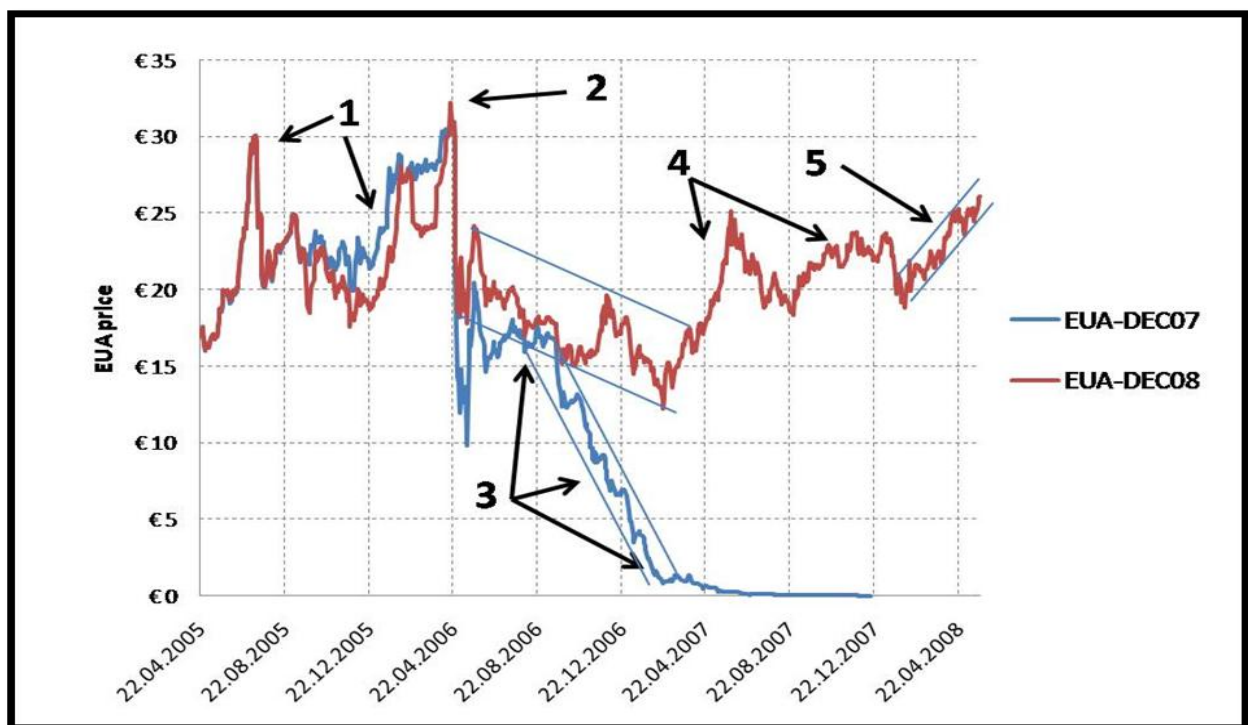
¹³⁵ "Carbon 2007 – A new climate for carbon trading", Point Carbon, 2007-03-13, p12, www.pointcarbon.com (Copyrighted by Point Carbon, permission to use granted by editor Kjetil Røine)

Figure 4.1: Short-term price drivers in the EU ETS**Figure 4.2: Long-term price drivers in the EU ETS**

4.2 Carbon price development

This chapter will examine the price path for EUAs since futures trading became available in early 2005. It is informative to look at this to get an overview of the price movements and the significant political factors controlling the market. The EU ETS was highly criticized because of the collapse of the price for EUAs in 2007, and this section, among other things, will try to explain how this happened. The focus will be on the main price drivers explained in the previous chapter. The market information is collected from Montel Powernews¹³⁶ which follows the carbon market with daily news and commentaries from traders. The fundamentals behind the price movements recognized are complex and will be addressed at best. For practical reasons, the specific sources will not be cited in the text but they are all taken from Montel Powernews' daily carbon market news updates. The historical price data is gathered from The European Climate Exchange¹³⁷. The time series data of ECX EUA Dec07 and EUA Dec08 from April 22nd 2005 to May 23rd, 2008 is plotted in Figure 4.3.

Figure 4.3: Historical Data – ECX EUA Futures Contract



As already noted, the ECX is the largest EUA exchange and it has been chosen as a focal point of the price development analysis. Both EUA futures products commenced

¹³⁶ Montel Powernews website: <http://www.montelpowernews.com/>. Login needed to access news search.

¹³⁷ European Climate Exchange website, Market Data, ECX Historical Data, EUA Futures: <http://www.ecxeurope.com/>

trading on April 22nd, 2005. The EUA Dec07 future's date of maturity was December 17th, 2007 when it settled at the lowest possible trading price of €0.01. Five main fundamental price changes and trend channels have been recognized with the fall in 2 and 3 for EUA Dec07 as the most momentous and commonly known:

4.2.1 April 22nd, 2005 – April 19th, 2006: The beginning

This period stretches from the beginning of the EUA Futures trade at the ECX in April 2005 until the prices reached a high on April 19th, 2006. The market was still small and it was thus very difficult to explain price movements due to the great number of price driving factors and the immaturity of the market. When the ECX commenced trading, there had been trading going both on Nord Pool and Over-the-counter (OTC) market for some time. Prices were at all-time-high around €17.00 and a reasonable explanation at the time was that the power sector was short on allowances, and the presence of speculative players in the market. However, both liquidity and the price saw an upward trend and reaching new record levels almost every day due to high oil prices, and dry weather conditions in Europe generating a lack of hydropower which needed to be compensated by thermal power production. The market reached a top of almost €30 in mid-June 2005 but softened quickly, allegedly because of the entrance of Eastern European sellers. The market price stayed around €20-25 until the end of the 2005 with fuel switching, political factors and the lack of liquidity in the market being the largest drivers. Power companies were the most active participants during this time. Increasing oil and gas prices together with cold and dry European weather conditions caused the EUA prices to swirl upwards at the beginning of 2006. As the trading entered April 2006, prices were around €30 and experts forecasted EUA prices of €40 and up in short time.

4.2.2 April 20th, 2006 – May 12th, 2006: The drop

As the April 30th deadline for companies in the EU ETS to surrender allowances from 2005 approached (See Chapter 3.1 about surrendering allowances), reports began being published throughout the EU revealing much lower carbon emissions than the market and regulators had expected. Consequently, EUA prices dropped over 10% from April 25th to April 26th and reached a low of about €10.00 on May 12th. The situation was brutal and very dramatic for market players, and as the over-allocation of EUAs came to light, traders put their entire trust in the market into doubt. Questions about the transparency of the carbon market and the way new information in emissions reports were released did cause major controversy

because of a data fiasco at the CITL causing emissions data from 20 countries being released before the advertised date.

4.2.3 May 15th, 2006 – April 12th, 2007: The downfall

Carbon prices firmed to trading around €15-21 after the low on May 12th, 2006. The front-year contracts were relatively stable but traders called the EUA market a wild card and nervous trading widely based on rumors developed. Fundamentals as the activity of German power plants and weather gained increasing influence in the market as well, and second phase EUA products as EUA Dec08 followed a downward trend. Bearish oil and gas prices and softening German power consumption caused the market to fall at the end of September 2006 and phase I products were trading downwards but around €11-13 until November. Some market players argued that because of unfamiliarity with trading, the surplus of EUAs was not coming to the market. The Stern Report was released around this time and NAPs for phase II came under discussion, causing phase II products to stop falling and trade sideways while phase I products dropped. Due to high selling activity of phase I products by EU-ETS carbon emitting companies because of over-allocation and the consequently plunging price, the phase I/phase II spread widened into the beginning of 2007. Because of this, the trading moved to phase II products. The phase I products that no one needed continued its fall towards €0.01 at maturity in December 2007. At the end of this period, some traders assumed that first phase allowances were pulling down the second, and rumors about phase II NAPs and the number of CERs allowed in the ETS flourished. Although still following a negative trend, the EUA Dec08 were positively influenced by the EU 2020 environmental goals announced at the end of February 2007 and cuts in the Member States' NAPs for phase II.

4.2.4 April 13th, 2007 – February 2nd, 2008: A maturing market

On April 13th, 2007 the EUA Dec08 broke through the technical resistance of the negative trend. This marked the final independence of the first phase products and was the start of a carbon price rise on the back of stronger German power consumption, bullish phase II policy news, power versus carbon hedging by power plants and natural sellers failing to enter the market. Experts were however surprised by the rise and suggested that it reflected the immaturity and illiquidity of the market at that point. In the meantime, however, the liquidity grew, new market players as financial institutions entered the market, and the European Climate Exchange (ECX) saw its average daily volume increase by 233% year on year. The

EUA Dec08 rose to €25.15 on May 29th with massive profit taking place the following week causing the price to fall back to around €21.00. Fundamentals as buying interest from power plants, other carbon emitting companies in the EU-ETS and financials, weather, fuel prices, German power and second phase NAPs as well as technical trading drove the maturing EUA market throughout the summer and the rest of 2007. At the beginning of 2008, rumors of plans by the European Commission to cut back on free allocation of allowances to companies after 2012, stronger German power and oil/gas prices gave the market a bullish sentiment. Rumors of an over-supply of CERs, selling and lack of faith in the market caused the EUA Dec08 to reaching a low of €18.84 on February 5th, 2008.

4.2.5 February 6th, 2008 – May 23rd, 2008: The recent rise

As seen in Figure 4.3, there has been an upward trend of the EUA Dec08 since February 6th, 2008 where prices have firmed from the low registered on February 5th. The reason to this recent rise is said to be the boost in oil and gas prices as well as a more mature market where fundamentals are able to control the prices more significantly. Although coal prices have firmed significantly over the same period, the relative rise of gas has attributed to the bullish sentiment on carbon. Up until the end of this thesis' analysis period, carbon prices rose to over €26 on the back of the strong energy commodity markets in addition to concerns about supply of CERs.

It can be said that the first phase of the EU ETS experience provided a preview of some of the pitfalls associated with 'making' a market. Both phases of the EU ETS have inspired a fair amount of debate regarding what exactly a unit CO₂e will be worth. Consequently, the single most important lesson from the first phase of the EU ETS was to not over-allocate allowances.

4.3 Analysis

The following steps will be taken in formulating this econometric analysis: First, a general statement of the problem has to be made. Note that the author has not found any previous studies on this specific area. Second, the formulation and presentation of the theory relevant for performing the analysis will be discussed. Third, the collection of data and statistical interpretation of the model will be presented. The fourth section will present the analysis and evaluate the model from a theoretical perspective with respect to the problems initially posed. If findings are sufficient, a fifth conclusion part will try to evaluate whether the outcome is right, i.e. if special circumstances have caused it or if the outcome will sustain and be reliable in the future as well. The econometrics used in this analysis are kept simple and more complex models and analyses have been ruled out. Hence, be aware that this analysis model is unlikely to be able to completely capture every relevant real-world phenomenon, but it should present a sufficiently good approximation that will be useful for the purpose at hand.

4.3.1 Formulation of the theoretical problem

This analysis will assess if a relationship exists between returns on carbon emission futures and the rate of return on the overall stock market. We can introduce this by stating that in the way production and the overall economy (GPD) will influence energy used, the energy used will in turn increase emissions and influence the demand for carbon emissions. A booming economy would thus see a rise in carbon emission prices. In addition, Sam C. Syvertsen, a much sought after Carbon Emissions Trading lecturer and the Director of Analysis of Markedskraft ASA¹³⁸, one of Norway's leading power and carbon analysis and trading companies, has stated that one of the biggest analytical challenges in the carbon market is to discover a methodology to make a bridge between the short and long term price perspectives. The discount rate used is one of the biggest questions in of this theme. Power companies or financial institutions can invest and trade in carbon emissions products as an alternative to disinvest/sell their carbon emitting business or invest in other assets. Stock markets are the largest place to perform these alternatives for carbon market participants, and a discount rate of carbon emission products derived from the EU industry average would thus be a plausible solution. This chosen area of study is therefore the result of the big

¹³⁸ Markedskraft ASA website: <http://www.markedskraft.com/index.asp>

analytical challenges in the carbon market as well as a wish to provide a comprehensive, albeit easy to follow, overview of whether the carbon prices can be said to be influenced by stock markets. The last point is an important one since the analysis cannot explain which variable is dependent on which or whether there is a third variable influencing them both. This is called a spurious relationship and will be addressed later on.¹³⁹

4.3.2 Formulation of the model and presentation of relevant theory

This thesis will not go into developing a single discount rate, but simply look at the connection between the EU's largest stock markets and the price of carbon futures in order to create a Beta coefficient (β). The appropriate risk premium and discount rate for the carbon futures can then be calculated from a model such as the Capital Asset Pricing Model (CAPM)¹⁴⁰ or the Arbitrage Pricing Theory (APT)¹⁴¹. The beta measures the extent to which returns on an asset and the market move together. Formally, CAPM Beta for an asset i is defined as:

$$\beta_i = \frac{\text{Cov}(r_i, r_M)}{\sigma_M^2}$$

where r_i is the return of asset i , r_M the return of the market portfolio M and σ_M^2 the variance of M over a specified period of time. Covariance measures how much the return on two risky assets move in tandem. A positive covariance means that the asset returns move together, while a negative covariance means that the returns move inversely. Variance σ^2 and standard deviation σ is a measure of volatility and riskiness of an asset or portfolio. In this analysis,

¹³⁹ Brooks, Chris. (2002): Introductory econometrics for finance. (Page 367-368). Cambridge University Press

¹⁴⁰ CAPM is a model that gives a precise prediction of the relationship that we should observe between the risk of an asset and its expected return: $E r_i = r_f + \beta_i [E(r_m) - r_f]$. Assumptions: All investors aim to maximize utilities, are rational risk-averse, are price takers and cannot influence prices, can lend and borrow unlimited under the risk free rate of interest. Securities are highly divisible into small parcels. No transaction or taxation costs incurs. Source: Bodie, Zvi et al. (2005): Investments. 6th Ed. (In Chapter 9: The Capital Asset Pricing Model, p281-316). McGraw-Hill

¹⁴¹ APT is an asset pricing theory that is derived from a factor model, using diversification and arbitrage arguments. The theory describes the relationship between expected returns on securities, given that there are no opportunities to create wealth through risk-free arbitrage investments. Source: Bodie, Zvi et al. (2005): Investments. 6th Ed. (In Chapter 11: Arbitrage Pricing Theory, p343-363). McGraw-Hill

the two risky assets are carbon emission futures and the stock market portfolio. If β_i is greater than 1, the carbon emission futures' rate of return is more sensitive to changes in the level of the overall market than is the average asset. The CAPM is an estimation of the discount rate given that the asset is added to a well-diversified portfolio. There are heavy assumptions behind this model, see reference 140, and it is thus not believed to be perfectly applicable in the real world. CAPM is however widely used and it will be the theoretical basis of this part of the analysis. When using CAPM, the model only takes into account the market risk of the asset, i.e. the tendency of an asset's returns to respond to swings in the market, since it assumes all investors are well-diversified and not affected by individual risks in each asset (nonsystematic risk). In this case, the nonsystematic risk of EUA futures will be the main price drivers discussed in Chapter 4.1 such as weather and ETS policies.¹⁴²

Beta for financial use can be calculated directly from two time-series in a spread sheet or by using regression analysis. In practice it is common to use between two and five years of monthly returns in order to estimate Beta. Computing Beta with very short horizon returns (such as daily returns) may lead to problems related to non-synchronous trading. This will be explained and become evident in the first test. Regression analysis is one of the most important tools used in econometrics and is concerned with describing and evaluating the relationships between a given variable and one or more other variables. While dealing with relationships between variables, it is important to be aware of the difference between regression and correlation. The correlation between two variables measures the degree of linear association between them and it is not implied that changes in X cause changes in Y or vice versa. The correlations used in this analysis will also be explained in a significance perspective depicted from the P-value. The P-value of a test is the probability of observing a test statistic at least as extreme as the one computed given that the null hypothesis is true.¹⁴³ In a simple regression, the dependent variable (y) and the independent variable (x) are treated very differently. The y variable is assumed to be random and have a probability distribution while the x variable is assumed to be non-stochastic and have fixed values in repeated samples. Regression as a tool is thus more flexible and more powerful than correlation. Note, however, that as a general rule we cannot determine the value of y for a

¹⁴² Bodie, Zvi et al. (2005): Investments. 6th Ed. (In Chapter 9: The Capital Asset Pricing Model, p281-316). McGraw-Hill

¹⁴³ Keller, G., Warrack, B. (2003). Statistics for Management and Economics. Page 327. Brooks/Cole – Thomson Learning

value of x that is far outside the range of the sample values of x .¹⁴⁴ Finding a relationship between two variables and proving that this is a significant one is thus two different questions. It is important to assess how well the linear model fits the data. If the fit is poor, we should discard the linear model, draw the conclusions needed and perhaps seek another one.

The following null-hypothesis has been developed:

- H_0 : No linear relationship exists between returns on carbon emission futures and the rate of return on the overall stock market.

$$\beta = 0$$

The following alternative hypothesis has been developed:

- H_1 : A linear relationship exists between returns on carbon emission futures and the rate of return on the overall stock market.

$$\beta \neq 0$$

The null hypothesis specifies that there is no linear relationship, which means that the linear slope projected by the regression is 0, i.e. $\beta = 0$. We perform a two-tail test to determine whether there is sufficient evidence to infer that a linear relationship exists, $\beta \neq 0$. The alternative hypothesis test this.

A linear regression approximates a straight line y_t between the two data points in question. The mathematic description of the linear regression line in the following analysis is

$$y_t = \alpha + \beta x_t + \varepsilon_t$$

Coefficient α is a constant and coefficient β is the Beta already introduced. ε is a random disturbance term which is not be calculated, but added to the model to make it more realistic since all of the data points cannot lay exactly on a straight line.¹⁴⁵

¹⁴⁴ Brooks, Chris. (2002): Introductory econometrics for finance. (In Chapter 3: p42-43). Cambridge University Press

¹⁴⁵ Brooks, Chris. (2002): Introductory econometrics for finance. (In Chapter 3: p42-132). Cambridge University Press

Type I error occurs when we reject a true null hypothesis, and a Type II error is defined as not rejecting a false null hypothesis. A significance level of 5% is set in order to reject the null hypothesis, 2.5% on each side. Hence, a P-value under 0.025 on the constant will be needed to reject. The test statistic used is the ‘Student t distribution’ because of the limited amount of data and knowledge about the mean of the following samples:

$$t = \frac{y - \beta}{s_y}$$

where s_y is the standard error of y which is calculated by a formula with $v = n - 2$ degrees of freedom, where n is the number of observations. The critical value of t will thus be found separately in each test, and have to be smaller than the observed value in the analysis in order to reject the null hypothesis.¹⁴⁶

The null hypothesis does not initially say anything about the significance of the relationship. Because of this, the tests run will be interpreted in two ways: First, a Beta to be used in a CAPM of carbon emissions futures will be computed the best way possible. Second, the null hypothesis will be tested with a two-way significance level of 5%. This approach is in line with the formulation of the theoretical problem in 4.3.1. A regression analysis gives numerous outputs, and the test of Beta addresses only the question of whether there is enough evidence to infer that a linear relationship exists. But it will also be useful to measure another strength of that linear relationship: This regression analysis will also focus on the coefficient of determination, which is denoted R^2 . In financial analysis, the slope coefficient β is a measure of the asset’s market-related or systematic risk because it measures the volatility of the asset price that is related to the overall market volatility. An example: If $\beta_i = 0.70$ for asset i we will interpret this to mean that for each 1% increase in the market portfolio M , the average increase in asset i ’s return is 0.70%. R^2 measures the proportion of the total risk that is systematic, and if $R^2 = 45\%$, 45% of asset i ’s total risk is market related and 55% associated with events specific to asset i rather than the market. This is called

¹⁴⁶ Keller, G., Warrack, B. (2003). Statistics for Management and Economics. (In Chapter 8: Continuous Probability Distributions, p252-258). Brooks/Cole – Thomson Learning

nonsystematic risk.¹⁴⁷ In this case, as earlier mentioned, the nonsystematic risk of EUA futures will be the main price drivers discussed in Chapter 4.1 such as weather and ETS policies.

4.3.3 Collection of data and statistical interpretations

The data used in this analysis is market data gathered from European Climate Exchange (ECX) and STOXX Ltd. Publicly available historical data of EUA futures is gathered from the ECX website, using the EUA Dec08 futures contract as a benchmark and dependent y variable.¹⁴⁸ Broad stock data in order to create a market portfolio of the EU is gathered from the STOXX Ltd. website that provides the Dow Jones STOXX indices which have become Europe's leading indices over the last years.¹⁴⁹ The indices Dow Jones EURO STOXX 50® (SX5E) and Dow Jones EURO STOXX® TMI Electricity (SXEELC) have been chosen as best matches for this study although the EU area should not be confused with the smaller Eurozone. The SX5E is Europe's leading Blue-chip index for the Eurozone and covers 50 stocks from 12 Eurozone countries.¹⁵⁰ The SXEELC is a sector index and the Industry Classification Benchmark for major electricity companies in Europe and the Eurozone. SX5E or SXEELC will thus be the independent x variable. As already discussed, power companies in Europe are the largest carbon dioxide emitters and traders. It would thus be interesting to see the difference between an analysis concerning the market portfolio SX5E and the overall performance of power companies in SXEELC. Presumably, the systematic risk, β and R^2 , will be higher in the latter. The raw data used are time series data with a daily frequency from April 22nd, 2006 to May 23rd, 2008 which is consistent with the analysis in Chapter 4.2.

For a number of statistical reasons, it is preferable not to work directly with the price series of the data, and raw-price series are usually converted into series of returns. The series of returns can be simple or continuously compounded returns also called log-returns, which are achieved as follows:

¹⁴⁷ Keller, G., Warrack, B. (2003). Statistics for Management and Economics. (In Chapter 18: Simple Linear Regression and Correlation, p617-629). Brooks/Cole – Thomson Learning

¹⁴⁸ European Climate Exchange website, Market Data, ECX Historical Data, EUA Futures: <http://www.ecxeurope.com/>

¹⁴⁹ STOXX Ltd. is a joint venture of Deutsche Börse AG, Dow Jones & Company and SWX Swiss Exchange: <http://www.stoxx.com> (Login needed).

¹⁵⁰ Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.

Simple returns: $R_t = \frac{p_t - p_{t-1}}{p_{t-1}}$

Continuously compounded returns: $r_t = \ln\left(\frac{p_t}{p_{t-1}}\right)$

where: R_t denotes the simple return at time t

r_t denotes the continuously compounded return at time t

p_t denotes the asset price at time t

\ln denotes the natural logarithm

Since this is a financial analysis, the continuously compounded return will be used. There are two main reasons for this: Firstly, the concept of return in finance often relates to the return over an infinitesimally short period of time. The frequency of the compounding of the return does not matter and thus returns across assets can more easily be compared. Secondly, log returns are time-additive and are more likely to have desirable statistical properties such as normality.¹⁵¹

The software used to perform the regression analysis is Minitab 15 Statistical Software¹⁵² and Microsoft Excel.

4.3.4 Analysis outcome

This part will present the outcomes of the regression analysis. Firstly, descriptive analysis of the data used will be presented followed by the regression data and graphs. Secondly, interpretation and conclusion will be made. The four regression tests will first be discussed in relation to finding a Beta for CAPM, and second the significance of the relationship. These points should be dealt with independently by the reader. The fifth test is a correlation analysis with historic oil prices.

¹⁵¹ Brooks, Chris. (2002): Introductory econometrics for finance. (In Chapter 1: p1-11). Cambridge University Press

¹⁵² Minitab 15 Statistical Software by Minitab Inc.: <http://www.minitab.com/>

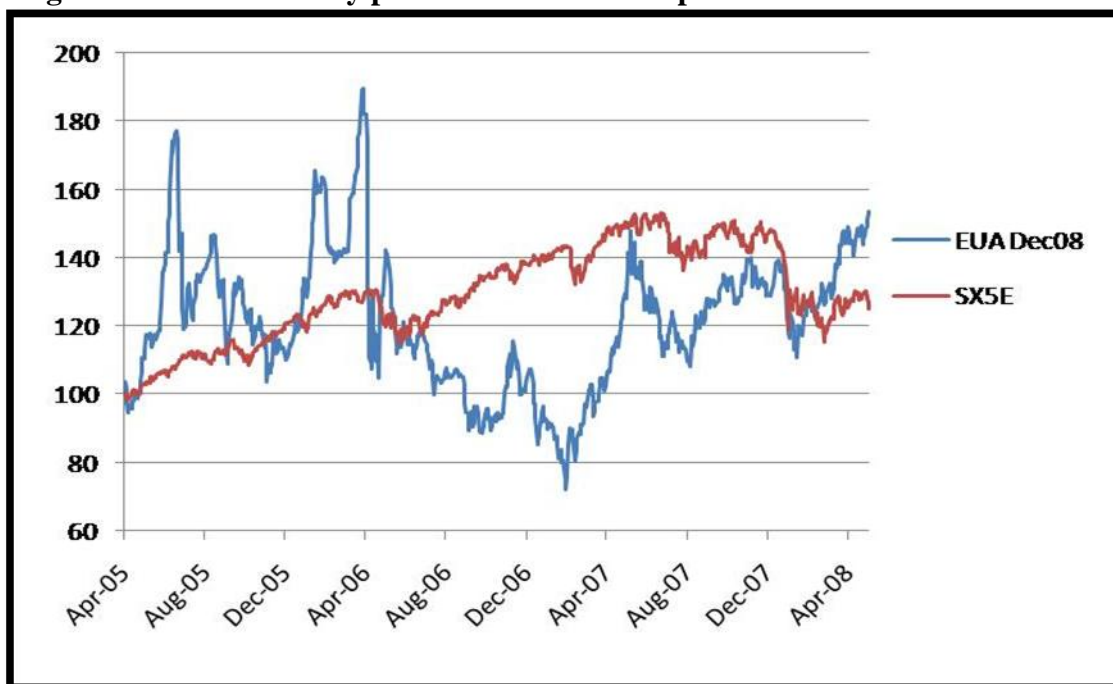
Five tests have been chosen:

- 1) Daily returns EUA Dec08 and SX5E, April 22nd, 2006 – May 23rd, 2008.
- 2) Monthly returns EUA Dec08 and SX5E, April 22nd, 2006 – May 23rd, 2008.
- 3) Weekly returns EUA Dec08 and SX5E, January 1st, 2008 – May 23rd, 2008
- 4) Monthly returns EUA Dec08 and SXEELC, April 22nd, 2006 – May 23rd, 2008.
- 5) A correlation analysis with oil, April 22nd, 2006 – May 23rd, 2008.

4.1.1.1 Test 1: Daily returns EUA Dec08 and SX5E, April 22nd, 2006 – May 23rd, 2008.

This test uses the daily log returns on closing prices for EUA Dec08 and SX5E in order to infer if a linear relationship exists. The daily data gathered from ECX and STOXX was not synchronized and had to be adjusted due to data missing on different dates throughout the period because of country specific holidays and other unknown factors. Figure 4.4 shows relative price and index developments of each time-series.

Figure 4.4: Relative daily price and index developments EUA Dec08 and SX5E



All Minitab outcomes from Test 1 can be found in Appendix 4.1. There are 784 observations in this test and descriptive analysis of the data shows among many other things a standard deviation (StDev) of 2.90% for EUA Dec08 and 1.14% for SX5E. This means that the

volatility of EUA Dec08 is higher than SX5E. This can also be interpreted from Figure 4.4. Critical value of t in this test is $t_{0.025,783} = 1.960$.¹⁵³ The histogram shows a decent normality around 0% return on each time series, and the correlation between the two is calculated to 0.035 which explains a positive, but extremely small relation. In addition, the high correlation P-Value of $0.321 > 0.025$ tells us that this is not significant.

The linear regression gave the following outcome:

$$y_t = \alpha + \beta x_t + \varepsilon_t = \text{EUA Dec08 (daily)} = 0.00052 + 0.0905 \text{ SX5E (daily)}$$

where

$$\beta = 0.0905 ; R^2 = 0.1\% ; T = 0.99 ; P = 0.321.$$

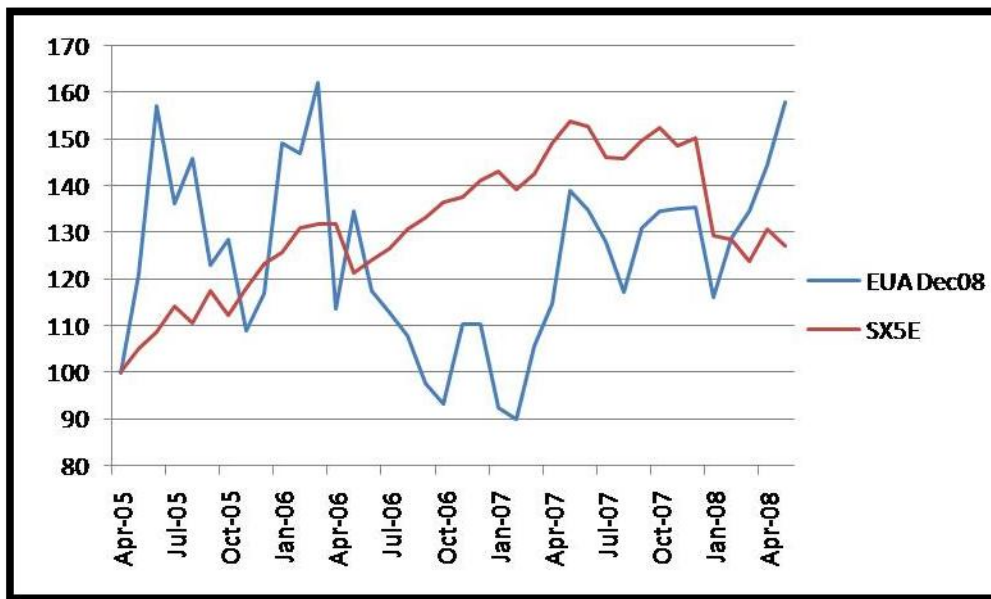
This would mean that for every 1% increase of SX5E, the EUA Dec08 would increase with 0.0905%. This relationship would explain only 0.1% of the total risk of EUA Dec08. But as already discussed, if Beta is computed with very short horizon returns (such as daily returns), it may lead to problems related to non-synchronous trading. It was thus to expect that the relationship and outcome of this test would be small and of little use.

The t-value is 0.99 and P-Value 0.321. The t value is under the critical value of 1.96 and P-Value is over its critical value of 0.025. Hence, this result is not statistically significant and H_0 , not surprisingly, cannot be rejected.

4.1.1.2 Test 2: Monthly returns EUA Dec08 and SX5E, April 22nd, 2006 – May 23rd, 2008.

This test is using the monthly log returns on the monthly closing prices for EUA Dec08 and SX5E in order to infer if a linear relationship exists. This test will follow best practice where it is common to use between two and five years of monthly returns in order to estimate Beta. Figure 4.5 shows relative price and index developments of each variable.

¹⁵³ Keller, G., Warrack, B. (2003). Statistics for Management and Economics. Table 8.2: Critical Values of t, p254. Brooks/Cole – Thomson Learning

Figure 4.5: Relative monthly price and index developments EUA Dec08 and SX5E

All Minitab outcomes from Test 2 can be found in Appendix 4.2. The number of observations is 37 and descriptive analysis of the data shows a StDev of 13.37% for EUA Dec08 and 4.22% for SX5E. As in the previous test, the volatility of EUA Dec08 is higher than SX5E. This time it is much higher because of the monthly data used which causes larger price leaps. EUA Dec08 shows a relatively good distribution around the mean, while SX5E reveals a more skewed position. Critical value of t in this test is $t_{0.025,36} = 2.030$.¹⁵⁴ The correlation between the two series is 0.064 with a P-Value of $0.706 > 0.025$ which is positive but very small and insignificant.

The linear regression gave the following outcome:

$$y_t = \alpha + \beta x_t + \varepsilon_t = \text{EUA Dec08} = 0.0110 + 0.203 \text{ SX5E}$$

where

$$\beta = 0.203 ; R^2 = 0.4\% ; T = 0.38 ; P = 0.706.$$

¹⁵⁴ Keller, G., Warrack, B. (2003). Statistics for Management and Economics. Table 8.2: Critical Values of t , p254. Brooks/Cole – Thomson Learning

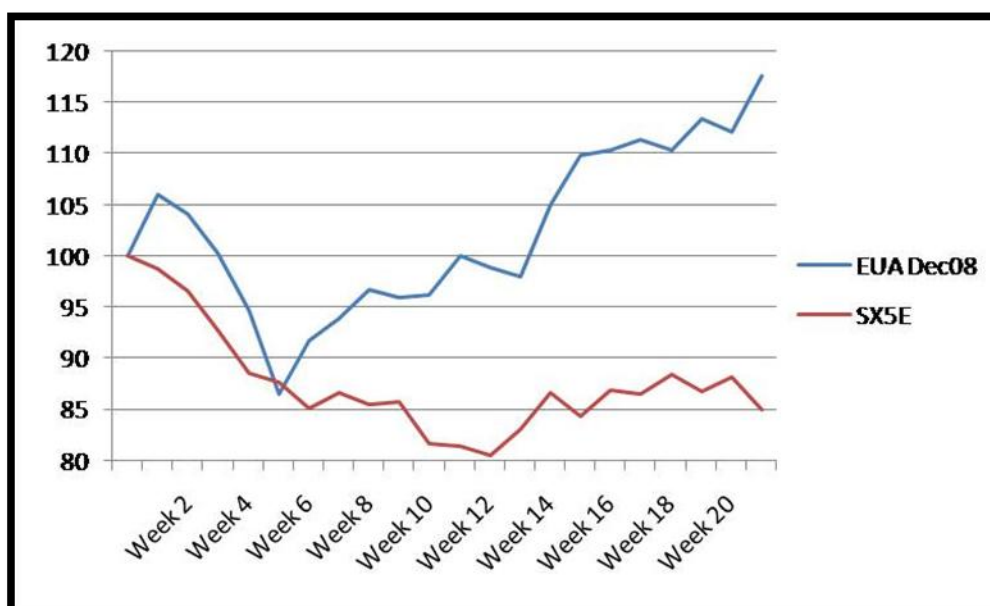
This would mean that for every 1% increase of SX5E, the EUA Dec08 would increase with 0.203%. This shows a much stronger relationship than in Test 1, but it would explain only 0.4% of the total risk of EUA Dec08. This means that there are other factors considerably more important for driving the price of EUAs. If best financial analysis practice should be used, a Beta of 0.203 would be the one to use in a CAPM calculation.

The t-value is 0.38 and P-Value 0.706. The t value is under the critical value of 2.03 and P-Value is over its critical value of 0.025. Hence, this result is not statistically significant and H_0 cannot be rejected.

4.1.1.3 Test 3: Weekly returns EUA Dec08 and SX5E, January 1st, 2008 – May 23rd, 2008

From Chapter 4.2 there are reasons to believe that the market for carbon emissions have matured over the last years. By matured means increased volume, liquidity and a wide range of different traders. The first phase of the EU ETS was hampered by large problems in the allocation of allowances and other political issues. Hence, would the second phase provide a more stable environment and closer relation with the EU stock markets? Since monthly data will provide a too small population and daily data can cause analysis flaws, this test will use weekly (Friday) closing prices from 2008 in order to see if a closer relation can be found. Figure 4.6 shows relative price and index developments of each variable. The world's and Europe's stock markets had a slump at the beginning of 2008 and EUA prices had a substantial drop during the same period. They have however risen relative to the stock market during the rest of the analysis period. May 23rd, 2008 is at the end of week 21.

Figure 4.6: Relative weekly price and index developments EUA Dec08 and SX5E in 2008



All Minitab outcomes from Test 3 can be found in Appendix 4.3. The number of observations is 21 and descriptive analysis of the data shows a StDev of 4.00% for EUA Dec08 and 2.62% for SX5E. Volatility is higher for EUAs in this test as well, but the difference is smaller than it was in Test 2. Critical value of t in this test is $t_{0.025,20} = 2.086$.¹⁵⁵ It is difficult to infer normality from the histograms, and correlation between the two series is calculated to be 0.139 with a P-Value of $0.547 > 0.025$. This is still a small insignificant positive correlation but far larger than the ones found in Test 1 and 2. It is not statistically significant.

The linear regression gave the following outcome:

$$y_t = \alpha + \beta x_t + \varepsilon_t = \text{EUA Dec08} = 0,00935 + 0,212 \text{ SX5E}$$

where

$$\beta = 0.212$$

$$R^2 = 1.9\%$$

$$\beta = 0.212 ; R^2 = 1.9\% ; T = 0.61 ; P = 0.547.$$

This would mean that for every 1% increase of SX5E, the EUA Dec08 would increase with 0.212%. This shows a similar relationship as in Test 2 and a Beta for EUAs of about 0.2 is thus believed to be desirable for a CAPM calculator. However, the linear equation explains only 1.9% of the total risk of EUA Dec08. This is larger than the previous tests, but there are still factors considerably more influential to the EUA market than the performance of EU stock markets.

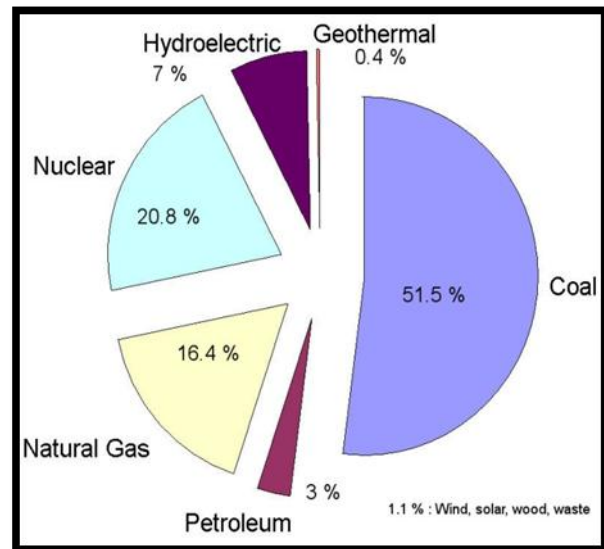
The t-value is 0.61 and P-Value 0.547. The t value is under the critical value of 2.086 and P-Value is over its critical value of 0.025. Hence, this result is not statistically significant and H_0 cannot be rejected.

¹⁵⁵ Keller, G., Warrack, B. (2003). Statistics for Management and Economics. Table 8.2: Critical Values of t, p254. Brooks/Cole – Thomson Learning

4.1.1.4 Test 4: Monthly returns EUA Dec08 and SXEELC, April 22nd, 2006 – May 23rd, 2008.

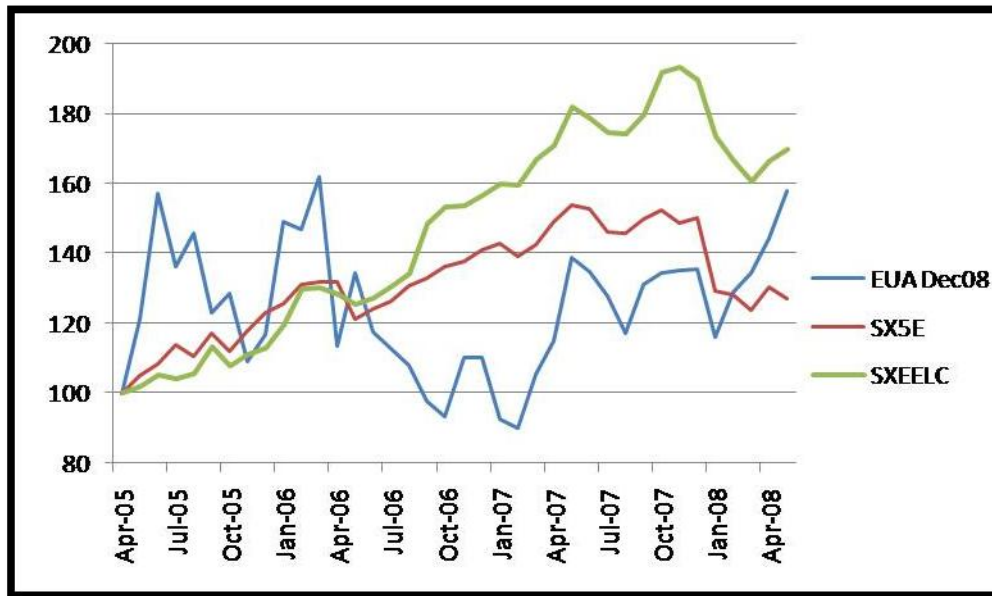
This test deals with the relationship between the EUA Dec08 futures contract and the Industry Classification Benchmark for major electricity companies in Europe and the Eurozone, SXEELC. Power companies in the EU are the largest carbon dioxide emitters and traders and it would be interesting to see the difference between an analysis concerning the market portfolio SX5E and the overall performance of power companies in SXEELC. Figure 4.7¹⁵⁶ describes the main energy sources of electrical power in 2005 and gives some in-depth backup to this fact. The overall main source is coal with 51.5%, and fossil fuels alone stand for over 70% of the world electrical power.

Figure 4.7: Sources of Electrical Power



Monthly returns for the whole data period have been chosen since this is the best practice in financial analysis for estimating Betas. Figure 4.8 shows relative price and index developments similar to Figure 4.5 but with the SXEELC added as the thick dark yellow line. One can clearly see the relationship between SX5E and SXEELC and the correlation between the two is calculated to 0.712 with P-Value of $0.00 < 0.025$ which is highly statistically significant.

¹⁵⁶ Energy Information Administration. 2005. "October 2005 Monthly Energy Review: Petroleum"; <<http://www.eia.doe.gov/emeu/aer/petro.html>>

Figure 4.8: Relative monthly price and index developments EUA Dec08 and SX5E

All Minitab outcomes from Test 4 can be found in Appendix 4.4. The descriptive statistics for EUA Dec08 monthly was given in Test 2 (StDev 13.37% and a relatively good distribution around the mean). The SXEELC StDev is 3.84% and the data is relatively well distributed around the mean as well. The number of observations is 37 as in Test 2. Critical value of t in this test is $t_{0.025,20} = 2.030$.¹⁵⁷ Correlation between the two is 0.132 with a P-Value of $0.435 > 0.025$. This is not statistically significant, but the computed correlation is however reasonably higher than 0.064 in Test 2.

The linear regression gave the following outcome:

$$y_t = \alpha + \beta x_t + \varepsilon_t = \text{EUA Dec08} = 0,0058 + 0,460 \text{ SXEELC}$$

where

$$\beta = 0.460 ; R^2 = 1.7\% ; T = 0.79 ; P = 0.435.$$

As expected, the Beta of 0.460 in this test is higher than the one of 0.203 in Test 2. This Beta explains 1.7% of the variation in EUA Dec08, which is 0.9% more than in Test 2.

¹⁵⁷ Keller, G., Warrack, B. (2003). Statistics for Management and Economics. Table 8.2: Critical Values of t , p254. Brooks/Cole – Thomson Learning

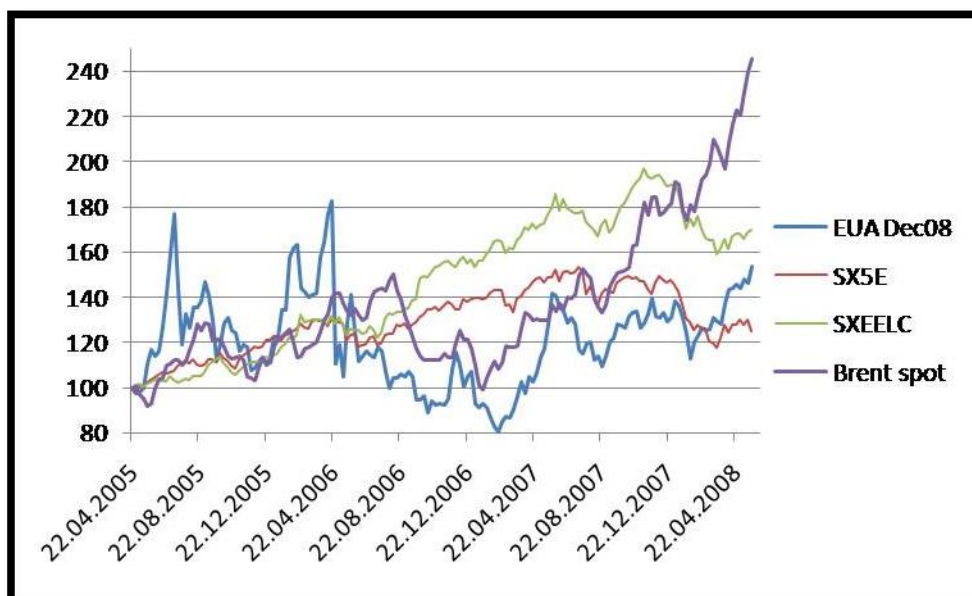
The t-value is 0.79 and P-Value 0.547. The t value is under the critical value of 2.03 but higher than 0.38 in Test 2. The P-Value is over its critical value of 0.025 but lower than 0.706 in Test 2. Nevertheless, this result is not statistically significant and H_0 cannot be rejected.

Unsurprisingly, we can infer that the market performances of electricity companies within the EU are more, but still not significantly, related to the carbon price than the overall stock markets are. It is however not given that if power companies are performing well, the demand for EUAs will increase. There are a lot of factors not introduced in these tests that are far more influential. This is a complex issue and the test was introduced to spot a difference from Test 2.

4.1.1.5 Test 5: A correlation analysis with oil, April 22nd, 2006 – May 23rd, 2008.

Fuel prices as oil and gas are from Figure 4.1 and 4.2 believed to account for 20% of the influence of carbon prices. This test will simply look at the correlation between oil prices and the price of EUAs. Historical Brent Crude Oil Spot prices are gathered from the US Energy Information Administration.¹⁵⁸ Figure 4.9 shows the relative weekly price development of the variables with the Brent spot and EUA Dec08 lines given more weight.

Figure 4.9: Relative weekly price and index developments



¹⁵⁸ Energy Information Administration website: http://tonto.eia.doe.gov/dnav/pet/pet_pri_wco_k_w.htm

This graph gives an interesting overview of the relative price developments. The correlation between Brent spot and EUA Dec08 is calculated to 0.137 with a P-Value of $0.082 > 0.025$. The P-Value is relatively lower than in the previous tests but still not statistically significant. Complete correlation calculations can be found in Appendix 4.5.

4.3.5 Analysis evaluation and conclusion

This analysis part has firstly dealt with finding a CAPM Beta for EUAs, and secondly with whether a linear relationship exists between returns on carbon emission futures and the rate of return on the overall stock market.

After test 2 and 3, the CAPM Beta for EUA Dec08 was set to be around 0.20. This means that for every 1% increase of the EU's stock market index SX5E, the EUA Dec08 will increase with 0.20%. This would be interesting theoretical news for the well-diversified investor. On the other hand, the relation could only explain 0.4 - 1.9% of the total risk of EUA Dec08. This means that more than 98% of the risk of EUA Dec08 is asset specific variation and in practice an investor would have to be exceptionally well-diversified to eliminate this risk.

Nonetheless, from the regression analyses, the null hypothesis could not be rejected by the outcomes of any of the tests. No test of correlation or regression constant was statistically significant in a two-way significance level of 5%. T values were too low and P-Values too high and would cause Type I error if accepted as appropriate to reject H_0 . We can thus infer that no linear relationship exists between returns on carbon emission futures (EUAs) and the rate of return on the overall European stock market.

Even so, this is an interesting find and as already introduced, there should be other factors considerably more important for driving the price of EUAs than the stock markets. They were all presented in Chapter 4.1. Other tests could be sought in order to sort this out. Such regression models on the price drivers from Ch 4.1 would prove to be very intricate and such regressions of this analysis could be argued to have spurious relationships. Such spurious relationships give impressions of a worthy link between two groups that is invalid when objectively examined. To emphasize a correlation or a simple relationship between two variables does not imply that one causes the other. A thorough evaluation needs to be done in order to figure out if A causes B, if B causes A or if a new factor C causes both A and B. Another option is that some unknown factor is the cause of the relationship between

A and B. A third option is that the relationship observed is so complex it can be labeled 'coincidental'. The last option is about self-reinforcing when A is causing B when B is causing A.

From the carbon price development in Chapter 4.2, major ups and downs in the market were explained by fuel prices, power companies selling or simply 'lack of faith in the market'. Since both financials and installations are trading in the market, psychological factors of a downturn in the stock market can easily cause a lack of faith in the alternative EUA market. The small relationship between stock markets and EUAs are complex but thus not believed to be entirely coincidental. Hence, it can be plausible to believe that other factors such as oil prices are influencing both stock markets and EUA prices over the period. The analysis in Test 5 shows signs of this but no conclusions can be made due to no statistically significant outcome.

This analysis part of the thesis has touched a lot of interesting themes when it comes to the carbon emission market. Although the analyses can only explain the relationship between April 22, 2005 and May 23, 2008, it is the author's view that the non-linear relationship between EUAs and European stock markets will persist in the short and middle term over the next years. A lot of uncertainties due to the political regulations of the EU ETS have caused great swings in the EUA-prices and the outcome of these analyses. And although the market have matured and liquidity improved, the uncertain political nature of the scheme and other nonsystematic changes will rule out most cyclical movements from investors and others trading on both stock markets and energy exchanges. If size increases and a global market emerge, the movements of a global carbon price in the long term would be related to the overall world production spiced with shocks of technological leaps and political and structural changes. Further analytical investigation and other detailed analyses regarding multiple regressions of all price drivers, cointegration and Error Correction Models were considered in relation to explain the price movements of EUA futures more thoroughly. An Error Correction Model is a dynamic model in which the movement of the variables in any periods is related to the previous period's gap from long-run equilibrium. Such a model requires strong relationships which the existing analyses could not provide. Consequently, because of a non-significant outcome, a lack of further price driver data and the current comprehensive nature of this thesis it was ruled out.

5. Concluding discussion and suggestions for further study

5.1 Summing up

This thesis has provided a comprehensive overview of the carbon market with focus on the EU ETS, and an analysis of the relation between European stock markets and the price of EUA futures. Chapter 2 provided a rational essential background about the emergence of emissions markets with history of emissions trading, the developments that lead to the Kyoto Protocol, and the basic economics behind it. Relatively uncomplicated economic textbook models were used to explain why emissions trading has emerged as a cost efficient solution to mitigate carbon emissions. Furthermore, the existing markets of carbon emissions were explained and a distinct line had to be drawn between the various voluntary markets and compliance markets as the EU ETS. Chapter 3 provided an overview of the more practical parts of carbon emissions markets, namely the trading. It introduced the variety of products that are eligible for trading today, the exchanges where the trading takes place and the participants. It furthermore presented an analysis of the relative size of the global carbon market compared to the world's stock exchanges which showed that the global carbon emissions market is projected to be 0.09% of the total capitalization of the world's stock exchanges in 2007 and thus as large as the Warsaw Stock Exchange in Poland was in 2007. Chapter 4 dealt with the price for carbon emissions allowances, what the price drivers are, and a broad explanation of the carbon price development of the EU ETS since carbon trading commenced in 2005. Moreover, the main analytical challenge of this thesis was presented in Chapter 4.5 and provided a comprehensive, albeit easy to follow, study of the relationship between the EUA Dec08 futures price and the main European stock markets from April 22, 2005 to May 23, 2008. The analysis found a CAPM Beta of 0.2 but showed no linear relationship exists between returns on EUA Dec08 futures and the rate of return on the overall European stock market.

5.2 Suggestions for further study

This thesis is comprehensive by nature and has touched a lot of interesting aspects of today's carbon emissions markets. The focus has been on providing the reader with a good overview

of the market and some analyses for backing up or rejecting hypotheses about the market. As mentioned in the introduction, the politics and market constantly changes and is believed to change fast in the near future as well. Hence, this chapter will finish up with providing some aspects of future developments that will be interesting to follow. These are not believed to be a major part of this thesis but to function as a stand point for further studies on the topics.

First of all, the development of the EU ETS will be an essential progress to follow. Several possible improvements of the EU ETS were scrutinized by Simon Tilford in a report released in October 2007 regarding “How to make EU emissions trading a success”¹⁵⁹. Three topics were recognized. First, a larger centralization of the scheme is suggested with longer time frames of the scheme’s periods, such as 30-50 years, in order to reflect the underlying industries’ investment horizons. An EU-wide, not country-wise, emission cap for industries in order to prevent unequal treatment in Member States that distorts competition is said to be needed. By expanding the EU ETS Commission’s resources one could secure a high degree of independence of the regulations. Political influence of the scheme has, as we saw in Chapter 4.1, been large. Where a central bank has to stabilize between price stability (inflation) and long-term growth and employment, the EU ETS Commission should be reformed to work to stabilize between the support of industries and long-term GHG emission cuts. New industrial sectors such as transport and agriculture could be introduced into the scheme as well but there are large problems with monitoring, regulating and tracking this as today’s date. Second, introducing large scale auctioning of allowances are being suggested, where auction profits could be used by governments fund renewable energy investments or carbon capture and storage (CCS) for coal-fired power plants.¹⁶⁰ Third, CCS is an approach that captures CO₂ from larger fossil power fuel plants and stores it instead of releasing it into the atmosphere. Technology for CCS is already commercial available but too high expenses and uncertainty about the storage has hindered its commercial development. It is however an important issue for the future since roughly half of the CO₂ emissions comes from large sources.¹⁶¹

¹⁵⁹ Tilford, S. (2007): “How to make EU emissions trading a success”. Chapter 4. Centre for European Reform

¹⁶⁰ Point Carbon Market News, 13 June, “UK opposition party will use auctioning money to fund CCS”: <http://www.pointcarbon.com/news/1.935081>

¹⁶¹ Freund, P., Kaarstad, O (2007): Keeping the Lights on. (Esp. in Chapter 5). Universitetsforlaget

The emergence of a US Emissions Trading System would be another interesting aspect for the future. An US ETS could quickly become the largest carbon trading scheme in the world, and linking it to the EU ETS would be important to avoid international competition distortion in certain industrial sectors because of structural differences between the schemes.¹⁶² If this happens, it will be increasingly important for the developed world to ensure the developing world's follow-up on this in order to prevent industry migration because of ever-increasing production cost due to high carbon prices in the EU and US. This could be achieved by e.g. comprehensive agreements with developing countries involving structural and major trade partners. The steps to prevent competition loss could be achieved by using revenues from auctioning to ensure short term tactical tax reliefs or compensations in the ETS, and restrict CDM-projects allowed only to complying developing countries. As an example, there would be little sense in Europeans striving to improve the environmental efficiency of their buildings, if the steel used to construct those buildings is being produced inefficiently in China.¹⁶³

The steps towards a global carbon market will be filled with tricky political obstacles or fundamental shifts due to new information of the observed climate change or technological shifts. It is however an interesting and important market to follow and a good example of basic economics being used in practice to provide the most cost efficient solution.

¹⁶² Tilford, S. (2007): "How to make EU emissions trading a success". Centre for European Reform

¹⁶³ Tilford, S. (2007): "How to make EU emissions trading a success". Chapter 6. Centre for European Reform

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Appendices

Appendix 1

EU-wide cap for 2008-2012, Summary information (all figures are annual):¹⁶⁴

Member State	1 st period cap	2005 verified emissions	Proposed cap 2008-2012	Cap allowed 2008-2012 (in relation to proposed)	Additional emissions in 2008-2012	JI/CDM limit 2008-2012 in %
Austria	33.0	33.4	32.8	30.7 (93.6%)	0.35	10
Belgium	62.1	55.58	63.3	58.5 (92.4%)	5.0	8.4
Bulgaria	42.3	40.6	67.6	42.3 (62.6%)	n.a.	12.55
Cyprus	5.7	5.1	7.12	5.48 (77%)	n.a.	10
Czech Rep.	97.6	82.5	101.9	86.8 (85.2%)	n.a.	10
Denmark	33.5	26.5	24.5	24.5 (100%)	0	17.01
Estonia	19	12.62	24.38	12.72 (52.2%)	0.31	0
Finland	45.5	33.1	39.6	37.6 (94.8%)	0.4	10
France	156.5	131.3	132.8	132.8 (100%)	5.1	13.5
Germany	499	474	482	453.1 (94%)	11.0	20
Greece	74.4	71.3	75.5	69.1 (91.5%)	n.a.	9
Hungary	31.3	26.0	30.7	26.9 (87.6%)	1.43	10
Ireland	22.3	22.4	22.6	22.3 (98.6%)	n.a.	10
Italy	223.1	225.5	209	195.8 (93.7%)	n.k.	14.99
Latvia	4.6	2.9	7.7	3.43 (44.5%)	n.a.	10
Lithuania	12.3	6.6	16.6	8.8 (53%)	0.05	20
Luxembourg	3.4	2.6	3.95	2.5 (63%)	n.a.	10
Malta	2.9	1.98	2.96	2.1 (71%)	n.a.	Tbd
Netherlands	95.3	80.35	90.4	85.8 (94.9%)	4.0	10
Poland	239.1	203.1	284.6	208.5 (73.3%)	6.3	10
Portugal	38.9	36.4	35.9	34.8 (96.9%)	0.77	10
Romania	74.8	70.8 ^[7]	95.7	75.9 (79.3%)	n.a.	10
Slovakia	30.5	25.2	41.3	30.9 (74.8%)	1.7	7
Slovenia	8.8	8.7	8.3	8.3 (100%)	n.a.	15.76
Spain	174.4	182.9	152.7	152.3 (99.7%)	6.7	ca. 20
Sweden	22.9	19.3	25.2	22.8 (90.5%)	2.0	10
UK	245.3	242.4	246.2	246.2 (100%)	9.5	8
SUM	2298.5	2122.16	2325.34	2080.93 (89.5%)	54.61	-

¹⁶⁴ European Commission homepage, Press release, "Emissions trading: EU-wide cap for 2008-2012 (...)": <http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/1614&format=HTML&aged=0&language=EN&guiLanguage=en#fn7>

Appendix 2

List of Annex I parties to the UNFCCC ¹⁶⁵

Australia	Portugal
Austria	Romania
Belarus **	Russian Federation **
Belgium	Slovakia **
Bulgaria	Slovenia **
Canada	Spain
Croatia **	Sweden
Czech Republic **	Switzerland
Denmark	Turkey **
Estonia	Ukraine **
European Community	United Kingdom of Great Britain and Northern Ireland
Finland	United States of America
France	
Germany	
Greece	
Hungary	* Observer State
Iceland	** Party for which there is a specific COP and/or CMP decision
Ireland	
Italy **	
Japan	
Latvia	
Liechtenstein **	
Lithuania	
Luxembourg	
Monaco **	
Netherlands	
New Zealand	
Norway	
Poland	

¹⁶⁵ Source: UNFCCC website, Parties and Observers: http://unfccc.int/parties_and_observers/items/2704.php

List of Non-Annex I Parties to the UNFCCC:

Afghanistan
Albania **
Algeria
Angola
Antigua and Barbuda
Argentina
Armenia **
Azerbaijan
Bahamas
Bahrain
Bangladesh
Barbados
Belize
Benin
Bhutan
Bolivia
Bosnia and Herzegovina
Botswana
Brazil
Burkina Faso
Burundi
Cambodia
Cameroon
Cape Verde
Central African Republic
Chad
Chile
China
Colombia
Comoros
Congo
Cook Islands
Costa Rica
Cuba
Cyprus
Côte d'Ivoire
Dem. People's Republic of Korea
Liberia
Libyan Arab Jamahiriya
Madagascar
Malawi
Malaysia
Maldives
Mali
Malta
Marshall Islands
Mauritania
Mauritius
Mexico
Micronesia (Federated States of)
Mongolia
Montenegro
Morocco
Mozambique
Democratic Republic of the Congo
Djibouti
Dominica
Dominican Republic
Ecuador
Egypt
El Salvador
Equatorial Guinea
Eritrea
Ethiopia
Fiji
The former Yugoslav Republic of Macedonia
Gabon
Gambia
Georgia
Ghana
Grenada
Guatemala
Guinea
Guinea-Bissau
Guyana
Haiti
Honduras
India
Indonesia
Iran (Islamic Republic of)
Israel
Jamaica
Jordan
Kazakhstan **
Kenya
Kiribati
Kuwait
Kyrgyzstan
Lao People's Democratic Republic
Lebanon
Lesotho
Saint Lucia
Saint Vincent and the Grenadines
Samoa
San Marino
Sao Tome and Principe
Saudi Arabia
Senegal
Serbia
Seychelles
Sierra Leone
Singapore
Solomon Islands
South Africa
Sri Lanka
Sudan
Suriname
Swaziland

Myanmar	Syrian Arab Republic
Namibia	Tajikistan
Nauru	Thailand
Nepal	Timor-Leste
Nicaragua	Togo
Niger	Tonga
Nigeria	Trinidad and Tobago
Niue	Tunisia
Oman	Turkmenistan **
Pakistan	Tuvalu
Palau	Uganda
Panama	United Arab Emirates
Papua New Guinea	United Republic of Tanzania
Paraguay	Uruguay
Peru	Uzbekistan **
Philippines	Vanuatu
Qatar	Venezuela (Bolivarian Republic of)
Republic of Korea	Viet Nam
Republic of Moldova **	Yemen
Rwanda	Zambia
Saint Kitts and Nevis	Zimbabwe

* Observer State ** Party for which there is a specific COP and/or CMP decision

List of Annex II parties to the UNFCCC:

Australia
 Austria
 Belgium
 Canada
 Denmark
 European Union
 Finland
 France
 Germany
 Greece
 Iceland
 Ireland
 Italy
 Japan
 Luxembourg
 Netherlands
 New Zealand
 Norway
 Portugal
 Spain
 Sweden
 Switzerland
 Turkey
 United Kingdom of Great Britain and Northern Ireland
 United States of America

List of Annex B Countries in UNFCCC:

Australia
Austria
Belgium
Bulgaria
Canada
Croatia
Czech Republic
Denmark
Estonia
Finland
France (including Monaco)
Germany
Greece
Hungary
Iceland
Ireland
Italy (including San Marino)
Japan
Latvia
Lithuania
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Romania
Russian Federation
Slovakia
Slovenia
Spain
Sweden
Switzerland (including Liechtenstein)
Ukraine
United Kingdom
United States of America

Appendix 3

Total value of world's exchanges:

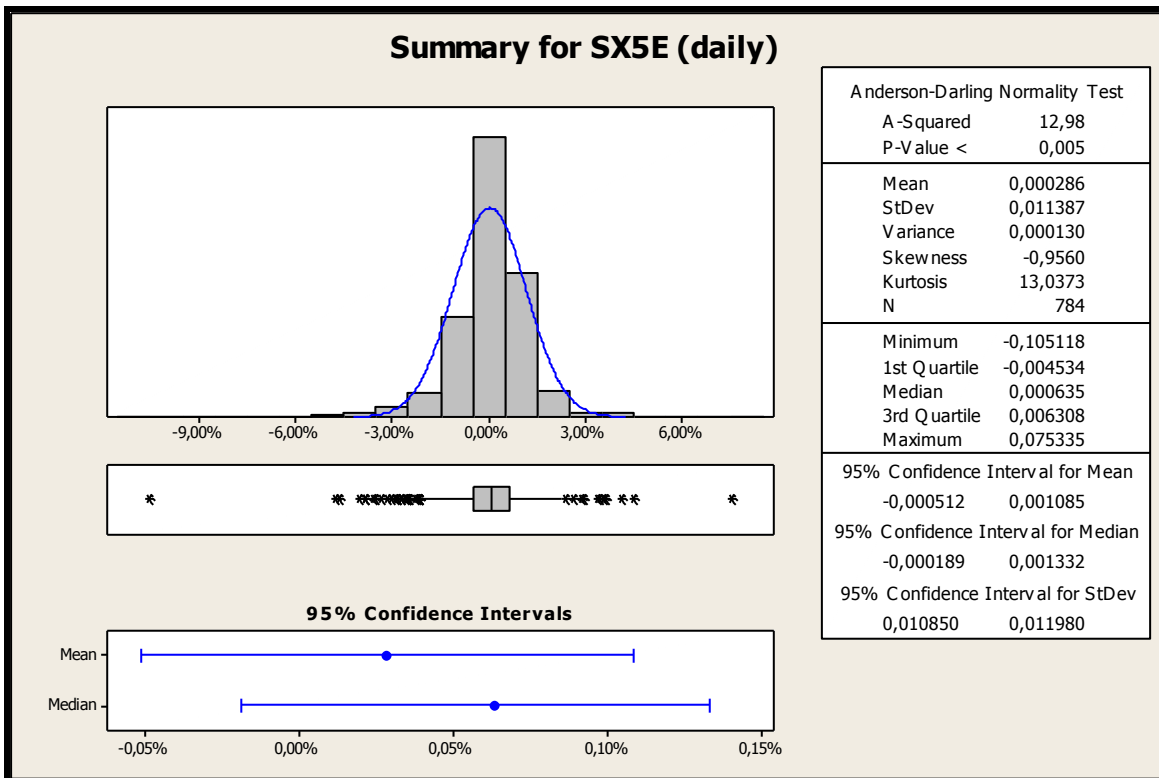
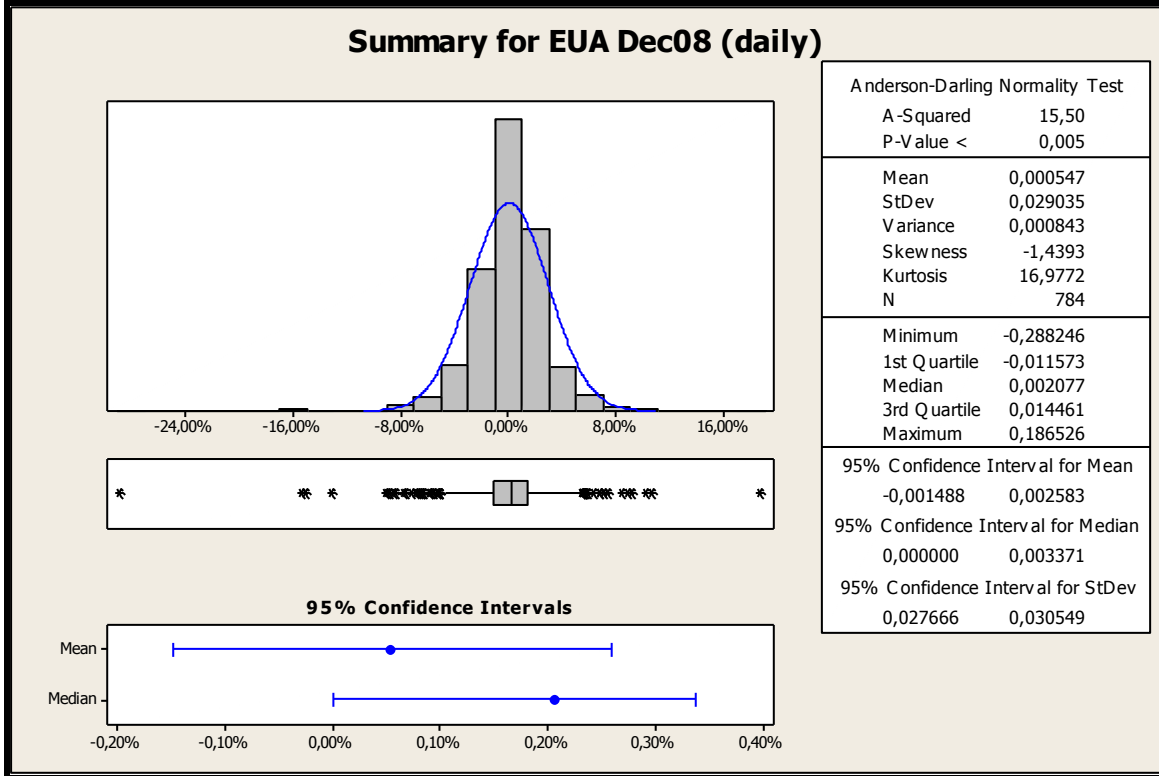
Global carbon market 2008 prediction (Point Carbon):		€ 63 000 millions	
All numbers in millions		0.7293	EUR/USD
Exchange	Year-to-date, 2007 (USD)	Euros, avg exch. rate 2007	
1	NYSE Group	29,209,971.2	21,302,832.0
2	Nasdaq	15,320,133.4	11,172,973.3
3	London SE	10,324,334.6	7,529,537.2
4	Tokyo SE Group	6,475,765.1	4,722,775.5
5	Euronext	5,648,451.9	4,119,416.0
6	Deutsche Börse	4,323,675.4	3,153,256.4
7	Shanghai SE	4,070,072.4	2,968,303.8
8	BME Spanish Exchanges	2,970,616.0	2,166,470.3
9	Borsa Italiana	2,311,826.9	1,686,015.4
10	Hong Kong Exchanges	2,138,698.5	1,559,752.8
11	Shenzhen SE	2,102,443.8	1,533,312.3
12	Korea Exchange ¹	2,010,958.7	1,466,592.2
13	Swiss Exchange ⁵	1,886,095.1	1,375,529.2
14	OMX Nordic Exchange ⁴	1,863,306.8	1,358,909.6
15	TSX Group	1,648,617.1	1,202,336.5
16	Australian SE	1,378,520.0	1,005,354.6
17	Taiwan SE Corp.	1,010,554.5	736,997.4
18	National Stock Exchange India	761,074.1	555,051.4
19	American SE	670,191.0	488,770.3
20	Sao Paulo SE	607,558.2	443,092.2
21	Oslo Børs	549,794.0	400,964.7
22	JSE	425,325.1	310,189.6
23	Singapore Exchange ²	381,622.3	278,317.1
24	Bombay SE	347,681.8	253,564.3
25	Istanbul SE	296,410.2	216,172.0
26	Osaka SE	264,434.4	192,852.0
27	Bursa Malaysia	169,405.0	123,547.0
28	Athens Exchange	169,404.7	123,546.9
29	Irish SE	137,029.9	99,935.9
30	Wiener Börse	130,082.6	94,869.2
31	Mexican Exchange	123,907.7	90,365.9
32	Thailand SE	118,259.7	86,246.8
33	Jakarta SE	114,468.7	83,482.0
34	Tel Aviv SE	101,178.9	73,789.8
35	Warsaw SE	87,948.7	64,141.0
36	Cairo & Alexandria SEs	60,502.5	44,124.5
37	Santiago SE	49,899.0	36,391.4
38	Budapest SE	47,551.1	34,679.0
39	Philippine SE	29,251.8	21,333.4
40	New Zealand Exchange	24,227.3	17,669.0
41	Colombia SE	16,849.7	12,288.5
TOTAL	\$100,417,083.3	€ 73,234,178.9	

* World carbon market 2008

*The last 10 exchanges were removed due to lack of space: Lima, Teheran, Buenos Aires, Cyprus, Ljubljana, Colombo, Mauritius, Luxembourg, Bermuda and Malta.

Appendix 4.1

Descriptive statistics:



Correlations: EUA Dec08 (daily); SX5E (daily)

Pearson correlation of EUA Dec08 (daily) and SX5E (daily) = 0,035
P-Value = 0,321

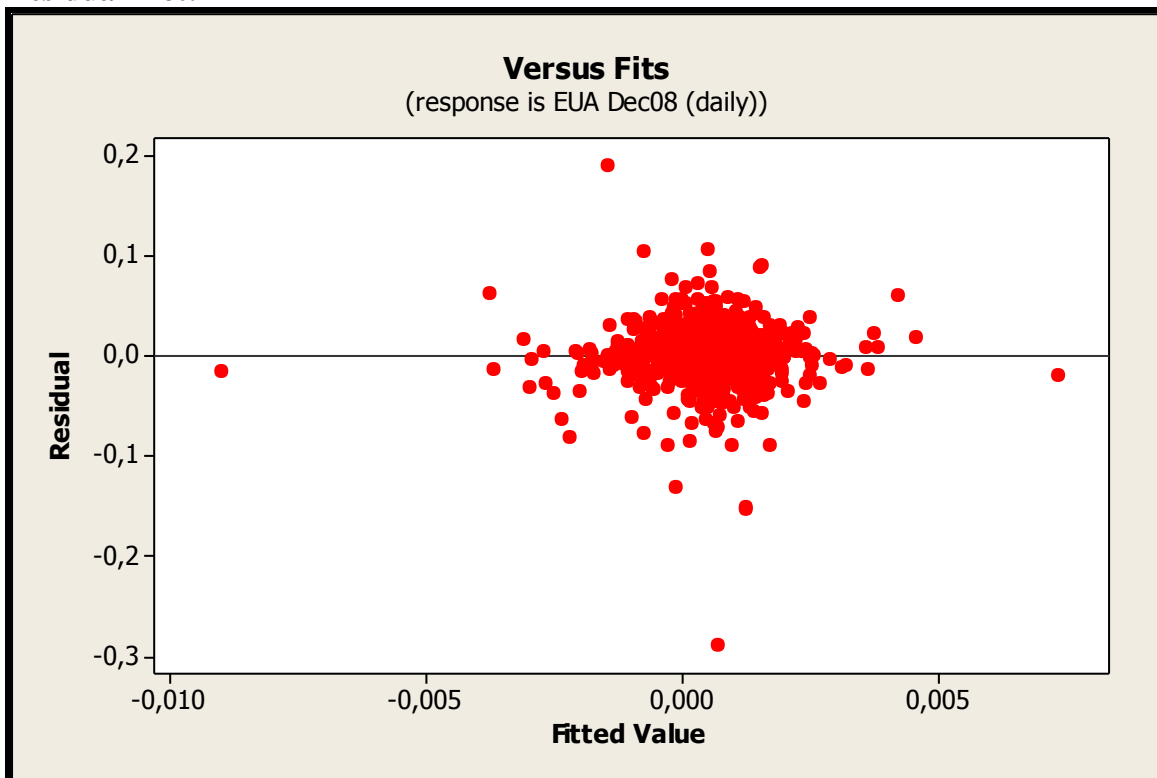
Regression Analysis: EUA Dec08 (daily) versus SX5E (daily)

The regression equation is
EUA Dec08 (daily) = 0,00052 + 0,0905 SX5E (daily)

784 cases used

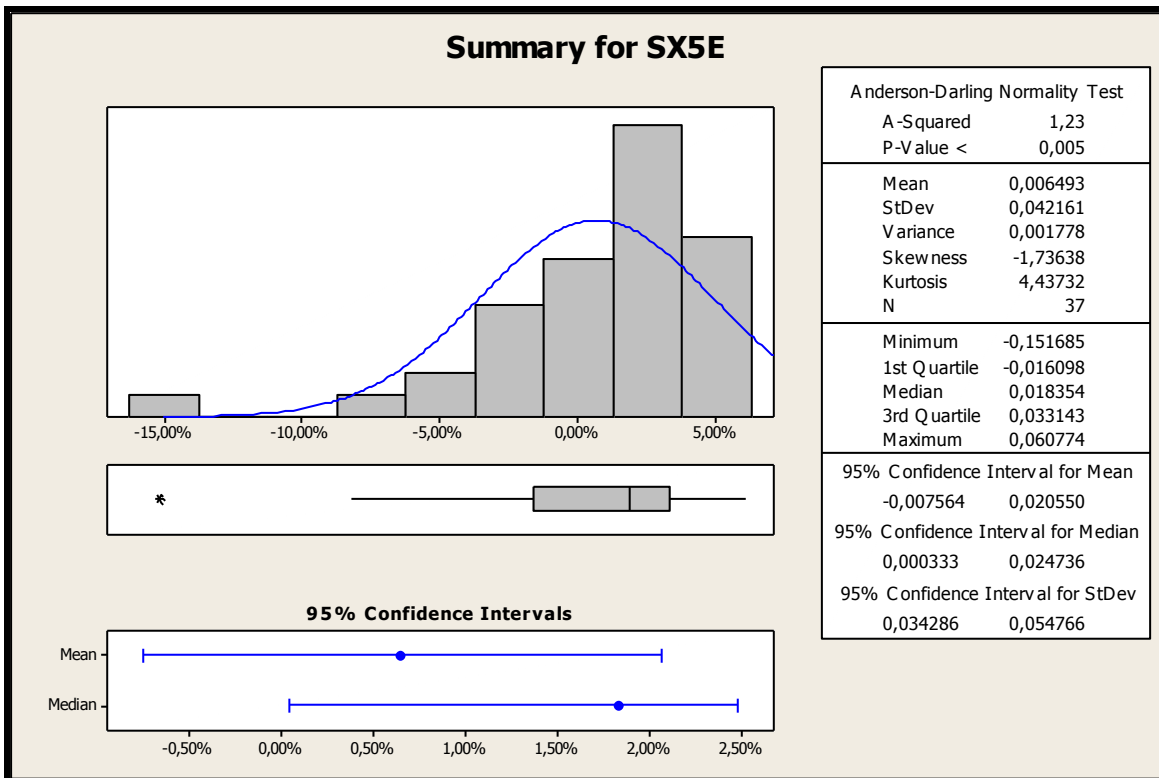
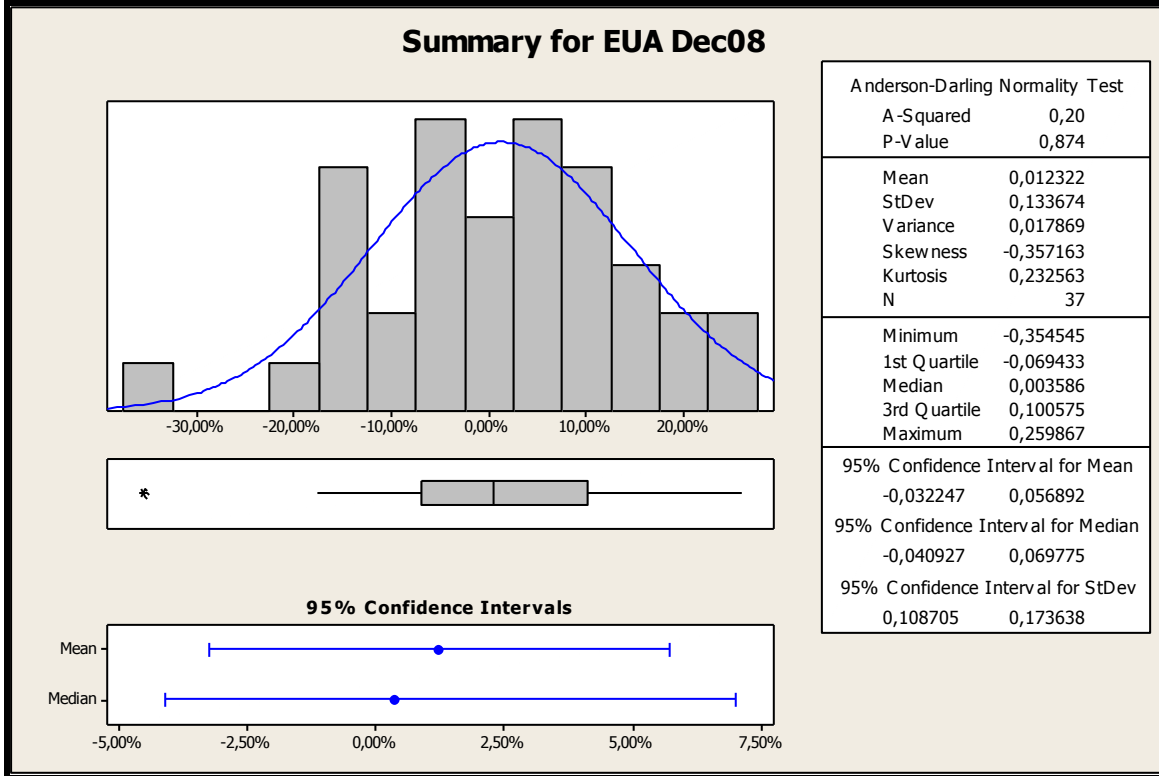
Predictor	Coef	SE Coef	T	P
Constant	0,000521	0,001037	0,50	0,615
SX5E (daily)	0,09046	0,09113	0,99	0,321

S = 0,0290358 R-Sq = 0,1% R-Sq(adj) = 0,0%

Residual Plot:

Appendix 4.2:

Descriptive statistics:



Correlations: EUA Dec08; SX5E

Pearson correlation of EUA Dec08 and SX5E = 0,064
P-Value = 0,706

Regression Analysis: EUA Dec08 versus SX5E

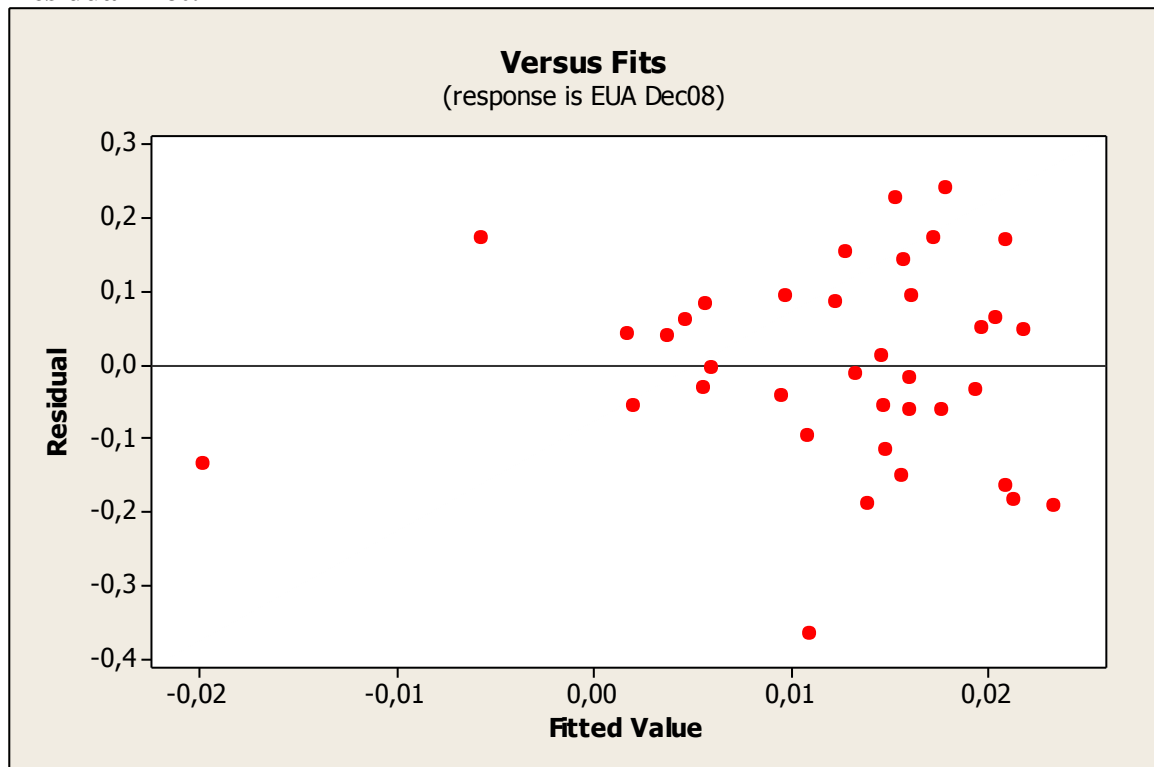
The regression equation is
EUA Dec08 = 0,0110 + 0,203 SX5E

37 cases used

Predictor	Coef	SE Coef	T	P
Constant	0,01100	0,02251	0,49	0,628
SX5E	0,2035	0,5348	0,38	0,706

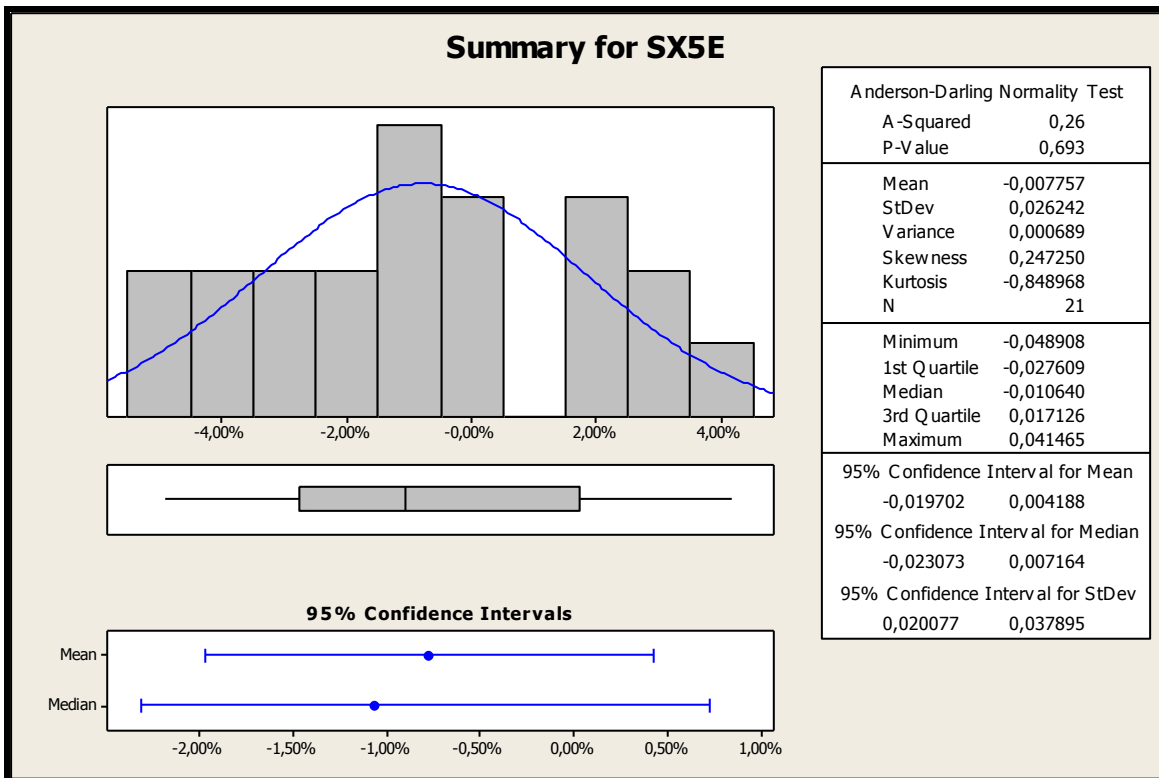
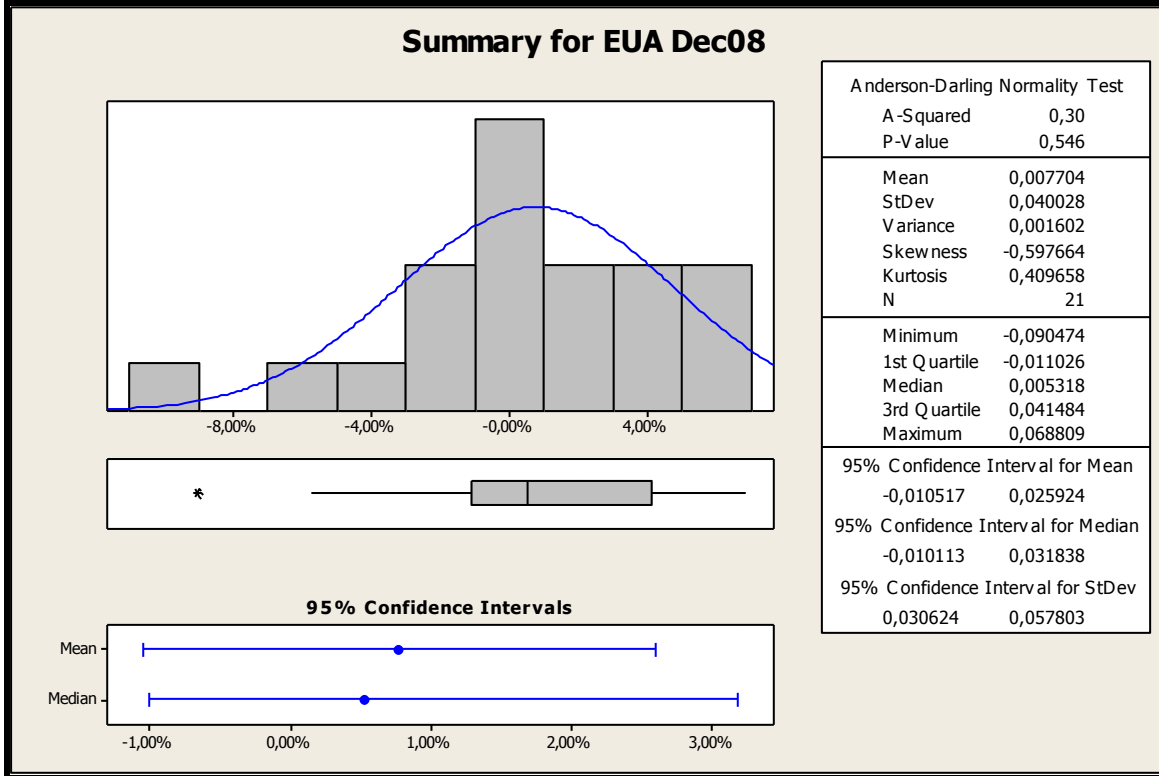
S = 0,135291 R-Sq = 0,4% R-Sq(adj) = 0,0%

Residual Plot:



Appendix 4.3

Descriptive statistics:



Correlations: EUA Dec08; SX5E

Pearson correlation of EUA Dec08 and SX5E = 0,139
P-Value = 0,547

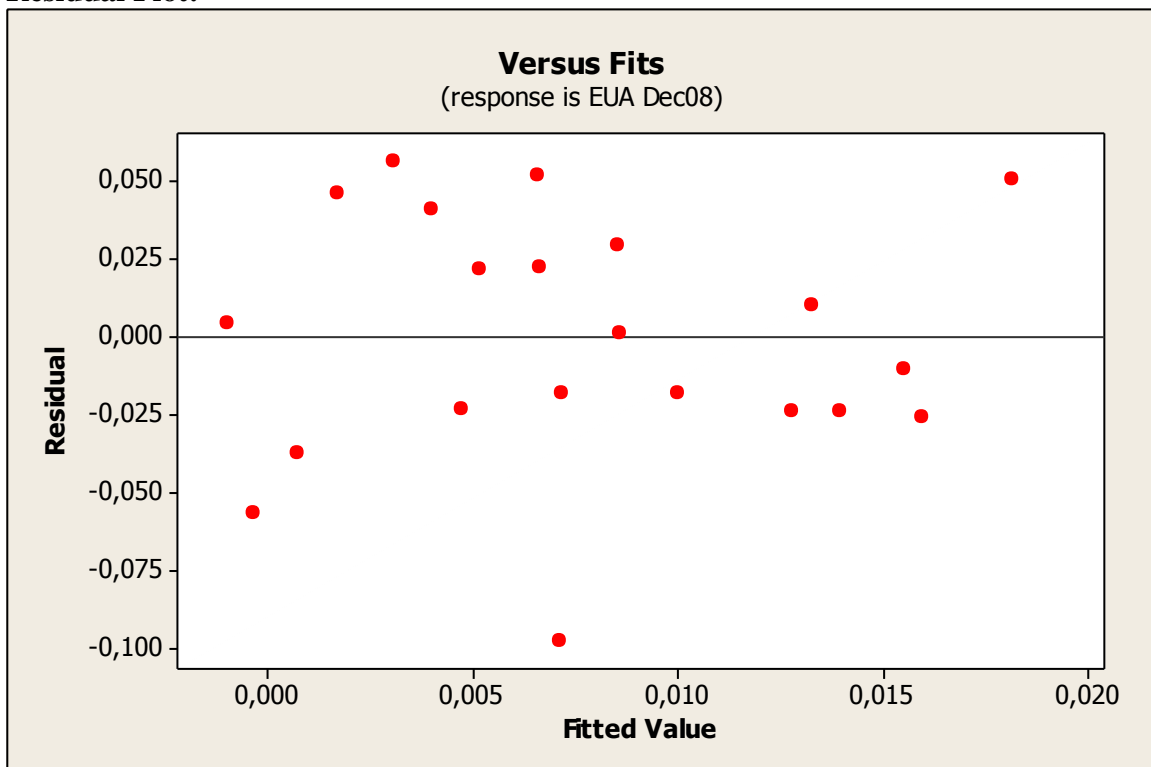
Regression Analysis: EUA Dec08 versus SX5E

The regression equation is
EUA Dec08 = 0,00935 + 0,212 SX5E

21 cases used

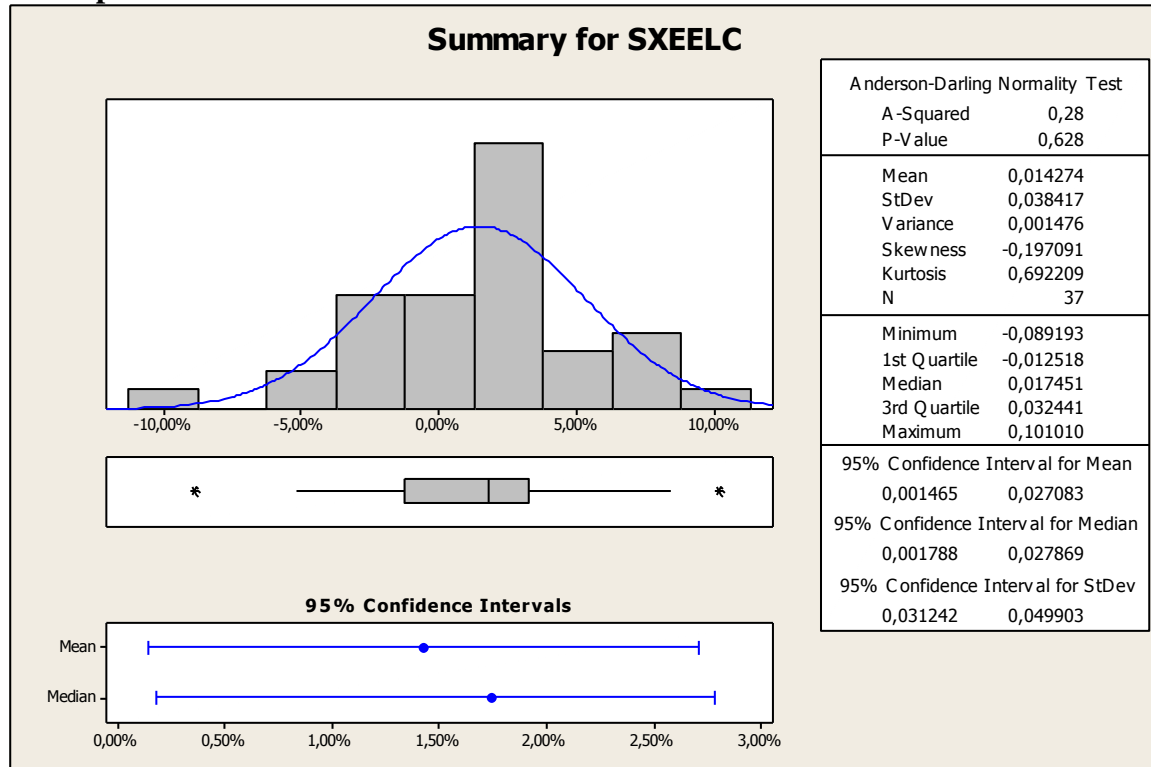
Predictor	Coef	SE Coef	T	P
Constant	0,009351	0,009273	1,01	0,326
SX5E	0,2124	0,3465	0,61	0,547

S = 0,0406677 R-Sq = 1,9% R-Sq(adj) = 0,0%

Residual Plot:

Appendix 4.4

Descriptive statistics:



Correlations: EUA Dec08; SXEELC

Pearson correlation of EUA Dec08 and SXEELC = 0,132
P-Value = 0,435

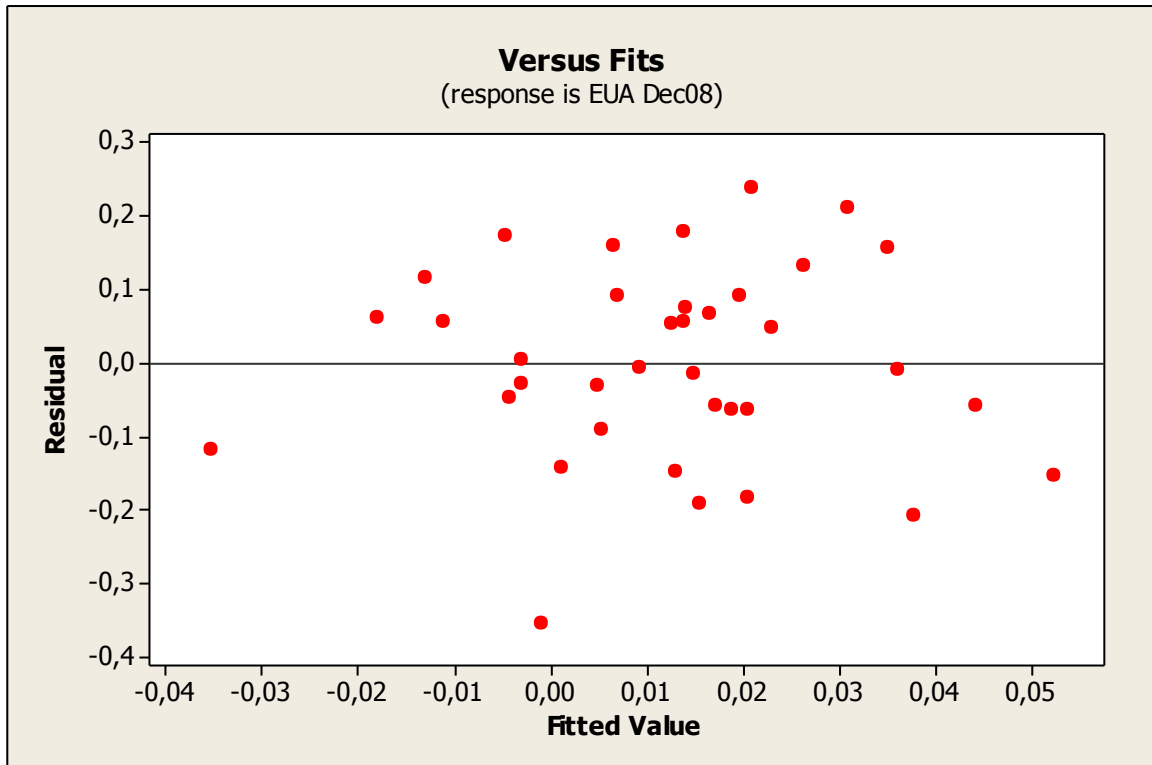
Regression Analysis: EUA Dec08 versus SXEELC

The regression equation is
EUA Dec08 = 0,0058 + 0,460 SXEELC

37 cases used

Predictor	Coef	SE Coef	T	P
Constant	0,00576	0,02361	0,24	0,809
SXEELC	0,4600	0,5830	0,79	0,435

S = 0,134381 R-Sq = 1,7% R-Sq(adj) = 0,0%

Residual Plot:**Correlations: SX5E; SXEELC**

Pearson correlation of SX5E and SXEELC = 0,712
P-Value = 0,000

Appendix 4.5

Correlations: Brent spot; EUA Dec08

Pearson correlation of Brent spot and EUA Dec08 = 0,137
P-Value = 0,082

Correlations: Brent spot; SX5E

Pearson correlation of Brent spot and SX5E = -0,055
P-Value = 0,488

Correlations: Brent spot; SXEELC

Pearson correlation of Brent spot and SXEELC = 0,032
P-Value = 0,689

Abbreviations

(Pages where explanations can be found)

AAUs	- Assigned Amount Units (p 42)
AR4	- IPCC's fourth assessment report, 2007 (p 17)
CCS	- Carbon Capture and Storage (p 5, 79)
CCX	- The Chicago Climate Exchange (p 38)
CERs	- Certified Emission Reductions (p 40 ++)
CDM	- Clean Development Mechanism (p 20 ++)
CITL	- Community Independent Transaction Log, EU (p 36, 44, 60)
CO ₂	- Carbon Dioxide
CO _{2e}	- CO ₂ equivalent unit (p 11)
ECX	- European Climate Exchange (p 49)
EEX	- European Energy Exchange (p 50)
ERUs	- Emission Reduction Units (p 41)
ERs	- Emission Reductions (p 43)
EU	- European Union
EUAs	- European Union Allowances (p 40)
EU ETS	- European Union Emissions Trading Scheme (p 30)
FCCC	- Framework Convention on Climate Change, same as UNFCCC (p 19)
GDP	- Gross Domestic Product (p 5, 15)
GHGs	- Greenhouse Gases (p 10)
GWP	- Global Warming Potential (p 11)
Installations	- I.e. power plants, oil refineries and other carbon intensive factories covered by the EU ETS (p 30)
IPCC	- The Intergovernmental Panel on Climate Change (p 17)
ITL	- International Transaction Log (UNFCCC)
JI	- Joint Implementation (p 20 ++)
LULUCF	- Land Use, Land-Use Change and Forestry (p 42)
MCA	- Marginal Cost of Abatement (p 22)
MSC	- Marginal Social Cost (p 22)
NAP	- National Allocation Plans (p 30, 44, 59)
NCDEX	- National Commodity & Derivatives Exchange in Mumbai, India (p 50)

NGACs	- New South Wales Greenhouse Abatement Certificates (p 42)
NO _x	- Nitrogen Oxides
NSW GGAS	- New South Wales Greenhouse Gas Abatement Scheme (p 35)
NZITS	- New Zealand Emissions Trading Scheme (p 35)
NYMEX	- New York Mercantile Exchange (p 10, 50)
NYSE	- New York Stock Exchange (p 50)
OTC	- Over-The-Counter market (p 36)
ppm	- Parts Per Million
PPP	- Purchasing Price Parity (p 15)
RGGI	- Regional Greenhouse Gas Initiative (p 35)
RMUs	- Removal Units (p 42)
UK ETS	- The United Kingdom Emissions Trading Scheme (p 37)
UN	- United Nations
UNEP	- United Nations Environment Programme (p 17)
UNFCCC	- United Nations Framework Convention on Climate Change (p 19)
US ETS	- United States Emissions Trading Scheme (p 80)
SAR	- IPCC's second assessment report, 1995 (p 17)
SO ₂	- Sulfur Dioxide
SX5E	- Dow Jones EURO STOXX 50® (p 66)
SXEELC	- Dow Jones EURO STOXX® TMI Electricity (p 66)
TAR	- IPCC's third assessment report, 2001 (p 17)
VERs	- Verified Emission Reductions (p 42)
WCI	- The Western Climate Initiative (p 39)
WMO	- World Meteorological Organization (p 17)