

2012

# A study of the determinants of the European Union Allowance (EUA) price in the European Union Emissions Trading Scheme (EU ETS)

Alina Maydybura

*University of Wollongong*, [alinam@uow.edu.au](mailto:alinam@uow.edu.au)

---

## Recommended Citation

Maydybura, Alina, A study of the determinants of the European Union Allowance (EUA) price in the European Union Emissions Trading Scheme (EU ETS), Masters of Finance - Research thesis, School of Accounting & Finance, University of Wollongong, 2012.  
<http://ro.uow.edu.au/theses/3481>

## **UNIVERSITY OF WOLLONGONG**

### **COPYRIGHT WARNING**

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

**A Study of the Determinants of the European Union Allowance (EUA)  
Price in the European Union Emissions Trading Scheme (EU ETS)**

by Alina Maydybura

Masters by Research (Finance)

Supervisors

Professor Brian Andrew

Dr Andrew Tan

School of Accounting & Finance

Faculty of Commerce

University of Wollongong

## **Dedication and Acknowledgements**

I would like to take the opportunity to thank my supervisors Professor Brian Andrew and Dr Andrew Tan for your infinite support, useful comments and valuable advice over the duration of my research degree. You fulfilled my study with inspiration and drive for success. You have taken over the role of my parents and friends and without you I would not be where I am now. Please accept my deepest gratitude and appreciation. Also, many thanks to Dr Khorshed Choudhri, Dr Martin O'Brien, and Associate Professor Abbas Valadkhani for your guidance and assistance throughout my degree.

I have decided to dedicate this thesis to two groups of people who have had an immense influence on my life, both academic and personal.

First of all, I would like to thank my parents Oleksandr and Valentyna, the people who have provided me with everything I have ever needed and who have supported me throughout my thorny journey of life. I believe this thesis is a fine example of my ability which has been achieved by your hard work as parents and as role models.

Second, this thesis is dedicated to my fiancé Hamza. Your moral support, your deep understanding and your great personality have inspired me to achieve what I have always cherished.

## **Statement of Original Authorship**

The work contained in this thesis has not been previously submitted for a degree or diploma at any other higher education institution. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due references are provided.

## Table of Contents

Dedication and Acknowledgements.....	i
Statement of Original Authorship .....	ii
List of Figures .....	vi
List of Tables.....	vi
List of Abbreviations and Acronyms .....	vii
Abstract .....	viii
Chapter 1 .....	1
1.1. Introduction and Background.....	1
1.2. Research Objectives and Questions .....	19
1.3. Research Motivations and Contributions .....	22
Chapter 2 .....	28
2. Literature Review.....	28
2.1. The Influence of Regulatory Processes and Government Intervention on the Design and Settings of the Scheme.....	28
2.2. High Volatility of Carbon Price .....	35
2.3. Factors that Affect the Price of Carbon.....	37
2.4. Neoliberalism .....	44
2.5. Theoretical Foundations, Ideology of Climate Change and Sceptics .....	49
Chapter 3 .....	54
3. Theoretical Framework.....	54
3.1. Economic Theories.....	54
3.1.1. Theory of Perfect Competition.....	54

3.1.2. Government Intervention .....	57
3.2. Finance Theories .....	60
3.2.1. Efficient Market Hypothesis (EMH).....	60
3.2.2. Behavioural Finance.....	63
Chapter 4 .....	70
4. Data and Methodology.....	70
4.1. Data .....	70
4.2. Methodology and Methods.....	85
Chapter 5 .....	88
5. Empirical Results of Pricing Relationship from the EU ETS.....	88
5.1. Correlation.....	88
5.2. Autocorrelation or Serial Correlation.....	92
5.3. Regression Results .....	93
Chapter 6 .....	107
6. Discussion and Conclusion.....	107
7. Appendix. Stationarity and Cointegration .....	114
8. References.....	121

## List of Figures

Figure 1.	Carbon Trading Schemes .....	2
Figure 2.	Structure of a Carbon Market.....	4
Figure 3.	ECX Monthly Volume .....	10
Figure 4.	Carbon Price Volatility .....	11
Figure 5.	Price of Carbon: Evidence from Phase One (2006 – 2007) .....	12
Figure 6.	Price of Carbon: Evidence from Phase Two (2008 – 2009) .....	13
Figure 7.	Factors Influencing Carbon Price in the Secondary Carbon Market ...	22
Figure 8.	Relationship between Carbon Price and Its Hypothesised Drivers.....	71
Figure 9.	Europe's Four Largest Emitters (2007) .....	72
Figure 10.	Total EU–27 Gross Electricity Generation (2008) .....	73
Figure 11.	EU–27 Electricity Production by Source (2008).....	74
Figure 12.	Electricity Production in Individual Countries by Source (2008) .....	75
Figure 13.	Electricity Production by Source – France (2009) .....	76
Figure 14.	Electricity Production by Source – Germany (2008) .....	77
Figure 15.	Electricity Production by Source – Italy (2008).....	78
Figure 16.	Electricity Production by Source – UK (2008) .....	79
Figure 17.	Carbon Footprint of Various Energy Sources .....	81



## List of Tables

Table 1.	Price and Volume of the ECX Contracts .....	9
Table 2.	Lessons Learnt from the EU ETS .....	15
Table 3.	Countries by CO <sub>2</sub> Emissions due to Human Activity (2007) .....	72
Table 4.	Electricity Production in Individual Countries by Source (2008).....	75
Table 6.	Regression A – Eviews Output.....	95
Table 8.	Regression C – Eviews Output .....	97
Table 9.	Regression D – Eviews Output.....	98
Table 10.	Regression Output Summary (in terms of probabilities) .....	99
Table 11.	Unit Root Probabilities – Eviews Output (quarterly data).....	114
Table 12.	Unit Root Probabilities – Eviews Output (monthly data).....	116

## List of Abbreviations and Acronyms

AAU	Assigned Amount Unit
CCE	Chicago Climate Exchange
CDM	Clean Development Mechanism
CER	certified emissions reduction
CITL	Community Independent Transaction Log
CO <sub>2</sub> e	carbon dioxide equivalent
ECX	European Climate Exchange
EPA	Environmental Protection Agency
ERPA	Emissions Reduction Purchase Agreement
ERU	Emissions Reduction Unit
ETS	Emissions Trading Scheme
EUA	European Union Allowance
GWP	global warming potential
ICE	Intercontinental Exchange
IETA	International Emissions Trading Association
IPCC	Intergovernmental Panel on Climate Change
ITL	International Transfer Log
JI	Joint Implementation
NAP	national allocation plan
OECD	Organisation for Economic Cooperation and Development
OTC	over the counter
RGGI	Regional Greenhouse Gas Initiative
REC	Renewable Energy Certificates, tradable environmental commodities in the United States
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VER	verified emissions reduction

## **Abstract**

In 2005 the European Union (EU) began the first phase of the largest and most ambitious emissions trading system (EU ETS) ever attempted, which then applied to all members of the EU. From its second phase in 2008, the EU ETS applies to all 27 members of the EU together with the three members of the European Economic Area, being Norway, Iceland and Lichtenstein. Under the EU ETS, permits to emit carbon into the atmosphere known as European Union Allowances (EUAs) are traded in a manner which is similar to the trading of financial instruments and a range of derivatives has developed with the total value of the market now above €120b, a market dominated by a few large players.

Essentially, the carbon market establishes an arena that plays the role of a mediator between the environment/climate and the economy. At this stage significant market failures in the operation of the European carbon market have been noted. Evidence from Europe demonstrates that the EU ETS has failed to reduce emissions in Phase One (2005-2007) and is not yet succeeding in Phase Two (2008-2012) of its operation. The EU Scheme has not worked in an economic sense as emissions were only marginally reduced, while the major problem with the European carbon market was its substantial price volatility. This left carbon participants with uncertainty, thus introducing more ambiguity and instability into the carbon market. Consequently, the price of carbon collapsed to almost zero in Phase One, creating no price incentive to reduce pollution. As a result, instead of being reduced, carbon emissions from installations covered by the EU ETS actually rose during the first three years of its

operation. This leaves many with scepticism regarding the effectiveness and efficiency of the EU ETS.

This thesis reports the results of an empirical investigation into the factors which appear to drive the carbon price and the key determinants of the price of an EUA. Empirical studies underpinned by a positivist social science approach have been implemented as the principal methodologies for conducting this research. Over the last decade a number of environmental products have been developed alongside the EUA, including Certified Emissions Reductions (CERs), Renewable Energy Certificates (RECs) and White Certificates (energy efficiency credits) and markets have developed for a range of these environmental products. A better understanding of the determinants of these markets will help regulators manage these new markets and market participants to deal with their exposure to the market and this study aims to further this understanding.

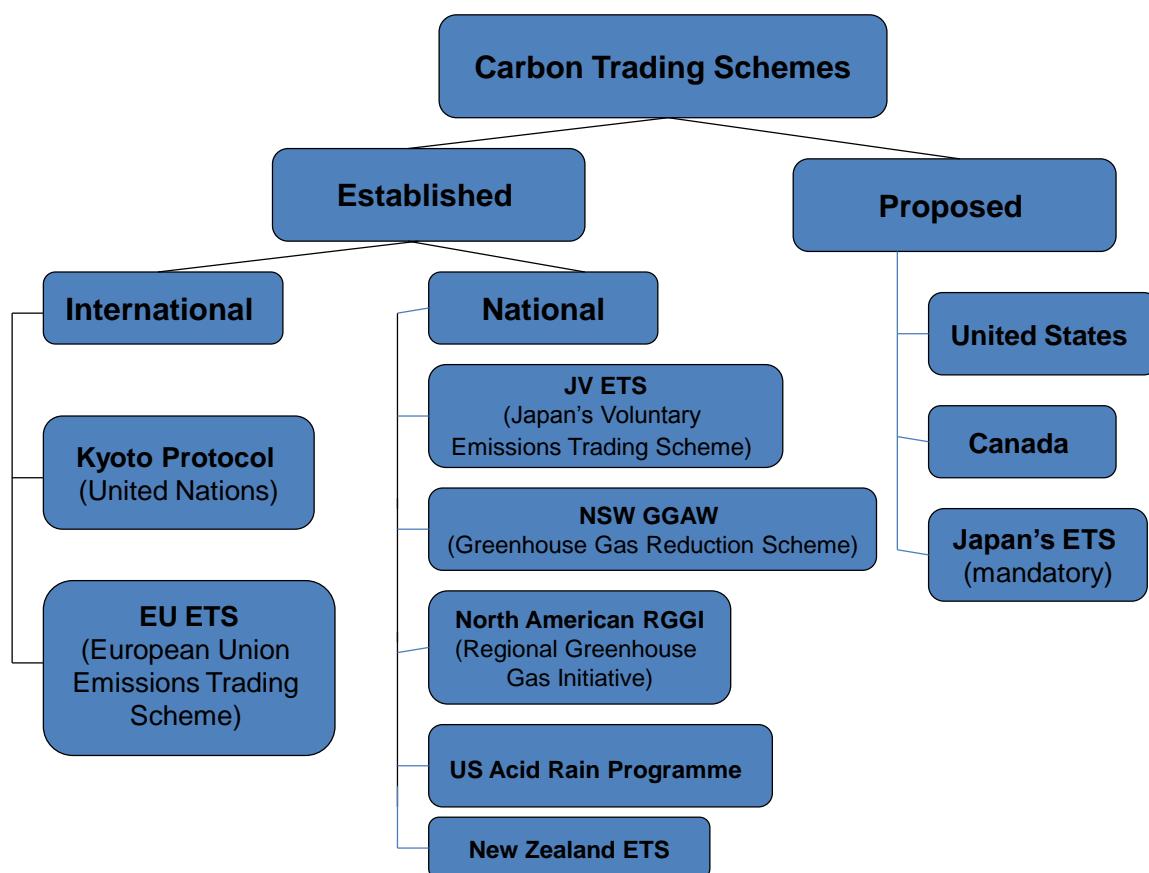
# Chapter 1

## 1.1. Introduction and Background

According to the [Pew Center on Global Climate Change \(n.d.\)](#), the scientific community has reached a strong consensus regarding the significance of global climate change. The world is undoubtedly warming, and there is a high probability that the warming is largely the result of emissions of carbon dioxide and other greenhouse gases resulting from human activities. Today, key policy-makers and the public are getting more concerned about the causes and potential consequences of climate change ([Pew Center on Global Climate Change, n.d.](#)).

In the past couple of years, several carbon trading schemes have been implemented around the world ([Reuters, 2008](#)). Amongst the already established international schemes are the EU ETS (European Union Emissions Trading Scheme) and the Kyoto Protocol (United Nations). The latter contains three sub-schemes to help signatories meet the targets: first, Clean Development Mechanism (CDM); second, Joint Implementation (JI); and third, Assigned Amount Units (AAUs) ([Reuters, 2008](#)). Amid the national schemes that have been launched and are currently operating is the New Zealand Emissions Trading Scheme (NZETS), Japan's Voluntary Emissions Trading Scheme (JV ETS), New South Wales Greenhouse Gas Reduction Scheme (NSW GGAW), North American Regional Greenhouse Gas Initiative (RGGI), and the US Acid Rain (SO<sub>2</sub>) Programme ([Reuters, 2008](#)). Proposed national schemes are expected to cover the United States, Canada, Japan (on a mandatory basis), and Australia (a proposed emissions trading scheme with an initial fixed price) in the near future ([Reuters, 2008](#)). The diagramme below (**Figure 1**) outlines both proposed and established carbon trading schemes.

**Figure 1. Carbon Trading Schemes**



Source: Reuters (2008)

There is a clear move around the world to develop emissions trading schemes (ETS). The European Union (EU) scheme is probably the best known, but others are being developed in New Zealand, Japan, and many US states and Canadian provinces. The North Eastern Regional Greenhouse Gas Initiative (RGGI) in the USA is now in operation and it applies to emissions in ten US states<sup>1</sup> (RGGI, 2011). The Western Climate Initiative (WCI) has established a trading mechanism that will apply in some Western states and some Canadian provinces<sup>2</sup> (Stockholm Environment Institute and

<sup>1</sup> The ten US states that participate in the RGGI are: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont

<sup>2</sup> WCI Partners include 11 jurisdictions: Arizona, California, Montana, New Mexico, Oregon, Utah and

[Greenhouse Gas Management Institute, 2011](#)). Also there are a number of other initiatives in the USA which may lead to an ETS, including the Midwest Greenhouse Gas Reduction Accord (which may cover six US states and one Canadian province) and the Energy Security and Climate Change Stewardship Platform for the Midwest (eleven US states and one Canadian province).

According to [Montgomery \(1976\)](#), emissions trading is “an administrative approach used to control pollution by providing economic incentives for achieving reduction in emissions”. The core purpose of emissions trading is to set a cap on emissions which creates scarcity, and impose trading in permits which represents the value of that scarcity. It is sometimes called a cap-and-trade or cap-and-tax approach ([Montgomery, 1976](#)). The way emissions trading works is such that a central body (government) introduces a limit or cap on the amount that can be emitted ([Montgomery, 1976](#)). Then businesses are granted emission permits and are obliged to have an equivalent number of allowances (or credits) that signify the right to emit a specific amount ([Montgomery, 1976](#)). The overall amount of allowances and credits cannot exceed the cap, thus limiting total emissions to that level ([Montgomery, 1976](#)). Therefore, businesses which want to augment their emission allowance need to purchase credits from those companies that pollute less ([Montgomery, 1976](#)). The transfer of allowances amongst businesses is known as emissions trading ([Montgomery, 1976](#)). Effectively, the buyer is paying a price for polluting, whilst the seller is being compensated for having decreased pollution by more than was required ([Montgomery, 1976](#)). As a result, theoretically, businesses capable of easily cutting their emissions most economically will do so, tackling emissions pollution reduction at the lowest feasible cost to society

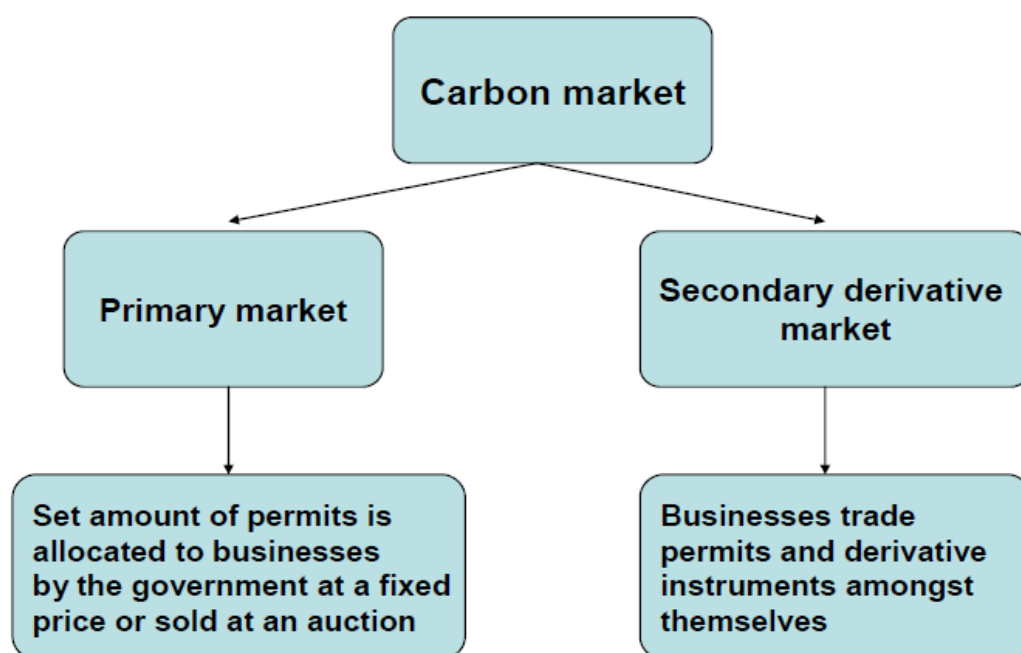
---

Washington in the US; and British Columbia, Manitoba, Ontario as well as Quebec in Canada.

(Montgomery, 1976). However, no empirical evidence exists to support this.

A carbon market is essentially the backbone of emissions trading. It underpins the environment in which emissions trading takes place. It can be divided into two broad sub-categories: the primary carbon market and the secondary carbon market. In the primary carbon market, a set amount of permits is allocated to businesses by the government at a fixed price or sold at an auction; whereas in the secondary carbon market, businesses trade permits and derivative instruments amongst themselves. The *Figure 2* below is a graphical representation of the fundamental structure of a carbon market.

**Figure 2. Structure of a Carbon Market**





The European Union Emission Trading System (EU ETS), which commenced in January 2005, is the largest multi-national emissions trading scheme in the world, and a major catalyst of the EU climate policy. According to the [European Climate Exchange \(2009\)](#), every year 30 billion tonnes of carbon dioxide (CO<sub>2</sub>) is pumped into the atmosphere. Europe emits about 5 billion tonnes of carbon dioxide ([European Climate Exchange, 2009](#)).

As specified in the Kyoto Protocol<sup>3</sup>, in 1997 the European Union countries agreed to a cap on their CO<sub>2</sub> emissions to be achieved by 2008–2012. In particular, the EU member states committed themselves to an overall reduction of 8% in annual emissions (from a 1990 base). This overall reduction obligation was then distributed within the EU following a Burden Sharing Agreement (BSA) ([Abadie and Chamorro, 2008](#)). The distinctive feature of both the Kyoto Protocol and the BSA is that they have allocated emission rights to nations and not to individual legal entities ([Abadie and Chamorro, 2008](#)). Consequently, three major instruments were developed with the aim of easing the fulfilment of these commitments: Joint Implementation (JI)<sup>4</sup>, Clean Development Mechanism (CDM)<sup>5</sup> and the Emissions Trading Scheme (ETS) – a

---

<sup>3</sup> **Kyoto Protocol** is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC), an international environmental treaty with the goal of achieving stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

<sup>4</sup> **Joint Implementation (JI)** is one of three flexibility mechanisms set forth in the Kyoto Protocol to help countries with binding greenhouse gas emissions targets (Annex I countries) meet their obligations. Under the JI project, any Annex I country can invest in emission reduction projects in any other Annex I country as an alternative to reducing emissions domestically. In this way countries can lower the costs of complying with their Kyoto targets by investing in greenhouse gas reductions in an Annex I country where reductions are cheaper, and then applying the credit for those reductions towards their commitment goal.

<sup>5</sup> **Clean Development Mechanism (CDM)** is an arrangement under the Kyoto Protocol allowing

system whereby CO<sub>2</sub> emission permits are traded ([Abadie and Chamorro, 2008](#)).

The EU ETS is a cap-and-trade system based on a structure that originated in the US with their Acid Rain program. According to [Ellerman and Buchner \(2007\)](#), the European Union Emissions Trading Scheme (EU ETS) is the world's first large experiment with an emissions trading system for carbon dioxide (CO<sub>2</sub>). The trading system started operating officially on 1 January 2005 covering the EU-15<sup>6</sup> in 2005, but the number of countries covered has since increased to 30 members since then. Based on 2005 emissions, the EU ETS currently addresses nearly 50% of all CO<sub>2</sub> emissions, which is approximately 40% of total annual GHG emissions ([Kruger, 2008](#)). The European Union Emissions Trading Scheme is an existing trading mechanism which is likely to be copied by others, if there is to be a global regime for limiting greenhouse gas emissions. As mentioned by [EurActiv \(2009\)](#), to minimise the economic costs of its commitments to combat climate change under the Kyoto Protocol, the EU countries have agreed to set up an internal market enabling companies to trade carbon dioxide pollution permits. Under the EU Emissions Trading Scheme (EU ETS), 10,000 energy-intensive plants and energy producers across the EU are able to buy and sell permits to emit carbon dioxide, representing around 40% of the EU's total CO<sub>2</sub> emissions. Industries covered by the scheme include: power generation, iron and steel, glass, cement, pottery and bricks. An emission cap is defined, for each individual plant, via a National Allocation Plan (NAP) submitted by

---

industrialised countries with a greenhouse gas reduction commitment (Annex A countries) to invest in projects that reduce emissions in developing countries as an alternative to more expensive emission reductions in their home countries.

<sup>6</sup> **EU-15** refers to the 15 member states of the European Union as of December 31, 2003. The 15 member states are: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the UK.

member states and approved by the Commission. Companies that exceed their quotas are allowed to buy unused credits from those that are better at cutting their emissions ([EurActiv, 2009](#)).

According to [European Environment Agency \(2009\)](#), the EU ETS is based on several trading periods. Phase One lasted from 2005 to 2007, under which utilities have received at least 95% of the allocated permits free of charge. Phase Two embraces the period 2008–2012, for which the percentage of allocated permits drops to 90%. From then on, consecutive five-year periods (starting from the 2013–2017 trading period) would span the potential post-Kyoto commitment periods. According to the EC plans, in 2013 power plants and energy-intensive industries would no longer receive a generous allocation of emissions allowances free of charge ([Abadie and Chamorro, 2008](#)). Instead, they would have to buy allowances at auctions organised by the member states ([Abadie and Chamorro, 2008](#)).

As a result of introducing of the emissions trading system by the EU, as [Ellerman and Buchner \(2007\)](#) point out, the world's largest ever market in emissions has been established, and the EU firms now face a carbon-constrained reality in the form of legally binding emission targets. Firms whose emissions exceed the allowances they hold at the end of the accounting period must pay a fine (during the pilot period, €40 for each extra metric ton of CO<sub>2</sub> emitted, and €100 during the commitment period). Those fined must also make up the deficit by buying the relevant volume of allowances ([Convery and Redmond, 2007](#)).

More specifically, European companies face the choice between investing in projects that help them to reduce greenhouse gas (GHG) emissions (so as to incur lower carbon payments or get some revenue from spare permits), or purchasing allowances

to release GHG emissions. Indeed, if initially the firm holds some emission allowances, installing the carbon capture and storage (CCS)<sup>7</sup> unit may make sense so as to sell the allowances at a high price; if the firm holds no allowances, installing the CCS unit may make sense so as to avoid the purchase of allowances at a high price (Abadie and Chamorro, 2008).

According to Kruger (2008), under the current scheme, the EU states benefit from a number of exemptions. First, at the moment whole sectors are not covered, including transport<sup>8</sup> and buildings, which represent the largest share of CO<sub>2</sub> emissions after the power-generation and energy-intensive industries. Second, member states can apply to opt out individual plants from the system. Third, in cases of force majeure, such as exceptionally low winter temperatures, additional emissions allowances can be issued by national authorities (Kruger, 2008).

One key aspect is the possibility to link the EU ETS with the Kyoto Protocol's Joint Implementation (JI) and Clean Development Mechanism (CDM). These flexible mechanisms allow member states to meet part of their target by financing emission reduction projects in countries outside the EU. The aim is to offer EU countries cheaper emission cuts than at home, while fostering technology transfers to developing countries (via the CDM) and other industrialised nations (via the JI), which have signed up to the Kyoto Protocol.

---

<sup>7</sup> **Carbon capture and storage (CCS)**, alternatively referred to as carbon capture and sequestration, is a means of mitigating the contribution of fossil fuel emissions to global warming. The process is based on capturing carbon dioxide (CO<sub>2</sub>) from large point sources, such as fossil fuel power plants, and storing it in such a way that it does not enter the atmosphere (Lackner et al, n.d.).

<sup>8</sup> The airline industry is to be included in the EU ETS in 2012.

According to the [European Environment Agency \(2009\)](#), the main source of information on the scheme at the EU level is the Community Independent Transaction Log (CITL), run by the European Commission, which checks and records all transactions between electronic registries set up by the countries participating in the scheme. It contains information on all installations covered by the scheme including their activity by sector, allocation and verified emissions on an annual basis ([European Environment Agency, 2009](#)).

The European Climate Exchange (ECX) is the leading marketplace for trading CO<sub>2</sub> emissions in Europe and internationally. It has grown so that in 2005, 94 million tonnes of CO<sub>2</sub> were traded on ECX with a total market value of €2.1 billion. In 2006, 452 million tonnes of CO<sub>2</sub> were traded with an overall market value of €9 billion. In year 2007, some 1 billion tonnes of CO<sub>2</sub> were traded with a market value €17.5 billion. In 2008, 2.8 billion tonnes of CO<sub>2</sub> were traded with a total market value of €55.9 billion. **Table 1** below presents a summary of data on price and volume on the ECX contract over a four-year period.

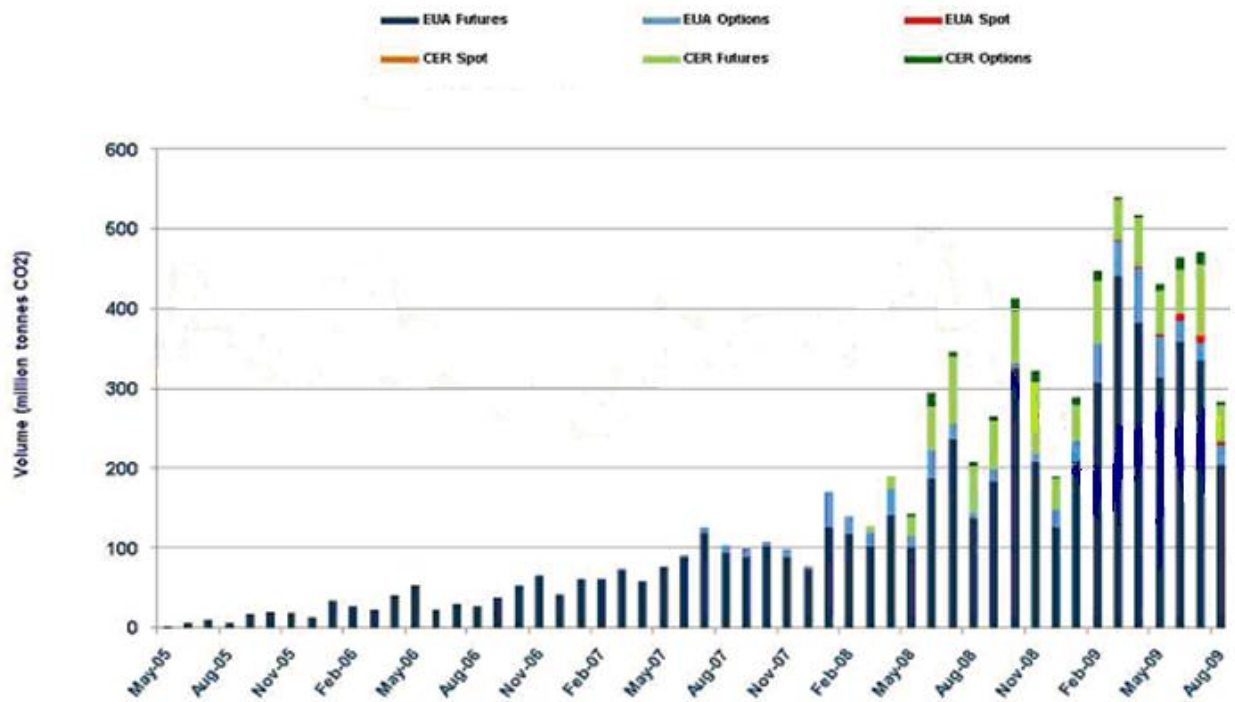
**Table 1. Price and Volume of the ECX Contracts**

Year	Volume (tonnes of CO <sub>2</sub> )	Market value	Average market price (per tonne)
2005	94 million	€2.1 billion	€ 22.34
2006	452 million	€9 billion	€19.91
2007	1 billion	€17.5 billion	€17.50
2008	2.8 billion	€55.9 billion	€19.96

Source: [European Climate Exchange \(2009\)](#)

The history of monthly volume on the European Climate Exchange from May 2005 to August 2009 is shown in **Figure 3** below:

**Figure 3. ECX Monthly Volume**



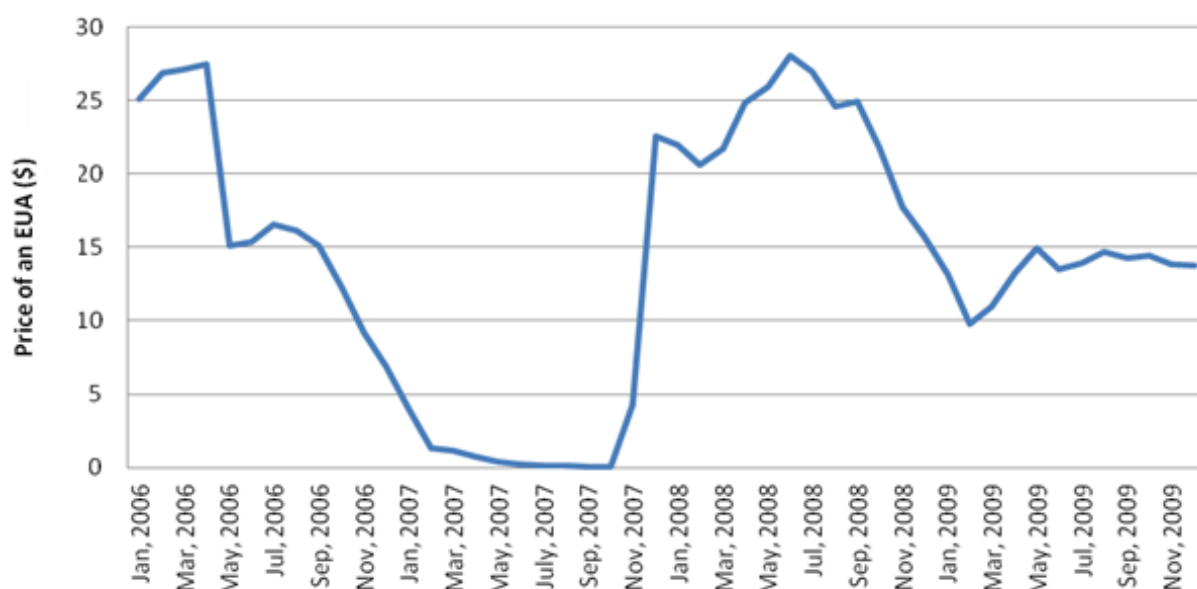
Source: [European Climate Exchange \(2009\)](#)

The graph above goes to demonstrate that overall the monthly volume of both EUA and CER futures, options and spot contracts sold on the ECX kept systematically increasing from 2005 to 2009. The diagramme illustrates that the majority of carbon trading took place in the form derivative instruments, mainly futures and options. In fact, according to [ECX \(2010\)](#), futures and options constitute about 96% of carbon trading in the relatively novel EU ETS.

As per **Figure 4** on the next page, evidence from Europe demonstrates that the EU ETS has failed in Phase One (2005-2007) and is having only limited success in Phase Two (2008-2012) of its operation. The EU scheme has not worked, as emissions were

not significantly reduced. The main reasons behind the EU ETS failure are overallocation of permits ([Houston et al, 2010](#)) and the fact that national targets for greenhouse gas reduction were not tough enough.

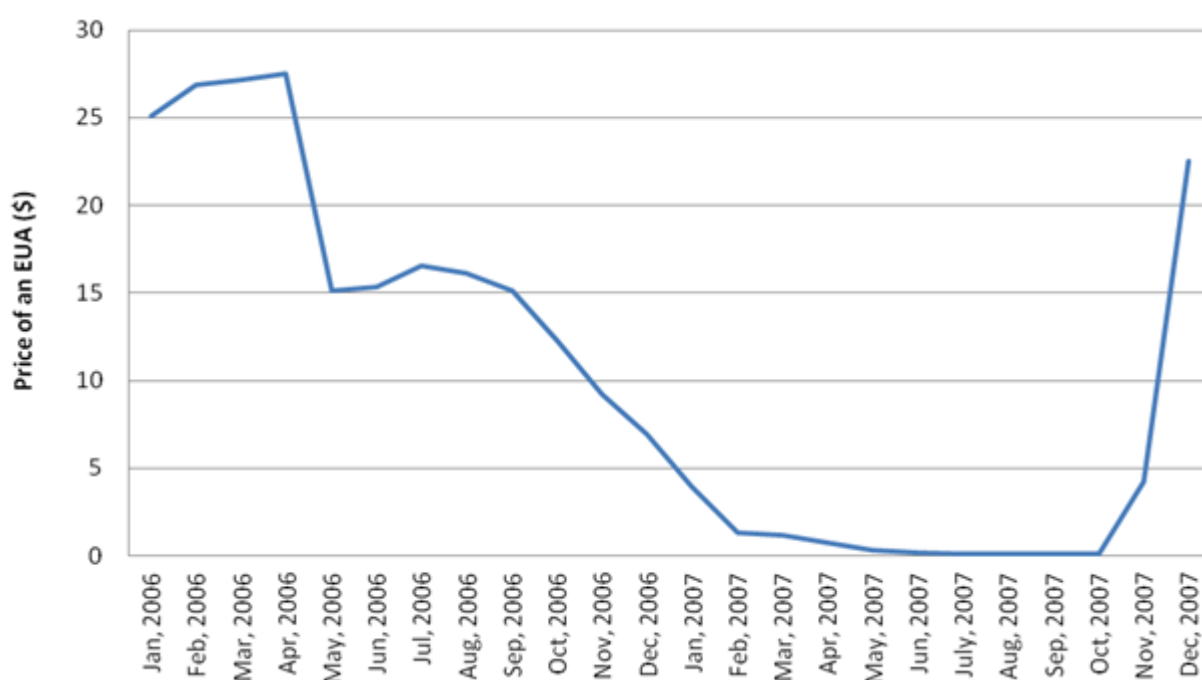
**Figure 4. Carbon Price Volatility**



The problem with the European carbon market was its substantial volatility, with its permit price fluctuating between €30 and €0.10 in Phase One (**Figure 5**) and €29 and €8 in Phase Two (**Figure 6**). Notably, as **Figure 5** demonstrates, in the last quarter of 2007 the carbon market observed a striking upturn in the EUA price. **Figure 5** also points to the fact that in May 2006 there was a sharp fall in price of carbon. [Carbon Positive \(2008\)](#) and [International Energy Agency \(2007\)](#) explain that it was the release of the 2005 verified figures which prompted a collapse in the EUA prices in May 2006 after confirming that the number of emission permits exceeded the level of emissions. The abrupt fall of the CO<sub>2</sub> price followed, as market players were made aware of the excess quantity of EU allowances for the year 2005. Participants realised that there were going to be far more spare allowances out to 2007 than they had thought.

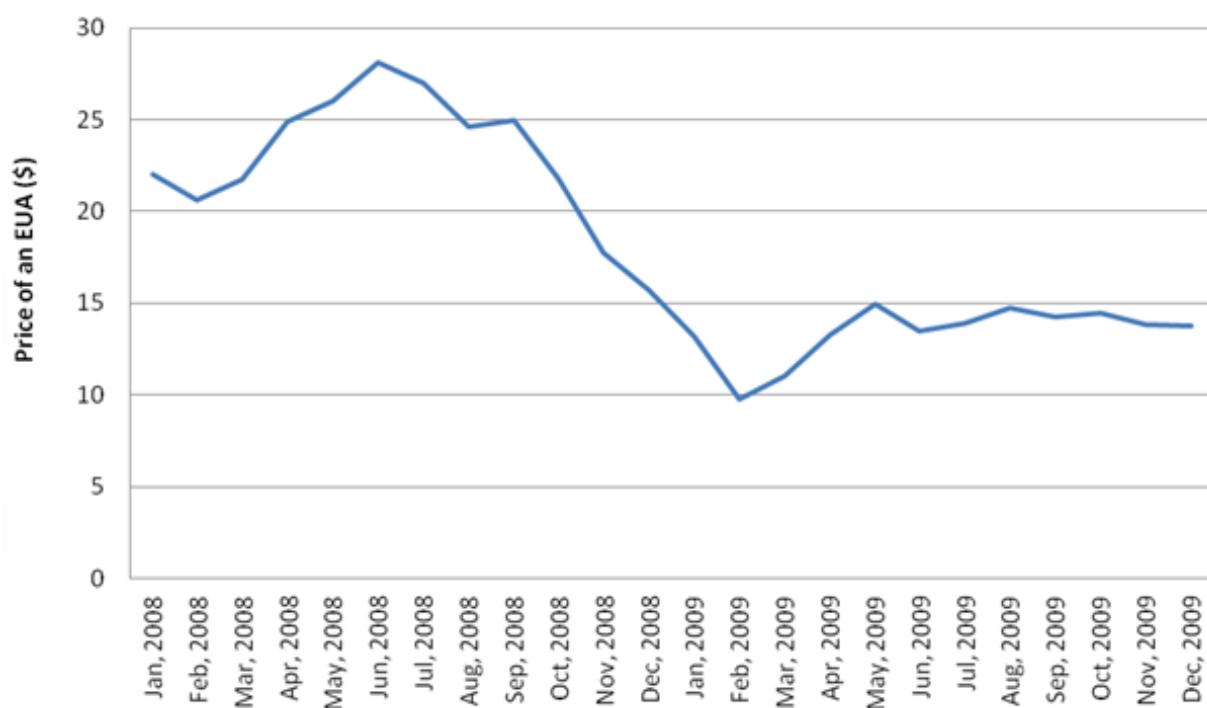
This left the carbon market participants with a significant level of uncertainty, thus introducing more ambiguity and instability into the carbon market. Consequently, when the price of carbon collapsed to almost zero (Sanin and Violante, 2009) there was no price incentive to reduce pollution. As a result of all these factors, instead of being reduced, carbon emissions from installations covered by the ETS actually rose by 1.9% in Phase One. This leaves many with skepticism in regard to the effectiveness and efficiency of the EU ETS.

**Figure 5. Price of Carbon: Evidence from Phase One (2006 – 2007)**





**Figure 6. Price of Carbon: Evidence from Phase Two (2008 – 2009)**



At the start of Phase Two of the EU ETS running from 2008 to 2012 companies are to receive free allocations of most EUA permits, each equivalent to one tonne of CO<sub>2</sub> emitted. As a result of generous allocations compounded by the impact of the global recession, many companies now find themselves in a position where they have far more permits to pollute than they require ([Sandbag, 2010](#)). Whether or not these companies choose to sell the permits to generate windfall profits they have been effectively handed significant assets by member state governments across the EU – thus [Sandbag \(2010\)](#) has termed these companies as ‘Carbon Fat Cats’.

According to [Kruger \(2008\)](#), there are six main lessons learned from the EU ETS “Trial” Period, which are derived from the design of the scheme and implementation issues. Lesson one is the need for high quality emissions data in order to set environmental goals ([Kruger, 2008](#)). In fact, evidence shows that Phase One caps were based on very limited data. In addition, complementary policies would be needed for

non-capped sectors. Lesson two is such that consistency and predictability are extremely vital in the efficient design and successful implementation of the scheme (Kruger, 2008). Evidence suggests that the EU ETS was subject to large variability in allocation method among member states. In addition, failure to credit plant shutdowns has created perverse incentives. Lesson three is the importance of keeping the scope of the scheme manageable and considering its contribution to emissions (Kruger, 2008). The scheme should aim to include the largest emitters that have sufficient resources for trading. Lesson four is the need to have flexibility and the ability to provide long-term certainty (Kruger, 2008). Under the EU ETS, the emitters did not have temporal flexibility due to the lack of banking between phases. Lesson five suggests that programme implementation should be efficient (Kruger, 2008). First, because the infrastructure for transfer of CDM credits under the EU ETS is not in place. Second, monitoring protocols are clear, but not all reporting is electronic. Third, the initial release of monitoring data is not coordinated. Fourth, the role of third-party verifiers affects timing of data submissions. Finally, lesson six states that transparency is extremely important for credibility (Kruger, 2008). Under the EU ETS, allowance transfers are not public data. In addition, the scheme adopted annual reporting, whereas quarterly reporting is considered to be more desirable (Kruger, 2008).

In conclusion, among the lessons learned from the EU ETS is the need for high quality emissions data in order to set environmental goals; consistency and predictability in the efficient design and implementation of the scheme; the importance of keeping the scope of the scheme manageable and considering its contribution to emissions; the ability to provide long-term certainty; programme implementation should be efficient; and that transparency is crucial for credibility (Kruger, 2008). **Table 2** below is the summary of the above discussion on the lessons learned from the EU ETS.

**Table 2. Lessons Learnt from the EU ETS**

	<b>Lesson</b>	<b>Comments</b>
<b>Lesson 1</b>	The need for high quality emissions data in order to set environmental goals	Phase One caps were based on very limited data. In addition, complementary policies would be needed for non-capped sectors.
<b>Lesson 2</b>	Consistency and predictability are extremely vital in the efficient design and successful implementation of the scheme	The EU ETS was subject to large variability in allocation method among member states. In addition, failure to credit plant shutdowns has created perverse incentives.
<b>Lesson 3</b>	The importance of keeping the scope of the scheme manageable and considering its contribution to emissions	Aim to include the largest emitters that have sufficient resources for trading.
<b>Lesson 4</b>	The need to have flexibility and the ability to provide long-term certainty	Under the EU ETS, the sources did not have temporal flexibility due to lack of banking between phases.
<b>Lesson 5</b>	Programme implementation should be efficient	First, because the infrastructure for transfer of CDM credits under the EU ETS is not in place. Second, monitoring protocols are clear, but not all reporting is electronic. Third, the initial release of monitoring data is not coordinated. Finally, the role of third-party verifiers affects timing of data submissions.
<b>Lesson 6</b>	Transparency is extremely important for credibility	Under the EU ETS, allowance transfers are not public data. In addition, the scheme adopted annual reporting, whereas quarterly reporting is considered to be more desirable.

Source: [Kruger \(2008\)](#)

In addition, according to [Betz \(2006\)](#), in order to reduce the volatility of the Australian carbon market, the following five EU ETS design lessons are likely to be useful. First, registries should be fully operational from the start of the scheme. Second, there should be more certainty regarding the total number of permits available from all sources, including new entrant reserves, and having no undecided legal claims. Third, an allocation process which ensures an effective price discovery (e.g. more auctioning at the beginning) should be adopted. Fourth, a suitable release process for sensitive information must be designed. Finally, there should be limited opportunity for political decisions that could affect prices.

Importantly, the EUAs are traded in a manner which is similar to the trading of financial instruments, and a range of derivatives has developed, with the current total market value being above €120b, representing a market dominated by a few key players. In addition, over the last decade a number of environmental products have been developed along with the EUAs, including Certified Emissions Reductions (CERs), Renewable Energy Certificates and White Certificates (energy efficiency credits), and markets have developed for a range of these environmental products.

Market-based solutions to solving the global warming problem are increasing around the world as it is believed that a cap-and-trade system will facilitate the abatement of greenhouse gas pollution at the lowest possible cost to the community. This may be true if it is properly established and monitored, but there are likely to be many problems in establishing a top-down market, a market created and imposed by government, for an artificial scarcity (emissions permits) created by government.

*Market economy* is the term that refers to the network of exchange relationships involving a division of labour through which men achieve gains from trade to better

their lives (Ebeling, 2004, p. 3). “Civil society and market economy are complementary in that both thrive on high levels of trust” (Gordon, 2004, p. 1). The neo-classical model of economics identifies broad areas of market failure and implicitly or explicitly invokes top-down interventions that would, presumably, make things right (Gordon, 2004; Cowen and Crampton, 2002). “The simplest approaches do not question the efficacy of the proposed fixes or the possibility of *government failures*” (Gordon, 2004, p. 2). Many also view market-determined income and wealth distributions as invariably demanding various top-down interventions. The conventional discussion of market failures misses the dynamics that people have incentives to discover ways to lower transaction costs and/or extend property rights, thereby bringing new goods and services into the exchange economy and out of the commons (Dollar and Kraay; Gordon, 2004). The paper by Gordon (2004) discusses the limitations of neo-classical economics and suggests a circumscribed role for *top-down planning*.

Gordon (2004, p. 4) offers a postulate that “top-down economic planning is an impossibility because in absent markets that reveal (and continuously refresh) scarcity signals (e.g. prices), complex decentralized coordination is impossible”. In fact, if planners were to magically divine an uncountable number of prices they would be overwhelmed by the sheer magnitude of the data (Gordon, 2004, p. 4). “Top-down planners are seriously staggered by their inability to tap diffused local knowledge, the sheer magnitude of which would in any event overwhelm them” (Gordon, 2004, pp. 8-9). Further, as highlighted by Gordon (2004, p. 9) “in a competitive market, local knowledge reappears, lessening the dependence on politics and increasing flexibility; public goods (and spaces) are provided more optimally; the capitalisation of benefits more efficiently finances public goods provision; and market-tested rules of

governance are developed”. Although many people assert that top-down planning is inevitable due to externalities and information problems; events, however, point to the opposite: the bottom-up approaches are inevitable because of these problems, exactly as the Hayekian critique makes clear ([Gordon, 2004](#)).

Friedrich Hayek, the winner of a Nobel Memorial Prize, put forward a view that it takes decentralised markets to generate the required information through trial-and-error learning processes, in which market participants are far more productive than top-down planners have or can ever be. This view undermines the widespread emphasis on all sorts of market failures and the presumed benign corrective capabilities of politics and government ([Gordon, 2004, pp. 8-9](#)). Notably, Hayek viewed the free price system, not as a conscious invention (that which is intentionally designed by man), but as spontaneous order, or what is referred to as "that which is the result of human action but not of human design" ([Hayek, 1991](#)). Thus, Hayek put the *price mechanism* on the same level as, for example, language. [Hayek \(1991\)](#) explained that price signals are the only means of enabling each economic decision maker to communicate tacit knowledge or dispersed knowledge to each other, in order to solve the economic calculation problem.

On this note, in the first phase of the EU ETS the price of EUAs rose to €30 and eventually fell to well below 10 Euro cents, as the imperfections of the market became rather obvious. In the second phase which began in 2008 the price has fluctuated between €29 and €8. An alternative market-based approach that exists in many countries is to impose a carbon tax on polluters, Finland, Sweden, Norway, Denmark, Germany and the UK tried this first, and the EU Council wanted to do this but could not get the unanimous agreement of all members to introduce a tax. Introducing an

ETS was politically easier as they did not need unanimous agreement between members. There is evidence which suggests that directly increasing the price of a pollutant through a tax has the effect of reducing demand (Hoeller and Wallin, 1991). This approach, for example, has been used in many places to reduce the use of petrol for motor cars, to discourage the use of plastic bags and bottles and it reduced carbon pollution in Denmark by about 3%.

Trading of emissions permits has begun and yet there is no definitive accounting standard which explains the nature of a permit and how it should be treated in the balance sheets of companies, though the International Accounting Standards Board (IASB) issued a draft standard (IFRIC 3 Emission Rights) in December 2004 and withdrew the draft in June 2005. It appears that emissions permits are being traded in a way that is similar to financial instruments though they do not appear to have the characteristics of financial instruments, and a range of derivative instruments have been developed for trading with derivatives now being some 96% of items traded at the London exchange. Effectively, the carbon market is dealing with something that does not have any accounting definition and does not have any physical substance (the EUA) and the lack of an accounting standard further emphasises the emptiness of the product being traded.

## **1.2. Research Objectives and Questions**

This thesis reports the results of research which has attempted to assess the main drivers of the price of an emissions permit. In addition to general demand and supply factors that influence price in the short-term, this study considers factors such as the

price of oil, coal and natural gas as well as variations in temperature, fluctuations in GDP and the effects of the global financial crisis which may affect carbon price in the medium term. An understanding of these price determinants is essential for a rational trade in permits or derivatives. Currently the markets offer futures which guarantee the delivery of numbers of permits at various times in the future, and options which guarantee the right of the buyer to purchase EUAs at a stated price, and the valuation model used for these futures and options is not clear at the moment. The purpose of the futures and options is also in question as they may be used for hedging against future price rises or as speculative instruments by buyers and sellers and the valuation model can be expected to vary in each case. It is interesting to note that the price of carbon is largely discovered from futures contracts. In fact, across all exchanges more than 90% of carbon trading takes place in derivatives and less than 10% in actual permits ([ACEL, 2007](#); [Isenegger and von Wyss, 2009](#)).

The main purpose of this thesis is to examine the factors that have shaped the price of carbon permits in the secondary market under the EU ETS. In addition, this thesis will seek to study EU ETS carbon price volatility during Phase I and Phase II of the European emissions reduction scheme. Among the most crucial research objectives is to identify the factors necessary to develop an efficient secondary carbon market and to draw inferences from the EU ETS experience for other carbon markets.

First, this study seeks to investigate some of the external factors<sup>9</sup> that have shaped the price of carbon permits in the secondary market under the EU ETS during January 2006-December 2009. The main goal being to build an understanding of the key

---

<sup>9</sup> **External factors** include the price of natural gas, oil and coal; as well as weather (temperature), level of GDP growth and the economic effects brought by the global financial crisis



determinants of the price of an EUA.

Based on my research objectives and the lack of literature available, I have considered the following four research questions.

- 1) What is the relationship between regulatory processes and government intervention<sup>10</sup> and the price of carbon?
- 2) How do regulatory processes and government intervention influence carbon price formation and trading?
- 3) If any, what is the interrelationship between regulatory processes and government intervention, external factors<sup>11</sup> and carbon price?
- 4) How does carbon price affect carbon market efficiency<sup>12</sup>?

**Figure 7** below is a graphical representation of the interrelationship among the factors that affect the carbon price in the context of the secondary carbon market.

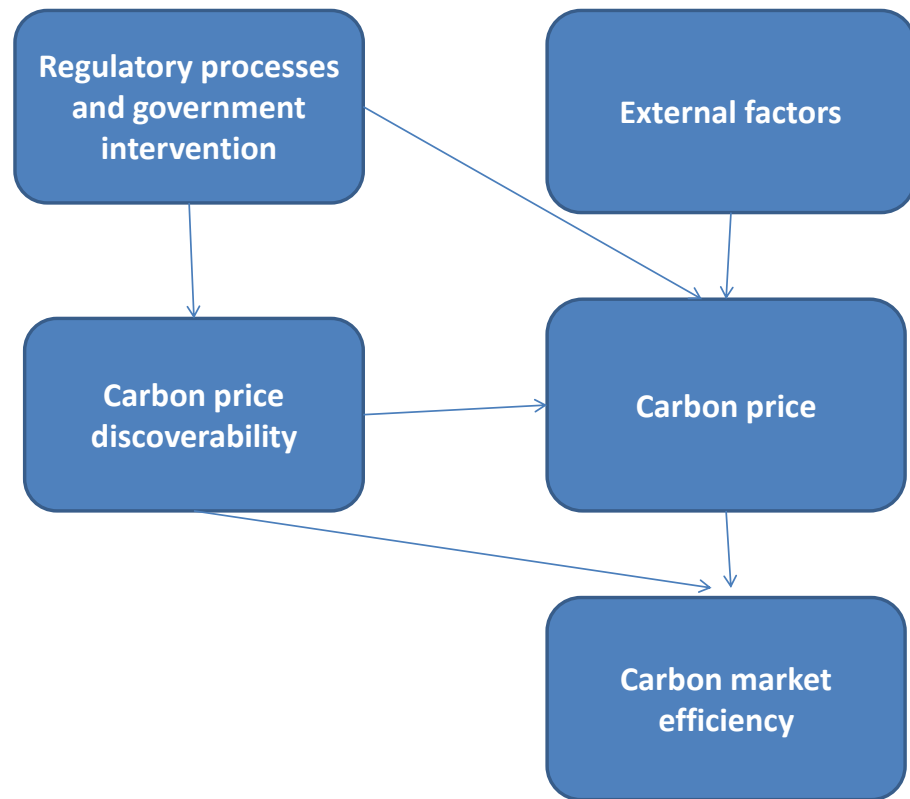
---

<sup>10</sup> **Regulatory processes and government intervention** refers to the predictability of regulatory processes and the potential impact of oversupply in the primary market and primary market volatility.

<sup>11</sup> **External factors** consist of economic well-being and level of industrial activity; coal, gas and oil prices; and weather conditions [temperature]

<sup>12</sup> **Market efficiency** stands for the level of informational efficiency in the secondary carbon market

**Figure 7. Factors Influencing the Carbon Price in the Secondary Carbon Market**



### **1.3. Research Motivations and Contributions**

First, a part of my motivation is to understand the importance of learning the lessons and avoiding mistakes from the first two phases of the EU ETS for the more efficient operation of the carbon market in the future. Lessons from the EU Emissions Trading Scheme show that it is hard to get the design of the scheme correct from the outset (Betz, 2009). According to the [Climate Change Law Practice Group Blog \(2007\)](#), the EU has been extensively criticised for the overallocation of greenhouse gas emissions allowances during Phase One of the European Trading System (EU ETS), which led to the collapse in the price of carbon both in the first and in the second phase. Under the EU ETS market design, permits are allocated free to market participants, which leaves

them with no price signal to follow. Consequently, the failures of the EU ETS, which has been widely criticised for oversupplying carbon permits ([Carbon Market Data, 2009](#)), provides further research motivation for investigating the factors which have contributed to the design of the scheme that caused the observed carbon price volatility. Finally, as proposed by [Daskalakis and Markellos \(2008\)](#), reviewing the functioning of the EU ETS market should be aimed at suggesting possible improvements. In fact, as highlighted by the authors, “the future of the EU ETS and its leading role in the global market for carbon emissions will depend on the success of any policy revisions and new measures that are expected soon to take place” ([Daskalakis and Markellos, 2008, p.104](#)).

Second, it is very important to investigate how we can avoid the onset of a *bubble* created by the carbon market. Evidence shows that markets are efficient and prices are appropriate in the medium term ([Brealey et al., 2008](#)). However, in the short-term, it is greed and fear that often drive the market. According to [BusinessLine \(2008\)](#), a recent surge of investor interest in the global carbon credit market has created ripe conditions for risk management products. But the rush of money into the green arena has also raised fears of a bubble, since share prices – as in the dotcom bubble – have risen in part on the back of expectations of future earnings growth rather than solid visible returns ([BusinessLine, 2008](#)). This is of great significance to the functioning of the EU ETS secondary market because if the market develops without appropriate valuation principles and this is exploited through the derivative mechanism, derivatives can get out of control and a carbon bubble may arise. Importantly, according to [Carbon Offsets Daily \(2009\)](#), within five years of trading the carbon derivative market will get five to ten times bigger than the market for actual permits. In fact, today sufficient evidence has been put forward to support this notion ([Chan, 2009; Yan, 2009](#)). In a

speech given by Bart Chilton, commissioner of the US Commodities Futures Trading Commission, it was forecast that the carbon market could be the world's biggest derivatives market in five years and carbon trading could grow to become worth between \$2–3.5 trillion ([Carbon Offsets Daily, 2009](#)).

As per [Yan \(2009\)](#), carbon trading is fundamentally derivatives trading. Notably, the report, written by [Chan \(2009\)](#) goes to explain that most carbon allowances and offsets are sold as futures or forward contracts and are therefore a type of derivative. [Chan \(2009\)](#) warns of the carbon derivatives market and of the risk from "subprime carbon" – contracts to deliver carbon credits that carry a relatively high risk of not being fulfilled and may collapse in value. They may be comparable to subprime loans or junk bonds, which are debts that carry a high risk of not being paid. According to [Chan \(2009\)](#), subprime carbon would most likely come from substandard carbon offset credits, which could trade alongside emission allowances in carbon markets. There goes the danger of establishing a large carbon derivatives market without first establishing robust and effective mechanisms to govern it. That notion includes the ability to estimate the intrinsic value of carbon permits as well.

Therefore, because “derivatives are bets on the future” ([Gettler, 2009](#)), the EU aim is to create a genuine and robust carbon price. This underpins the fact that understanding the value of the market and prudent regulation are crucial in avoiding the bubble. In addition, with the aim of avoiding the bubble, it is imperative to devise the appropriate design of the trading scheme. In fact, evidence proves that if you set up the wrong parameters of the ‘game’, you are very likely to lose ([Tan, 2009](#)).

Third, the EU ETS has numerous implications for the study of factors and approaches to the price discoverability of permits and the application of the insights of this

relationship to Australia. The matter is complicated as different market participants have different views in regard to the main drivers of the price of permits in the CO<sub>2</sub> market. Further investigation has to be pursued in order to work out how to reasonably determine carbon price, its integration, transparency, discoverability, volatility and, mostly, reliability. Amongst the most crucial research questions to be asked in this regard is whether there is any correlation between fluctuations in secondary permit prices and changes in such variables as: for example, economic well-being and level of industrial activity; predictability of regulatory processes; price of switching to technology; potential impact of oversupply in the primary market and primary market volatility; effect of competition; cost of energy; gas and oil prices; cost of renewable resources; banking of permits; carbon credits and price of carbon offsets; as well as weather. Given the resources and the time frame available, this thesis considers the relationship between secondary permit prices and changes in such variables as economic well-being and level of industrial activity marked by GDP, gas, oil and coal prices as well as weather.

According to [Ellerman and Montero \(2002, p.6\)](#), “in practice, firms will not know with certainty the number of permits they will demand in the near future, and, consequently, the market equilibrium price of permits becomes an uncertain variable”. Furthermore, it is very difficult to estimate the future price of carbon permits in Australia because no similar market exists and there were no analogous financial assets with which comparison could have been made. In addition, [Montero \(2002, p.6\)](#) suggests that “market efficiency requires a certain volume of trading”. The author defines trading volume as the “difference between emissions and allowance allocation” ([Montero, 2002, p.5](#)). According to [Montero \(2002, p.7\)](#), “unlike price information, the actual or observed trading volume does convey enough information for the analyst to conclude

whether the market is efficient”. “While a market with a significant trading volume and broad participation is more likely to approach efficiency, a market with a relatively low trading activity cannot be ruled as inefficient” (Montero, 2002, p.7). “Thus, in the absence of detailed individual-level data on costs and unrestricted emissions, it is not possible to conclude from trading activity data whether or not the market is delivering the least-cost solution” (Montero, 2002, p.7). “Because it is always difficult to collect and develop accurate firm-level information, looking at each firm’s final position in the market and comparing this to estimates of the (optimal) individual and aggregate volumes of trading becomes almost a futile exercise” (Montero, 2002, p.7). All of these uncertainties coupled with the EU experience underpin the significance of having a solid understanding of how the market structure and the allocation process can affect prices and this highlights the necessity of exploring the efficiency of carbon markets, as the secondary carbon market has developed in Europe.

Fourth and importantly, there has been very little research done on this matter and this further reinvigorates the call for a related study. From the existing literature, it can be concluded that most of the research was focused on emissions trading in the European Union (Alberola and Chevallier, 2009; Ellerman and Buchner, 2007; Convery and Redmond, 2007). In fact, as the Literature Review demonstrates, only a very small number of the studies up-to-date have tried to analyse the mechanisms driving the price of EUAs in the context of the EU ETS secondary markets. The majority of papers stress the significance of the existence of an efficient carbon market (World Bank, 2008; MacKenzie, 2008). Despite their importance the functioning of carbon markets is still a relatively unexplored area.

All of the above grounds explain my research focus. Essentially, the purpose of this study is to not only make a contribution to the financial literature, but to also provide useful guidelines to corporations, governments and individuals who trade in carbon markets.

## **Chapter 2**

### **2. Literature Review**

The literature review for the purpose of this thesis revolves around five key areas, namely: the influence of regulatory processes and government intervention on the design and settings of the EU ETS, carbon price volatility and the factors that affect the price of carbon, neoliberalism as well as the theoretical foundations and ideology of climate change.

#### **2.1. The Influence of Regulatory Processes and Government**

##### **Intervention on the Design and Settings of the Scheme**

The EC's decisions on NAPs play a key role in the determination of the size of the overall cap in the EU ETS ([Rotfuss et al, 2009](#)). The impact of the EC's decisions on EUA prices is voluminous. Legislation is aimed at directly changing the behaviour of polluters by outlawing or limiting certain practices ([Beder, 2006](#)). As identified by [MacKenzie \(2008\)](#), the primary role of the government under emissions trading is setting a cap on emissions. According to [Retamal \(2009\)](#), "carbon permits are a new type of immaterial commodity, highly dependent on political decisions". In fact, as outlined by the ECX ([2004](#)), the EU emissions trading market has been operating in an environment dominated by political and regulatory influence. The [ECX \(2004\)](#) and [Agritrade \(2004\)](#) proposed that policy and regulatory issues are among the key drivers that are likely to have an impact on the design and settings of the carbon market. [Convery and Redmond \(2007\)](#) researched the institutional framework and provided a thorough description of the major design features of the EU ETS. They emphasised the importance of rationality for the Kyoto governments in allocating permits to the



respective trading sectors. In addition, the authors identified that, even though during Phase One, member states were allowed to auction up to 5% of their total allowance allocation, only Denmark, Hungary, Ireland, and Lithuania have exercised the option to auction any permits in Phase One. This implies that, given the design and settings of the scheme, none of the firms in the countries considered (being the UK, France, Germany and Italy) bought any permits during the first phase of the EU ETS, they all received 100% of them for free.

[Kruger et al. \(2007\)](#) examined the structure of the EU ETS and observed that at one extreme lies a wholly centralised system in which the central environmental authority determines who will participate in the market, how many permits will be created, how these allowances will be distributed among the various emission sources (installations being regulated), as well as all the rules for compliance and trading. While at the other end of the spectrum is a completely decentralised system in which each country (or jurisdiction) runs its own system with no automatic links or connections to other jurisdictions ([Kruger et al., 2007](#)). Under the First Phase of the EU ETS it was essentially the European Commission (EC) that made decisions in regard to the structure of, and participation in, the system, but then member states individually decide on the allocation of their national cap level, allocating the country's permits to organisations, creating institutions to monitor, report, and verify their emissions, and making choices about some structural features (such as auctions and banking, for example). As the EU ETS now covers thirty European countries and the Commission is now well aware of the problem caused by separate country emissions schemes, the second phase of the scheme will tend to rely more heavily on centralised decision-making for the allocation of permits and for the monitoring and management of information sources and registries. This provides a useful laboratory for this thesis

in considering the political, economic and administrative challenges that have been faced by the EU ETS market participants.

The study by [Bettelheim and Janetos \(2010\)](#) found that the “structural flaws in the EU ETS are quickly reflected in exchange traded prices”. Clearly, the public report that the European Commission had allocated too many carbon permits in Phase One of the European carbon trading scheme was followed by an immediate collapse of EUA prices in April, 2006 ([Kirat and Ahamada, 2009](#); [Bettelheim and Janetos, 2010](#)). This sudden collapse of the carbon price followed the disclosure of the 2005 verified emissions by the European authorities ([Kirat and Ahamada, 2009](#)). The results revealed a net long position in the carbon market with more allowances than actual emissions ([Kirat and Ahamada, 2009](#)). Similarly, the recent announcement by the European Commission of its intention to curtail the use of CERs<sup>13</sup> in Phase Three (beginning in 2012) had an almost immediate depressing effect on both carbon prices and exchange activity. This clearly is a manifestation of poor market regulation ([Bettelheim and Janetos, 2010](#)) and limited market information sources. A further issue highlighted by the authors is, “the Achilles heel of the markets is the uncertainty created by repeated political and regulatory interference” ([Bettelheim and Janetos, 2010](#)). Under the EU ETS, this interference is further a result of dividing the scheme compliance into phases, which is undoubtedly in conflict with the need for long-term investment, perhaps measured in decades, aimed at overcoming global climate change ([Bettelheim and Janetos, 2010](#)). Evidence from Phase One and Phase Two so far suggests that such an environment prevents carbon markets from functioning

---

<sup>13</sup> **CER** stands for certified emissions reduction, which is a type of an emissions unit (or a carbon credit) issued by installations covered by the EU ETS in order to facilitate compliance with their obligations to surrender EUAs.

effectively.

[Ogunbona et al. \(2009\)](#) observed that the main lesson learned from the EU ETS is that the design and settings of the carbon trading scheme, which are based on a market-based approach, are confined and, indeed, limited by the boundaries set by a political process – the government sets the rules of the game in which the market participants play. The reality is that the political processes directly set the outcome of the carbon trading scheme. Therefore, as outlined by [Ogunbona et al. \(2009\)](#), the so-called market-based solution is only as good as the parameters and limitations set by governments are adequate. [Beder \(2006\)](#), [Garnaut Climate Change Review \(2008\)](#) and [Ellerman and Buchner \(2007\)](#) have also argued that the success and efficiency of the carbon trading scheme is highly dependent on the design and settings of the system.

In addition, according to [Betz \(2006\)](#), the deferred authorisation of National Allocation Plans (NAPs<sup>14</sup>) by the European Commission on Climate Change has also influenced the functionality of the EU ETS, undermining carbon price discoverability and resulting in substantial volatility. Importantly, because political decisions at various levels provide important signals to the carbon market, all of the studies mentioned above carry significant implications for the purpose of this thesis which will seek to highlight the relationships between regulatory processes and government intervention and trading in the carbon market.

In 2009, the British newspaper *The Economist* wrote that “climate change is the hardest political problem the world has ever had to deal with” ([Duncan, 2009, p.57](#)).

---

<sup>14</sup> The last NAP was approved six months after the EU ETS commenced, i.e. July 2005

Houston et al. (2010) argue that the initial failure of the carbon market was not so much due to inexperience as it was due to political tinkering by polluters, which refers to the policy-creation process and not the policy itself. According to Houston et al. (2010), it is the latter that must be examined in order to gain understanding of the carbon market's trading problems. "The policy creation process may be viewed as a game in which different groups of market stakeholders compete to obtain policies they desire, even if it is at the expense of the integrity of the market that they have created" (Houston et al., 2010, p. 2). Additionally, as Houston et al. (2010) point out, the policy-creation games which direct the EU ETS may have been two-levelled in nature. This means that "the diverse and opposing interests of the constituencies which the relevant policymakers represented, may have limited the outcome of the policymaking game" (Houston et al., 2010, p. 2). Bailey and Maersh (2009, p. 445) took a similar approach to that of Houston et al. (2010), arguing that "overlapping interpretations of the regulatory logic of emissions trading (as a cost effective means of meeting climate objectives) by the EU state and industry actors provided the driving force for a climate governing space and the consolidation of the EU governing authority in respect of the formal rule making elements of the EU ETS".

Ever since climate change has become an issue of public concern, economists have been making life difficult for environmentalists and politicians (Affalo, 2010). The main problem is that combating climate change requires sizeable investments that make rates of return look unattractive (Affalo, 2010). The benefits of investing in green energy are uncertain and distant. Nevertheless, politicians have felt public pressure and decided that such investments will be profitable for the whole of society over the long term and that they are worth undertaking. Therefore, the question no longer is whether they need to do something to mitigate climate change, but rather how

to do it effectively and efficiently (Affalo, 2010). Amongst the three policy instruments politicians are using to accomplish this goal (some of which have been mentioned in Chapter 1 of this thesis) are: *carbon pricing* underpinned by an ETS, *carbon tax* and *subsidies*.

First, *carbon pricing* provides a way of internalising social costs of pollution by giving companies incentives to reduce their production of GHGs. A carbon price can be set either by tax or through a cap-and-trade system. For political reasons, the EU governments have chosen to select the cap-and-trade option. Actually, taxes are never very popular, no matter what their purpose is. Potentially, the EU ETS could be very efficient because it keeps governments out of the decisions and gives companies more flexibility to choose the best way to cut carbon emissions. However, the results have so far been rather disappointing. The reason is that the emissions allowances have been set too high, resulting in a carbon price that is not high enough (Affalo, 2010).

The second way of pricing carbon is through a *carbon tax*. Norway and Sweden already have a carbon tax, and France will implement one in the near future (Affalo, 2010). It seems that a carbon tax would be the most efficient and effective way to mitigate carbon emissions as once the tax level is defined, it keeps the government out of business decision-making. Furthermore, carbon tax is also easy to practically implement. The only hurdle to this solution is the governments' fears of the consequences of this policy on their popularity among their electorate, pointing to political lobbying by most influential interest groups. However, it is becoming clearer that in most developed countries, where levels of debt relative to GDP have risen sharply due to the crisis, tax hikes would be needed anyway (Affalo, 2010).

The third way to combat GHG emissions is through *subsidies*. The rationale for the use

of this tool lies, again, in the need to modify incentives in order to improve the well-being of society. As a matter of fact, R&D in green technologies is too risky for most companies to undertake on their own as the costs are high and the technology tends to be large. On the other hand, it offers enough social benefits to deserve government support. Thus, there is no doubt that subsidies could be useful and even though government funding in the form of subsidies seems to be the most effective way of combating climate change, it also seems to be the less efficient one ([Affalo, 2010](#)).

Importantly, like other environmental markets, the EU ETS is created through political decisions and has to be framed in law ([Ministry for the Environment of New Zealand, 2011](#)). It must then be implemented through a series of regulatory decisions and operating guidelines, which could potentially have an impact on market price and developments ([Ministry for the Environment of New Zealand, 2011](#)). As a result, the market responds to occasional price signals from issues such as the number of EUAs that are issued. For example, as the scheme's watchdog, the European Commission (EC) must approve the decision by each government on how many EUAs that government can issue to its industry and energy companies. If the EC demands cuts to the government's original plans, the price history suggests that the market reacts to the prospect of supply being restricted beyond expectations and the price for EUAs will rise accordingly. However, these political price signals occur only occasionally. On a daily basis, it is the broader energy complex that provides price drivers ([Ministry for the Environment of New Zealand, 2011](#)).

To summarise, government intervention is needed to find an optimal solution to the climate change issue. However, governments must make every effort not to distort

some of the market mechanisms that are still deemed to be the best tools for allocating scarce resources.

## **2.2. High Volatility of Carbon Price**

According to [Poon \(2005\)](#), volatility refers to the “spread of all likely outcomes of an *uncertain variable*”, in this case being price. In theory, the price of permits under the EU ETS should establish the marginal cost of emissions reductions sufficient to meet the cap set in the scheme ([Betz, 2006](#)). The reality, however, appears somewhat different, resulting in substantial volatility.

In studying the market and price developments in the EU ETS, [Convery and Redmond \(2007\)](#) have argued that introducing a ban on banking allowances is likely to increase price volatility because as holders of surpluses begin to realise that those surpluses will have zero value, they are likely to surrender their surplus at the current price, which may essentially result in a price dip.

[Kruger \(2008\)](#) looked into some of the general factors that contribute to price volatility and put forward the idea that price volatility under the EU ETS was mainly caused by fuel prices, weather and policy developments. Importantly, the latter reasoning carries considerable implications for answering one of the research questions, which seeks to identify the influence of regulatory processes and government intervention on carbon price discoverability.

In assessing price volatility of the carbon market, [Betz \(2006\)](#) found that the main reason underlying the volatility is the fact that the EU ETS is a relatively new market and new markets generally require time to achieve real price discovery. It is unlikely

that a market structured like the EU ETS, with a small number of large players who are dominant, can easily achieve informational efficiency. There are three recent studies which shed some light on this issue with [Seifert et al \(2008\)](#) suggesting some evidence of efficiency based upon a test of autocorrelations, but only using a very small sample. In sharp contrast to this, [Daskalakis and Markellos \(2008\)](#) found significant autocorrelations in the data and dismissed the random walk notion as applying to carbon prices. The more recent study by [Montagnoli and de Vries \(2010, p.6\)](#) used a series of variance ratio tests to find that:

“For the sample periods 27 June 2005 to 28 December 2007 (Phase One) and 26 February 2008 to 4 April 2009 (Phase Two) the EMH is tested through variance-ratio tests while adjusting for thin trading. The results show that the EU ETS was inefficient during Phase One but efficient during the first period of Phase Two. This suggests that the carbon market shows the first signs of maturation after the learning and trial period of Phase One”.

However, they are aware of the problems created by the thin trading and advise “some caution in the interpretation of the results” ([Montagnoli and de Vries, 2010, p.5](#)). Their published information on trading volumes certainly raises questions about the study as it is lower than that reported in other sources and the use of non-parametric statistics<sup>15</sup> is an interesting departure from the earlier studies.

Though the carbon market is clearly still at a pilot stage of development, there is

---

<sup>15</sup> **Non-parametric** statistics are sometimes called *distribution free* statistics because they do not require that the data fit a normal distribution ([University of Wisconsin – Stevens Point, 2010](#)).



evidence to suggest that the carbon permit market is starting to show some signs of maturity as a centre of price discovery and dissemination and in the near future it is likely to grow in size and complexity ([Bettelheim and Janetos, 2010](#)) which will enhance this process.

### **2.3. Factors that Affect the Price of Carbon**

Research methods employed will build up a picture as to what factors determine the price of permits in the secondary carbon market. The approach is based on a time series of changes in such external factors as the level of industrial activity and, thus, the level of CO<sub>2</sub> emissions, gas, oil and coal prices, and weather conditions (indicated by temperature) in the UK, Germany, France and Italy. The study will also conduct a cross-sectional analysis of movements in the prices of permits.

Importantly, most of the literature in this field relates to the EU ETS and covers the factors that have shaped the price of carbon dioxide permits under the European scheme. [EurActiv \(2009\)](#), observed the overall trend that caused the slump in the price of the CO<sub>2</sub> markets. Official EU data published in May 2006, when the carbon price halved overnight, showed that firms in a group of countries, including large polluters such as Germany, were left with 44.1 million tonnes of extra CO<sub>2</sub> allowances for year 2005 ([EurActiv, 2009](#)). Among the EU's major polluters, only the UK had emitted more than its quota, forcing it to buy over 30 million tonnes of extra allowances in the EU carbon market ([EurActiv, 2009](#)). Research undertaken by [EurActiv \(2009\)](#) goes to emphasise that it was the supply surplus that caused carbon prices to crash, thus calling into question the credibility of the efficiency of the EU scheme ([EurActiv,](#)

2009). This study is related to my thesis because it provides useful insights in regard to the factors that have caused the crash of carbon price in Germany and the UK, both of which [countries] will be examined in my thesis.

Convery and Redmond (2007) argued that in the case of climate change and other environmental challenges, the market will not produce the 'right' carbon price. The authors refer to this as "market failure, which occurs because for exchanges to take place, assets must be owned, they must be divisible, and appropriate legal and institutional mechanisms must be in place to enable a price to emerge" (Convery and Redmond, 2007, p.88). Nevertheless, "in regard to climate change, none of these conditions has applied" (Convery and Redmond, 2007, p.88). Clearly, the ability of the atmosphere to absorb anthropogenic greenhouse gases cannot be owned, neither can it be readily divided and sold. Furthermore, as pinpointed by Convery and Redmond (2007, p.88), appropriate legal and institutional frameworks have not existed to enable competent exchange. Thus far, it may be put forward that "the carbon market has failed to reflect the scarcity value, and global warming pressures have intensified" (Convery and Redmond, 2007, p.88). This is an important implication for this thesis, as it will aim to critically examine the question of valuation vs. price in the secondary carbon market. The authors examined the features of the EU ETS that shape emissions trading and, therefore, price, and identified that amongst the key factors which had determined the price of permits were the nature, scope and allocation of allowances, cost of carbon reduction options, and CO<sub>2</sub> emission levels over the course of the trading period. In addition, Convery and Redmond (2007) expect that extra demand for permits will raise their price. This study provides some useful guidelines for my thesis where I will also look at some of the factors that drive changes in CO<sub>2</sub> emission levels and thus have an impact on the price of carbon. However, its major

limitation of the study by [Convery and Redmond \(2007\)](#) is that it only covers the period from December 1, 2004 to July 31, 2006, whereas I will be looking at a longer time series which includes more recent trends.

[Point Carbon \(2004\)](#) and the [European Climate Exchange \(2004\)](#) suggested that the price of carbon will depend on a number of factors, including weather, fuel prices and economic growth – all of which will be tested in my thesis. [Retamal \(2009\)](#) has also recognised that such factors as fuel prices (coal and gas) and weather have influenced the price of permits under the EU ETS. In the study on the carbon price determinants under the EU ETS, [Betz \(2006\)](#) determined that weather has a significant impact on emissions of the major covered installations since they are in the power and heat sector. According to [Betz \(2006\)](#), the summer of 2005 was hot and winter of 2005/06 was very cold and this led to a clear increase in energy requirements. In fact, as numerous other studies, including [Engle et al. \(1986\)](#), [Filippini \(1995\)](#), [Li and Sailor \(1995\)](#), [Henley and Peirson \(1997, 1998\)](#), [Considine \(2000\)](#), [Johnsen \(2001\)](#), and [Pardo et al. \(2002\)](#) have found, weather (temperatures) can affect the price of carbon due to its impact on the demand for and supply of electricity. This provides an important inference for my thesis, which will also aim to establish a relationship between changes in weather and carbon price over time.

In particular, [Engle et al. \(1986\)](#) identified a non-linear relationship between electricity sales and temperature. The authors ([Engle et al., 1986, p. 310](#)) recognised that “the relationship between temperature and electricity usage is highly non-linear, because electricity consumption increases at both high and low temperatures”. Nevertheless, it is important to note that estimating this relationship is further obscured by the need to take into consideration some of the other aspects, one of them being the level of

economic activity. Therefore, it can be concluded from this study that “extreme temperatures are invariably responsible for extreme electricity demand” (Engle et al., 1986, p. 310).

Further, Valor et al. (2001) have indicated that weather has a considerable effect on various segments of the economy. In fact, a lot of economic activities are influenced by changes in weather, so that expected revenues may seriously be affected by a deviation from typical weather conditions (Valor et al., 2001). In particular, the electricity market is one of the most susceptible sectors. This is explained by the fact that the demand for power is tied to a number of weather variables, primarily the air temperature. Furthermore, given that electricity cannot be stored for later use at a reasonable cost, it is normal to find that produced electricity is instantaneously consumed. The study by Valor et al. (2001) has explored the relationship between daily air temperature and electricity load in Spain. The results obtained from the analysis reveal correlation between daily air temperature and electricity, which is also supported by the results obtained by Engle et al. (1986). In addition, the work by Valor et al. (2001) reveals that maximum electricity demand values can be observed during both maximum (summer) and minimum (winter) temperatures. Moreover, the study Valor et al. (2001) shows that in the cold season the sensitivity of electricity load to daily air temperature tends to be more significant than that in the warm season (Valor et al. 2001, p. 1413). Interestingly, demand for electricity is represented by a weekly seasonality with minimum values on Sundays and maximum values during working days. Yet, it is important to note that this pattern may be disrupted by single public holidays within the week as well as by festivities such as Christmas or Easter. Overall, by seasons, the electricity load shows maximum values in winter and summer, whereas minimum values can be observed in the transition periods (i.e. spring and

autumn). To conclude, for the purpose of this thesis, the results from this study will be useful in understanding electricity load behaviour and its impact on the price of carbon.

In investigating the relationship between electricity demand and temperature in the European Union, [Bessec and Fouquau \(2007\)](#) have studied the trends in fifteen European countries between 1985 and 2000. The results obtained confirm the non-linearity of the link between electricity consumption and temperature. By distinguishing between North and South countries, the authors also found that the non-linear pattern is more profound in the warm countries. The plus of this study is that unlike [Valor et al. \(2001\)](#) and [Engle et al. \(1986\)](#), who only focused on the relationship between temperature and electricity demand in Spain and the United States, respectively; [Bessec and Fouquau \(2007\)](#) studied the trends in fifteen different European countries (i.e. Austria, Belgium, Denmark, Finland, *France*, *Germany*, Greece, Ireland, *Italy*, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and *the United Kingdom*), thus recognising the differences in temperature amongst countries.

However, an analysis of the carbon market between December 1, 2004 and July 31, 2006 by [Redmond and Convery \(2006\)](#) reveals that movements in energy prices have had the most significant impact on the development of the price of permits. The two energy commodities that were analysed by [Redmond and Convery \(2006\)](#) were oil and natural gas. The findings obtained by the authors revealed that increases in the price of oil appeared to have the greatest impact on the price of permits. [Redmond and Convery \(2006\)](#) believe that the price of oil shows up so strongly because it reflects the tying of gas contracts to oil prices. The limitation of the study is that the authors have only included oil and gas in their study, whereas this dissertation will also examine

some of the historic trends in changes of coal prices. In addition, the study only extends to the period from December 1, 2004 to July 31, 2006, whereas this thesis will be examining the more recent trends.

As per [Carbon Positive \(2006\)](#), one of the biggest factors affecting carbon prices have been energy prices, particularly gas and coal. In a scenario of gas prices have falling, it makes it more viable for power generators to switch from coal to gas. Lower carbon dioxide emissions from burning gas to generate power means less demand for EUA emissions permits to cover their EU ETS obligations. Similarly, as the report by [Carbon Positive \(2007\)](#) suggests, the carbon permit price has largely been driven by coal on one side and then oil and gas prices on the other side. If for example, the prices of oil and gas rise relative to coal, power companies shift generation away from gas and use more coal. The higher carbon emissions from burning coal require more carbon allowances per unit of power output, raising the EUA demand.

According to the [Ministry for the Environment of New Zealand \(2011\)](#), in the context of the EU ETS, the two main areas of price formation are: policy decisions (discussed earlier) and fundamentals, being the energy complex (weather, energy and economic activity). According to the [Ministry for the Environment of New Zealand \(2011\)](#), the European power generation sector accounts for 60% of the emissions covered in the EU ETS. As a result, it is the most important sector in the scheme and the relationship between the price of EUAs and the prices for oil, natural gas, coal, and electricity itself has been established ([Ministry for the Environment of New Zealand, 2011](#)). While the initial supply in the EU ETS was a political/regulatory decision, demand for EUAs is set by emissions; as companies emit more than their limit, they must buy EUAs to cover their extra emissions.

In general, CO<sub>2</sub> emissions depend on a number of factors, such as weather data (temperature), fuel prices and economic growth. Speaking of the weather, cold temperatures increase energy consumption and corresponding CO<sub>2</sub> emissions through power and heat generation ([Ministry for the Environment of New Zealand, 2011](#)). This finding is also supported by [Energy Brainpool \(2007\)](#) which notes the effects of temperature on the EUA prices. In many EU countries, power generators are able to switch their overall fuel use from coal to gas and back. The choice depends on which avenue leaves them with a better return given current power prices. With the EU ETS now in place, the installations must now also consider the cost of EUAs to cover the emissions associated with that fuel burn. Typically, burning coal to generate electricity results in the emission of twice as much carbon dioxide than natural-gas fired power stations ([Ministry for the Environment of New Zealand, 2011](#)). Importantly, the cleaner fuel faces a lower cost in buying EUAs to cover its emissions. So, according to the [Ministry for the Environment of New Zealand \(2011\)](#) since the EU ETS was introduced, power generators are able to calculate each day whether they would be more profitable generating from coal plants (including the cost of emissions resulting from the generation), or natural gas. This decision determines the intra-day demand for EUAs and is the major price driver in the EU carbon market on a daily basis.

The [Christian Science Monitor \(2007\)](#) estimated that the future price of carbon emissions may be difficult to identify. It implies that in my thesis I should aim to hypothesise rather than determine [assuming a certain degree of certainty] which factors will affect the price of permits in the EU ETS market, a relatively new and immature market with a relatively short history of trading.

Notably, according to [Convery and Redmond \(2007\)](#), as the EU member states attempt

to meet their own self-interest within the constraints imposed by the EU ETS, they influence price by shaping the quantity and timing of allowances coming to market and the incentives that firms face to abate, absorb the costs, or pass them through to consumers (which feed back to influence the demand for allowances). The bigger a member state's share of total allowances, the bigger its influence on price. This study prompted me to only include the UK, Germany, France and Italy in my thesis, as these countries possess the largest share of total allowances under the EU ETS ([Carbon Market Data, 2009](#)).

Finally, as the EU member states attempt to meet their own self-interest within the constraints imposed by the EU ETS, they influence price by shaping the quantity and timing of allowances coming to market and the incentives that firms face to abate, absorb the costs, or pass them through to consumers (which feed back to influence the demand for allowances). The bigger a member state's share of total allowances, the bigger its influence on price. Thus, on the basis of the literature reviewed, there is a need for more comprehensive and ample research into the pricing of permits in the secondary carbon market.

## **2.4. Neoliberalism**

The context of carbon trading gives rise to an increasing interest in how corporations and other social institutions are held accountable for their actions and how this process may lead to their actions being less socially and environmentally damaging ([Andrew and Cortese, 2011](#)). The work of [Beder \(2006\)](#) seeks to challenge the market as an appropriate site of “dialogic engagement” in which choices are maximised through the mechanisms of supply and demand and through “self-regulated” governance practices.



The author has argued that the environment should be central to policy formulation and that we should resist its characterisation as an “adjunct to production” (Beder, 2002, p. 50). It is important to shift the focus to climate change policy formulation to ensure that the ambitions of climate change abatement are not made subordinate to the ambitions of the market itself (Beder, 2001; Andrew and Cortese, 2011).

According to Andrew et al. (2010, p. 611), “public policy over the last 25 years has been dominated by neoliberal ideology which has driven solutions to emerging social, political and economic problems”. Under such a scenario, “emissions trading schemes founded on the core tenets of neoliberalism have emerged as the prevailing response to climate change by some of the developed countries” (p. 611). Ever since then the marketisation of climate policies and instruments has been subjected to growing challenges and debates by both the academia as well as the general public (Andrew et al., 2010).

In responding to the upsurge in carbon emissions into the atmosphere, the need for an urgent action by government, firms and individuals cannot be underestimated. Yet, as pinpointed by McKinsey & Company (2009, p. 10), “one thing is to have the potential to make deep cuts in GHG emissions; and another is for policy makers to reach consensus on and put into practice effective emission reduction policies and for companies, consumers and the public sector to take action towards making this reduction a reality”. The ultimate goal behind the emergence of the EU ETS is creating a robust market for global greenhouse gas emissions. According to Andrew et al. (2010), such “corporate response is in harmony with both the identification of the issue and the global influence of neoliberalism, which tends to adopt market based solutions to solving environmental issues.

Andrew et al. (2010) point to a number of environmental policies. Namely, Friedman et al. (2005, p. 274) denote a ‘toolbox’ of instruments that can be categorised by “the extent to which particular behaviour is directed by regulation”. Among some of them are tradable emissions challenge regulation and pollution charges (Friedman et al., 2005). The paper by Andrew et al. (2010) is based on the underlying assumptions that a) carbon pollution reduction is crucial and b) governments play a vital role to play in implementing the core environmental policies. The authors highlight that although today there are a number of policy instruments available for governments to choose from, emissions trading to date has been favoured globally as the instrument of mitigating carbon pollution (Andrew et al., 2010).

As mentioned earlier, the neoliberal ideology has dominated public policy in the past three decades and the EU ETS, as an environmental policy device, inevitably rests on its tenets. The mechanism of the EU ETS drives signatory companies to internalise the cost of pollution (i.e. carbon emissions) and thus create a price signal in the market (Andrew et al., 2010). Under such a system, companies can choose to invest in carbon abatement technologies. It is important to note here that this would largely rely on the cost of partaking in an ETS exceeding the cost of abatement. According to Andrew et al. (2010, p. 612), the EU ETS “infrastructure is fairly new, complex and is characterised by a lot of uncertainties”. Importantly, the authors highlight the fact that “most politicians and business leaders, as well as ordinary public do not seem to understand the complexities arising from an emissions trading scheme (Andrew et al., 2010, p. 612). Essentially, the EU ETS is a response to the market failure in addressing climate change and would have a different impact on the costs of pollution distributed economy wide (say, comparing to carbon tax). That is why as a market mechanism, the EU ETS requires a certain level of government intervention.

Carbon market is essentially a market for an unusual commodity in an unusual setting. There is evidence to suggest that price increases do affect market behaviour in aggregate. History shows that all markets without adequate regulation have failed, although each to a different extent. The inherent context of carbon trading surrounded by the design of its market mechanism inevitably draws attention to the idea of neo-liberalism and its role in the establishment of an EU ETS.

Neoliberalism is a term for different social and economic ideas. Neoliberals favour a free market economy, with everything it stands for, including private property of the means of production, the freedom for the market price to establish itself, as well as the freedom of everyone to do what they want. However, neoliberals do acknowledge that in some cases the freedom of the market fails or it does not yield the results wanted. It is argued that in such cases, the state should intervene. The main focus of the state should therefore be measures to regulate the following: monopolies and cartels, social fairness, equal opportunities, internalising external effects, as well as decreasing the effects of fluctuating business cycles. Neoliberals are openly against lobbying of groups and state interventions that aim to protect national interests, like import duties or subsidies. Neoliberalism is also against a centrally governed economy. Furthermore, neo-liberalism frowns upon the laissez-faire of classical liberalism.

Neoliberalism is a label for the market-driven approach to economic and social policy (Leys, 2010). It is based on neoclassical theories of economics that stress the efficiency of private enterprise, liberalised trade and relatively open markets, and therefore seeks to maximise the role of the private sector in determining the political and economic priorities of the state (Roy et al, 2007; Davis and Monk, 2007).

Neoliberalism seeks to transfer control of the economy from public to the private sector ([Cohen, 2007](#)), under the belief that it will produce a more efficient government and improve the economic health of the nation ([Prasad, 2006](#)).

[Friedman \(1962\)](#) developed an argument that economic freedom is an extremely important component of total freedom, is also a necessary condition for political freedom. [Friedman \(1962\)](#) commented that centralised control of economic activities had always been accompanied by political repression. In his view, the voluntary character of all transactions in a free market economy and wide diversity that it permits are fundamental threats to repressive political leaders and greatly diminish power to coerce ([Friedman, 1962](#)). Through the elimination of centralised control of economic activities, economic power is separated from political power ([Friedman, 1962](#)).

According to [Andrew et al. \(2010\)](#), neoliberalism rests on the idea of unrestrained free markets that are regulated by small governments. Under neoliberalism, the market apparatus is set by the state whose task is to establish and maintain “an institutional framework characterised by strong private property rights, free markets, and free trade” ([Harvey, 2005, p. 2](#)). [Cahill \(2009, p. 36\)](#) puts forward the notion of neoliberalism being “a form of the so-called managed capitalism whose reach has been expanded by the active involvement of the government in the economy and society throughout history”. Although there are some debates pertaining to the functioning of neoliberalism in practice ([Harvey, 2005; Cahill, 2009](#)), environmental solutions have seen the predominance of neoliberal influences upon them ([Andrew et al., 2010, pp. 612-613](#)).

In their paper, [Andrew et al. \(2010, p. 617\)](#) debate that “the neoliberal ideology has

dominated the choice of environmental policies, and this ideology is reinforced in the emerging carbon markets”. However, based on evidence that the EU ETS, in particular, has not worked well to solve the underlying environmental problems, the choice of the ETS as a principal market mechanism is rather difficult to understand without calling upon the concept of neoliberal ideology (Andrew et al., 2010). In addition, as suggested by Andrew et al. (2010, p. 617), “there is little evidence to support the idea that an ETS is superior to a tax-based approach to tackle carbon abatement, given the reliance on the government to establish infrastructure for ETS or carbon trading”. Even though in essence, “an ETS with permits sold by government is *a de facto tax*” (p. 617), given the current ideological context, emissions trading would nevertheless be easier to promote than carbon tax (Andrew et al., 2010).

## **2.5. Theoretical Foundations, Ideology of Climate Change and Sceptics**

The method used to conduct research rests on the methodological approach for the research. Methodology is inexorably linked to ontology, the view of physical and social reality and epistemology, the belief about knowledge (Chua, 1986a, p.605) behind the research method(s) applied. These underlying beliefs about reality and knowledge upon which the current research is being based are not always explicitly obvious in research on environmental issues i.e. climate change (Neuman, 2006, p.106). In order to understand this thesis, it is important to consider my view of reality and my perceived knowledge. When undertaking any given analysis or evaluation, one should remember that ontology, the believed reality, comes before and governs the epistemological and methodological assumptions adopted. Therefore, the correct

research method to use is dependent on how truth is defined ([Chua, 1986a, p.604](#)). This thesis is based on realist ontology, empiricist epistemology, positivist methodology and scientific research methods.

Recently, there has been much debate about the veracity of climate change. Here I would like to further refer to the article by [Slattery \(2010\)](#), in which the author quotes several academics who voice their concern as to the direction of the argument surrounding climate change as well as the perception of scientific opinion and research in that debate. The scientific community largely conforms to a given set of norms. These generally embrace universalism, organised scepticism, disinterestedness, communalism, and honesty ([Neuman, 2006, p.11](#)). Other than sourcing information from scientists and academics, there are also alternative ways of obtaining knowledge, which include authority, tradition, common sense, media myths, as well as personal experience ([Neuman, 2006, pp.3-6](#)). Authority may be represented by the view of parents and teachers. Tradition underpins the way something has always been done. Common sense is what everyone knows and what generally makes sense. Media myths are raised by television, movies, newspapers and magazines – all of which may portray many aspects of social life that people do not experience personally. Finally, one of the many different ways of obtaining knowledge is personal experience, which may be rather subjective ([Neuman, 2006, pp.3-6](#)).

As [Neuman \(2006, p.79\)](#) points out, there has been an ongoing debate regarding the definition of science itself. Notably, science is divided into two main categories: natural sciences and social sciences. Based on my realist perspective on the ontology of climate change and the underlying theoretical foundations, research on climate change is characterised as literature pertaining to natural sciences. The backbone of

this research is peer-reviewed science, which is defined as a collection of authentic scholarly papers, research, or ideas that have been subjected to the scrutiny of experts in a given (and often narrowly defined) field, who are qualified and able to perform an impartial review ([Gordon, 2003](#)). According to [Gaffikin \(2008, p.248\)](#), methodology is “the philosophical evaluation of investigative techniques within a discipline”. Peer reviewed science is undertaken via several methodological approaches.

A positivist approach to social science supports the view “that scientific knowledge is different from and superior to all other knowledge” ([Neuman, 2006, p.87](#)). Within the scientific community itself though there is contestability as to the validity of different methodological approaches in the climate change area. [Slattery \(2010\)](#) contends that the debate between scientific viewpoints and non-scientific viewpoints is unbalanced, and this may be so, but opinion, anecdote and the vested interest views of lobby groups all have a part to play in debate in a wider social context. The presence of a vast amount of information supporting the sceptical side of climate change is an indication of the deep divisions present in the debate surrounding climate change but most of this is not scientific research. The reality, perspective, interests and knowledge of the proponents in any debate need to be considered. According to [Gaffikin \(2008\)](#), one of the most important philosophical foundations when looking at theories is the basis for making claims to knowledge, that is: on what basis can we make a claim that what we state is knowledge is reliable knowledge?

In fact, the amount of literature pertaining to the climate change debate is voluminous. Media and scholarly articles form part of the debate as well as formal forums for discussion such as the Copenhagen Climate Change Summit in 2009. The following discussion evaluates some of the published debate leading up to the Copenhagen talks.

[Brook \(2008\)](#) explains that good science consists of evidence and ideas that are supported by observation, experiment and models with repeated testing and gradual refinement that lead to theories, paradigms and laws. The author also notes that scientists need to work harder at informing a public awareness as to the difference between good science and “denialist spin” ([Brook, 2008](#)). He also points to the tendency to hijack science for political and personal ideologies ([Brook, 2008](#)). In particular, in this study I will consider the regulatory framework of the EU ETS and attempt to explain the implications of the latter for the efficiency of the scheme. [Brook’s \(2008\)](#) arguments run along the same lines as [Slattery’s \(2010\)](#), i.e. science needs to make the public more aware of the rigour of the discipline and that self interested spin needs to be recognised for what it is.

[The Australian](#) newspaper opinion piece ([2009](#)) demonstrated how interest groups, in this case politicians, take scientific proposals into the realm of demonstrated fact for specific purposes. The author stresses that opinion formed via scientific method remains contestable and that interest groups need to stop hijacking scientific method for their own purposes. In the context of the debate on the veracity of climate change we see a difference in scientific opinion arising from different constructs of physical and social reality. Positivist methodologies lay claim to providing evidence about physical realities, while interpretative and critical methodological approaches lend more credence to social realities where other forms of evidence are considered ([Chua, 1986a, p.604](#)).

However, among scientists there can be different views on the same matter. It all depends on the ontological and epistemological views as well the methodology that has been relied upon in undertaking the research. [Joanne Nova’s Skeptics Handbook](#)



(2009) is an illustration of this. Nova (2009) demonstrates a sceptical view of climate change that is supported by peer reviewed scientific evidence.

In summary, the review of these publications indicates that there has been much debate within the scientific community relating to climate change (Neuman, 2006; Brook, 2008; Nova, 2009; Slattery, 2010; Kerr, 1989; Peake, 2005; The Australian, 2010; Trouson, 2010). Much of the dispute is about the way research is being utilised within the field and disseminated to the public. The media and political debates surrounding climate change often use scientific argument in a way that is not supported by the original intent of the scientific research methodology. This has contributed to an unbalanced debate with loud uninformed voices often overwhelming the findings of climate scientists.

In conclusion, having reviewed the different views on the veracity of climate change and the complexity of the problem, I have based my thesis on the methodological constructs of scientific research, using a mainstream positivist approach. In addition, I recognise that there are other methodological approaches which may be applied. How one views the existence of the world and how knowledge created is perceived, indicates the framework for how that knowledge is obtained and will also dictate the techniques and tools used in determining knowledge. Such knowledge creation is always open for debate and should remain contestable. This assertion is a basic underpinning of scientific research. Therefore, we should not be afraid to have the debate but we need to recognise and try to understand the reality of and the knowledge base for each participant's viewpoint.

## **Chapter 3**

### **3. Theoretical Framework**

For the purpose of this thesis, theory is mainly focused on two broad areas: economic theory and finance theory. While economic theory essentially involves the theory of perfect competition, and the role of government intervention underpinned by the laissez-faire principle; finance theory is principally concerned with the concept of the Efficient Market Hypothesis (EMH) and market microstructure theory.

#### **3.1. Economic Theories**

##### **3.1.1. Theory of Perfect Competition**

An invisible hand, the term initiated by Adam Smith, suggests that free interaction of players in a market economy leads to a desirable social outcome (Joyce, 2001). As further stated by Joyce (2001), an invisible hand process is one in which the market operates in a decentralised way, with no overt agreements between the market players. Essentially, the system should function even without the players having any knowledge of the market and this is why the process is called invisible (Joyce, 2001).

According to Taylor and Frost (2009), the model that is used most often to show how markets work is called perfect competition. A market is perfectly competitive if there are large numbers of buyers and sellers, and the goods traded are homogenous. In addition, buyers and sellers also need complete information and businesses must be completely free to enter or exit the market. This model is fundamentally derived from the supply and demand model, and presumes utility maximisation for buyers and profit maximisation for sellers (Taylor and Frost, 2009).

Nevertheless, as suggested by [Taylor and Frost \(2009\)](#), in practice, most markets do not encompass all the characteristics of perfect competition. Instead, imperfect competition tends to describe most markets. Under imperfect competition the number of sellers is small, or the goods traded somewhat differ from each other, or when consumers and producers are not able to acquire comprehensive information about prices. However, the model of perfect competition enables one to take a broad view of how markets operate and whether they operate efficiently. The model also makes it possible for one to comprehend what happens when markets fail ([Taylor and Frost, 2009](#)).

A major forecast of the perfect competition model is that a price will be the end result of the interaction amongst market players so that the quantity supplied is equivalent to the quantity demanded, known as the equilibrium price ([Taylor and Frost, 2009](#)). The perfect competition model, which incorporates the behaviour of buyers and sellers, aims to forecast the price, the quantity consumed by each buyer and the quantity produced by each seller. It also predicts marginal benefit of consumption for each buyer and marginal cost for each seller.

“If the price is higher than the predicted market price, then the quantity supplied is greater than the quantity demanded at that price. This is called a surplus. However, if the price is lower than the predicted market price, then the quantity demanded is greater than the quantity supplied. This is known as a shortage. Raising the price will decrease the quantity demanded and increase the quantity supplied until the shortage disappears. Thus, if the price falls when there is a surplus and rises when there is a shortage, the price will converge to the equilibrium price” ([Taylor and Frost, 2009](#)).

Even though the idea of upward and downward price movements to achieve

equilibrium between quantity supplied and quantity demanded does make sense, it is not a precise depiction of what happens in the real world market. In most markets, no one is capable of even observing the supply and demand curves. No one can scan a market and then adjust the price to stabilise supply and demand accordingly. In practice, market participants send price signals or place bids to buy or offer discounts. Therefore, it would be unwise to perceive the model of perfect competition as a literal description of how markets actually function. In turn, the legitimacy of the model depends upon its performance in forecasting prices and quantities in markets where real market participants conduct various transactions through buying and selling products and services (Taylor and Frost, 2009).

A vital feature of a perfectly competitive market is that it digests information very efficiently with the price revealing the marginal benefit for every consumer and the marginal cost for every producer. If a government were to establish the price in a real market, given such a large number of consumers and producers, it would be impossible to obtain such information (Taylor and Frost, 2009). A famous opponent of central planning and a strong proponent of the market structure, Freidrich von Hayek highlighted the significance of informational efficiency in the market (Taylor and Frost, 2009). According to Hayek, a key drawback of central planning, where the government establishes price and quantity, is that it is informationally inefficient (Taylor and Frost, 2009). Without private information about every consumer and producer, the government would not know exactly what price should be established. As evidence suggests, “production and consumption is handled well by the market and poorly by a central body” (Taylor and Frost, 2009). However, this idea is somewhat challenged by the Global Financial Crisis of 2007-2008 which suggests that unregulated or poorly regulated markets tend to extremes of behaviour, which leads to

market failure. Clearly, the market is capable of digesting information in an efficient manner. Deficiency in information efficiency is a primary reason for central planning not being able to function properly given the multifaceted and changing nature of the economic environment (Taylor and Frost, 2009).

### 3.1.2. Government Intervention

In economics, *laissez-faire* describes an environment in which transactions between private parties are free from state intervention (Bartlet, 1948). The phrase *laissez-faire* is French and literally means "let do", but it broadly implies "let it be", or "leave it alone" (Bartlet, 1948, p. 59). It is a term used to refer to a range of economic philosophies that aim to minimise or eradicate elements of government interference (Immordino et al., 2011). *Laissez faire* is an economic and political doctrine that holds that economies function most efficiently when unencumbered by government regulation (US History, 2010). Therefore, from here one can infer that the notions of *laissez-faire* and *government intervention* areonyms when performing in their prescribed role in society. Notably, advocates of *laissez faire* favor individual self-interest and competition, and oppose the taxation and regulation of commerce (US History, 2010).

In his time Bartlet Brebner (1948, p. 59) advanced “the perhaps startling thesis that the contemporary theory of 'laissez-faire' actually embraced a vigorous concept of state economic responsibility”. Ironically, the author associates *laissez-faire* with a political and economic myth. Further, as Bartlet Brebner (1948, p. 60) highlights:

“This is not to argue that *laissez faire* was not a powerful myth. As Hume said, though men are much governed by interest, yet even interest itself, and all human affairs, are

entirely governed by opinion. Although laissez-faire never prevailed in Great Britain or in any other modern state, many men today have been led to believe that it did”.

According to the [Cultural Dictionary \(2005\)](#), laissez-faire “describes a system that opposes regulation or intervention by the government in economic affairs beyond the minimum necessary to allow the free enterprise system to operate according to its own laws”. In other words, it is the “theory or system of government that upholds the autonomous character of the economic order, believing that government should intervene as little as possible in the direction of economic affairs” ([Dictionary.com, 2009](#)).

Clearly, proponents of laissez-faire support a vision of free markets with little or no state intervention. As outlined by [Carden \(2008\)](#), laissez-faire endorses the subjective theory of value, which holds that only buyers and sellers, while sharing information available in the marketplace, can decide how worthy products or services are to them and therefore determine a mutually agreeable price. [Carden \(2008\)](#) argues that supply and demand are the only sensible means of establishing prices. Moreover, the author deems that only prices established in a free market are capable of synthesising and conveying consumer preferences and relevant time sensitive information to millions of buyers and sellers. Furthermore, [Carden \(2008\)](#) also believes that any attempt to objectify these transactions by a centralised body will have a negative impact on the impartiality of the market.

According to [Reisman \(2006, p. 47\)](#), “capitalism, including laissez-faire capitalism, is a system based on state intervention, in violation of the free market”. In fact, as emphasised by [Reisman \(2006, p. 47\)](#), it is “state intervention that distinguishes capitalism from the free market”. Remarkably, [Reisman \(2006, p. 48\)](#), claims that

what he conceives of as a free market is namely a market without alleged state intervention”.

Originally, the concept of laissez-faire came from the economic theories of Adam Smith, who believed that private interests should have a free rein ([US Department of State, 2010](#)). According to Smith, as long as markets were free and competitive, the deeds of private individuals, induced by self-interest, would work together for the greater benefit of society ([US Department of State, 2010](#)). It is important to note here that Adam Smith did support some forms of government intervention, mostly those aiming to set ground rules for free enterprise ([US Department of State, 2010](#)). But it was his advocacy of laissez-faire practices that earned him support in societies built on faith in the individual and mistrust in power ([US Department of State, 2010](#)). However, as history shows, laissez-faire practices have not stopped private interests from asking the government for help in several instances ([US Department of State, 2010](#)).

As classified by the [US Department of State \(2010\)](#), government regulation can be divided into two broad categories: economic regulation and social regulation. Economic regulation mainly seeks to control prices. In contrast, social regulation, endorses motives that are not economic in nature, such as a cleaner environment, for example. In particular, social regulations intend to dampen or rule out detrimental corporate behaviour or to encourage behaviour considered to be socially desirable.

History has seen a repetitive swing between the principles of laissez-faire and demands for government regulation of both types, i.e. economic and social ([US Department of State, 2010](#)). In the last few decades, politicians (liberals and conservatives alike, in particular) have sought to reduce or eliminate some categories of economic regulation ([US Department of State, 2010](#)). However, political leaders

have had much sharper differences over social regulation ([US Department of State, 2010](#)). Liberals, in fact, have been much more likely to favour government intervention that promotes a variety of non-economic objectives, whereas conservatives have been more likely to perceive it as an intrusion ([US Department of State, 2010](#)).

## **3.2. Finance Theories**

### **3.2.1. Efficient Market Hypothesis (EMH)**

The EMH is closely related to the theory of perfect competition but is focused on the informational efficiency of markets, as it is generally accepted in finance that healthy competition amongst investors will tend to create an efficient market, in which prices will promptly reflect any new information in an unbiased manner, thus making it difficult to yield consistently superior returns ([Brealey et al., 2006](#); [Viney, 2007](#)). As [Brealey et al \(2008\)](#) further point out, all that market participants can rationally expect in an efficient market is a return just sufficient enough to reimburse them for the risk they take and the time value of money.

The efficient market hypothesis comes in three different forms: weak, semi-strong and strong. The weak form of the efficient market hypothesis conditions that prices efficiently impound all the information in the past series of stock prices, which makes it unfeasible for market participants to make superior returns simply by following patterns in stock prices ([Brealey et al., 2008](#); [Viney, 2007](#)). Otherwise stated, price changes are random. The semi-strong form of the efficient market hypothesis suggests that prices are inclusive of all published information, thus making it impossible for



market participants to earn consistently superior returns just by relying on publicly available data (Brealey et al., 2008; Viney, 2007). According to Rottfuss et al (2009), as of today little is known about the price formation in EU ETS and whether EUA prices fully and correctly reflect all publicly available information.

Finally, the strong form of the efficient market hypothesis advocates that stock prices effectively reflect all available information, including data from private sources (Brealey et al., 2008; Viney, 2007). Brealey et al. (2008) suggest that superior information is difficult to obtain because in the pursuit of it one market participant would have to compete with a tremendous number of other investors. The best that a market participant can do in this case is to assume that securities are fairly priced (Brealey et al., 2008).

The EMH stresses the informational efficiency of a market as opposed to the allocative efficiency and many markets have been found to possess weak-form informational efficiency. It remains an open question whether the European carbon markets are informationally efficient as three studies published so far present an ambiguous picture, though all agree that markets were not efficient in the first phase of the EU ETS (Seifert et al., 2008; Daskalakis and Markellos, 2008; Montagnoli and de Vries, 2010).

The EMH is a core part of finance theory. Notably, corporate finance has better and more substantial theories than the finance which bears upon capital markets, but even though the idea of the intrinsic value of a security is more substantial than the EMH, and it is at least testable, the EMH will never be a theory because it is not testable. It states that in an efficient market financial assets are priced correctly and reflect all relevant information available at a given time period. This therefore marks the

capability of efficient markets to adjust to exogenous shocks (Ng, 2010). It is worth highlighting the shortcomings of the EMH, in particular during a recession, as the principles of the EMH become inconsistent with the actual market conditions (Ng, 2010). The global financial crisis examined in this thesis is a good example of such notion. When the EMH is not consistent with the actual market conditions, this is known amongst researchers as the Financial Instability Hypothesis, which was put forward by Hyman Minsky (Ng, 2010). It is built upon the premise that financial systems are inherently unstable (Minsky, 1992). There are two internally generated destabilising forces: one is the lack of supply and the other is change in the asset price, both of which affect demand, in turn resulting in further price movement (Minsky, 1992).

According to Ng (2010), traders seek carbon permits with a degree of scarcity value, one for which supply cannot be increased to meet demand. By inference, a rise in the price of carbon signals to investors that carbon permits have become scarcer, and it is the lack of supply that stimulates demand. As mentioned earlier, the underlying premise of the EMH is that assets are always correctly priced and reflect all information available, based on both current economic conditions and the best estimates of how these conditions will change in the future. Thus, the EMH dismisses the idea that asset price bubbles may take place (Ng, 2010). Furthermore, it is patently true that any deviation from the equilibrium is short-lasting because, according to the EMH, the self-generating market forces will always bring it back to the equilibrium (Ng, 2010). This leaves us with inconsistency concerning the ability of efficient markets to adapt to external shocks without government intervention. The logic behind is such that if the market itself is efficient, then it should be able to adapt to external shocks on its own and without any help restore its desired equilibrium (Ng, 2010). So

making an inference from Ng's (2010) study, instead of blaming the European governments for making the EU carbon market inefficient, one should appreciate the role of the governments in monitoring and regulating the EU ETS in order to minimise financial instability and the difficulties that regulators face in achieving an informed market when the market is small.

In his paper, Ng (2010) concludes that the EMH is largely erroneous in general and closer scrutiny must be placed upon the carbon market to help untangle the carbon market inefficiency and instability. However, this is precisely why it is imperative for governments to strictly monitor and regulate the carbon market financial system in order to minimise instability and volatility that have been the inherent characteristics of the carbon market since it was born. Linking it to the earlier section of this chapter, in the context of carbon trading, it becomes rather obvious the role of the governments cannot be downplayed.

### **3.2.2. Behavioural Finance**

The idea behind carbon trading is quite similar to the trading of securities or commodities in a marketplace. Under the EU ETS, carbon is given an economic value, allowing people, companies and nations to trade it. If a nation buys carbon, it would be buying the rights to burn it, and a nation selling carbon would be giving up its rights to burn it. The value of carbon is then based on the ability of the country owning the carbon to store it or to prevent it from being released into the atmosphere. Simply put, the better you are at storing it, the more you can charge for it. Essentially a carbon market has been created to facilitate the buying and selling of the rights to emit GHGs. The industrialised nations for which reducing emissions is a daunting task can now buy the emission rights from another nation whose industries

do not produce as much of these gases.

On the one hand, carbon trading seems like a win-win situation: GHG emissions may be reduced while some countries reap economic benefit. On the other hand, critics of the idea suspect that some countries have been exploit the trading system, leaving behind pessimistic consequences. While carbon trading may have its merits, debate over this type of market is inevitable, since it involves finding a compromise between profit, equality and ecological concerns.

According to [Sewell \(2010, p. 1\)](#), “behavioural finance is the study of the influence of psychology on the behaviour of financial practitioners and the subsequent effect on markets”. [Sewell \(2010\)](#) deems that behavioural finance is of interest because it helps in explaining *why* and *how* markets might be inefficient. If behavioural finance is to replace the efficient markets hypothesis (EMH) as the most widely accepted paradigm, it is not sufficient to simply find flaws with the EMH ([Sewell, 2011](#)). Rather than representing a unified theory, behavioural finance often stands accused of consisting of little more than data mining for anomalies followed by the search for a behavioural explanation ([Sewell, 2011](#)). Notably, [Fama \(1998, p. 284\)](#) concluded that “market efficiency survives the challenge from the literature on long-term return anomalies”. Consistent with the EMH that the anomalies are chance results, apparent overreaction to information is about as common as underreaction, and post-event continuation of pre-event abnormal returns is about as frequent as post-event reversal ([Sewell, 2011](#)). Most important, consistent with the EMH prediction that apparent anomalies can be due to methodology, most long-term return anomalies tend to disappear with reasonable changes in technique ([Sewell, 2011](#)). In particular, [Kahneman and Tversky \(1979; 1996; 2000\)](#) have empirically shown that people are irrational in a consistent

and correlated manner. However, the case for the EMH can be made even in situations where the trading strategies of investors are correlated ([Sewell, 2011](#)). As long as there are some smart investors and arbitrage opportunities surrounding the context of their trading, they will exploit any mispricing. As a result, the irrational investors will lose money and eventually disappear from the market ([Sewell, 2011](#)).

Arguably, the efficient markets hypothesis (EMH), which constitutes the centre piece of the modern finance theory, has limited application in the case of carbon permits. One of the main arguments supporting such a predisposition points to the fact that a big segment of the secondary market for carbon permits is illiquid, while the EMH assumes liquid markets. A liquid market is essentially a market with many bid and ask offers and is characterised by high liquidity, low spreads, and low volatility. In a liquid market, changes in supply or demand have a fairly small impact on price. The EMH assumes that market prices reflect the fundamental value and change on the basis of new information. Thus, in an efficient market, no investment strategy can yield average returns higher than the risk assumed, and no trader can consistently outperform the market or accurately predict future price levels, as new information is instantly absorbed by the market prices ([Fama, 1970](#)).

Another EMH assumption is that, when markets are information efficient and transaction costs are relatively low, “professionally informed traders” quickly observe and exploit any price deviations from fundamental value through arbitrage trading, as such price deviations create an opportunity for profitable trading ([Avgouleas, 2009](#)). The result of such arbitrage activity is that prices reach a new equilibrium, which more accurately reflects the traded asset’s value and corrects any mispricing ([Avgouleas, 2009](#)). Accordingly, inefficient markets are exclusively due to information asymmetries, lack of competition, high transaction costs and various forms of conflict

of interests in the principal agent relationships that arise in market contexts (Avgouleas, 2009). However, behavioural finance challenges most of the assumptions of the EMH. The main tenets of behavioural finance are that: certain market phenomena called *anomalies* or *puzzles* cannot be explained by the EMH; and the corrective influence of arbitrage trading is limited due to a number of restrictions (Avgouleas, 2009). In fact, the evolutionary nature of carbon markets is one of the main explanations of market phenomena that both conform with and refute the assumptions of the EMH (Avgouleas, 2009). Furthermore, behavioural finance appears to be an even stronger and more convincing interpretative tool when used to explain market phenomena that are not representative of regular market conditions. As a result, it provides very convincing explanations of the causes of such considerable volatility present in the carbon market.

Accordingly, it has been so far assumed in this thesis that the carbon market is inefficient. But on the other hand, how could inefficiencies survive in a carbon market where many rational and individual investors/firms stand ready to take advantage of rewarding changes in the price of carbon? The latter reasonably seems to contradict the former. The first explanation to this dilemma would advocate limits to arbitrage, which are restrictions on the ability of a rational investor/firm wanting to buy or sell carbon permits so as to exploit the allegedly inefficient carbon market. In fact, it is limits to arbitrage that open doors to the study of behavioural finance and its effect on carbon trading. This goes to further suggest that individual investors/companies have built-in biases and misperceptions that can push carbon prices away from their fundamental values.

Theoretically speaking, arbitrage means an investment strategy that guarantees

superior returns without any risk. However, in practice, arbitrage is defined as a strategy that exploits market inefficiency and generates superior returns when prices return to their equilibrium values. This goes to imply that arbitrage goes hand-in-hand with market inefficiency, and the more inefficient the market is, the greater the arbitrage. Nevertheless, in an efficient market, if prices get out of line, then arbitrage forces them back in line with their fundamental value. In the context of a carbon market, the arbitrageur would buy underpriced carbon permits or offsets (thus driving their prices up) and sell overpriced permits and offsets (thus driving their prices down). The arbitrageur would therefore gain a profit by buying low and selling high and waiting for prices to congregate to fundamentals ([ECX, 2010](#)).

But let us not forget that arbitrage is not powerful enough to drive the carbon price to its equilibrium value, which gives rise to mispricing ([Carmona et al., 2010](#)). The subject matter being considered in this study revolves around the factors that determine the nature and direction of mispricing of carbon permits. Advocates of behavioural finance say that mispricing is driven by investor psychology. Clearly, it would be impractical to assume that people are 100% rational 100% of the time. This particularly shows in investors' attitudes to risk and the way they assess probabilities. Psychologists have observed that when making risky decisions people are particularly reluctant to incur losses. It may seem that investors do not focus solely on the current values of their holdings, but rather tend to look back. For example, if a firm sells a carbon permit for \$10, they may feel on top of the world if the permit only cost them \$5. But that firm would be much less happy if for instance it had cost them \$11 or \$12 to replace it. This hypothesis is founded on the basis of the *prospect theory* which states that the values investors place on a particular outcome are determined by the gains or losses that they have made since the asset was acquired or the holding last

viewed; and investors are particularly averse to the possibility of even a very small loss and need high returns to compensate for it ([Kahneman and Tversky, 1979](#)). Interestingly, the pain of a loss seems to depend on whether investors have experienced losses previously. In fact, traders may be more prepared to run the risk of a dip in the carbon market after they have enjoyed a run of unexpectedly fortunate prices ([Thaler and Johnson, 1990](#)). Then if they do happen to suffer a small loss subsequently, they at least have the comfort of still being ahead of everyone else.

Not surprisingly, most investors do not hold a PhD in probability theory, neither can they with absolute certainty predict future prices. Therefore, investors may systematically make errors in assessing the probability of uncertain events that may in turn affect carbon prices. Psychologists have found that when judging possible future outcomes individuals tend to look back at what happened in a few similar situations ([Brealey et al., 2008](#)). As a result, investors may place too much weight on a small number of recent events ([Brealey et al., 2008](#)). Moreover, given the relative ‘novelty’ of the carbon market, this further complicates the matter. For example, an investor might judge that four months of rapidly rising carbon prices (as it was throughout February – June 2008) is a good indication of future gains from investing in the carbon market. However, investors like that may not stop to reflect on how little one can learn about expected changes in the price of carbon purely on the basis of a four-month experience.

In addition, the majority of investors tend to be too conservative. Most people believe that they are better than others and most investors think that they are better than average stock ‘pickers’. But ironically, two speculators who trade with each other, cannot both make money, but may be prepared to continue trading just because each is



confident that the other party is rather a 'patsy' ([Brealey et al., 2008](#)).

In fact, advocates of behavioural finance suggest that these patterns of investor behaviour can explain why markets are not always efficient. Perhaps, the slothfulness in movement on behalf of investors to some of the very obvious drivers of the carbon price is due to conservatism, manifested as a sluggish response to the new information contained in these price signals. On top of that, the tendency to place too much emphasis on recent events, and therefore the underlying predisposition to overreact to recent news, could explain some of the most abrupt fluctuations in the price of carbon permits to date. Thus, behavioural finance may offer some reasonable interpretations of some of the puzzles and anomalies surrounding the carbon market. Nevertheless, it is crucial to point out that after all, the relative usefulness of behavioural finance will depend on whether it can be useful in predicting mispricing before it is actually observed in the market.

## **Chapter 4**

### **4. Data and Methodology**

#### **4.1. Data**

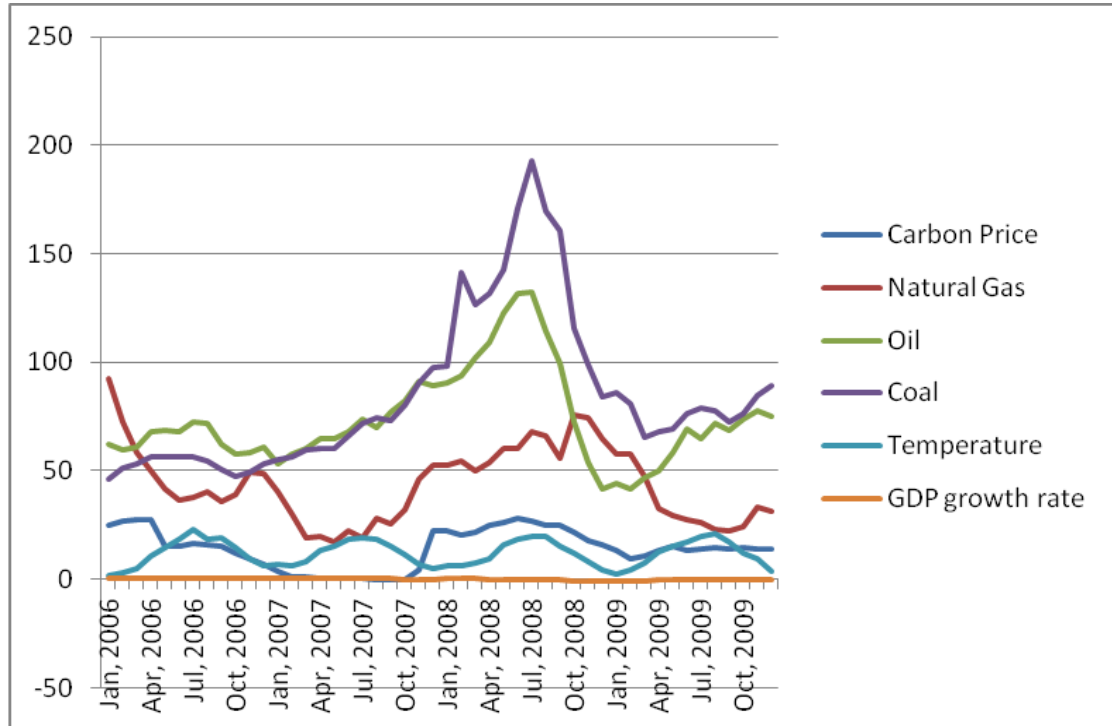
As set out in the report by the [Ministry for the Environment of New Zealand \(2011\)](#), the energy markets and the weather as well as economic growth ([Energy Brainpool, 2007](#)) determine to a great extent the price of carbon in the EU. That is why volatility in the energy markets, abnormal weather events or economic downturns in turn create volatility in the EU carbon market.

In this study, I empirically test whether changes in carbon price are linked to changes in the price of natural gas, oil and coal, as well as the variability of weather (temperature), fluctuations in the level of GDP and the occurrence of the global financial crisis (denoted as *GFC*), using longitudinal time series monthly data for four years from year 2006 to 2009<sup>16</sup> and covering four European countries, France, Germany, Italy and the UK. Hence, this dissertation covers all of the pilot phase of the EU ETS (2005-2007) and a substantial part of Phase Two (2008-2012), ending in December 2009. Overall, there are 48 observations for each series of data. **Figure 7** plots movements in the price of carbon permits, natural gas, oil and coal, as well as fluctuations in temperature and changes in GDP.

---

<sup>16</sup> The EU ETS officially commenced in January 2005. However, because no trading occurred on ECX prior to 9 January 2006, the time series for all variables begins from the latter date and covers a four-year period until 31 December 2009.

**Figure 8. Relationship between Carbon Price and Its Hypothesised Drivers**



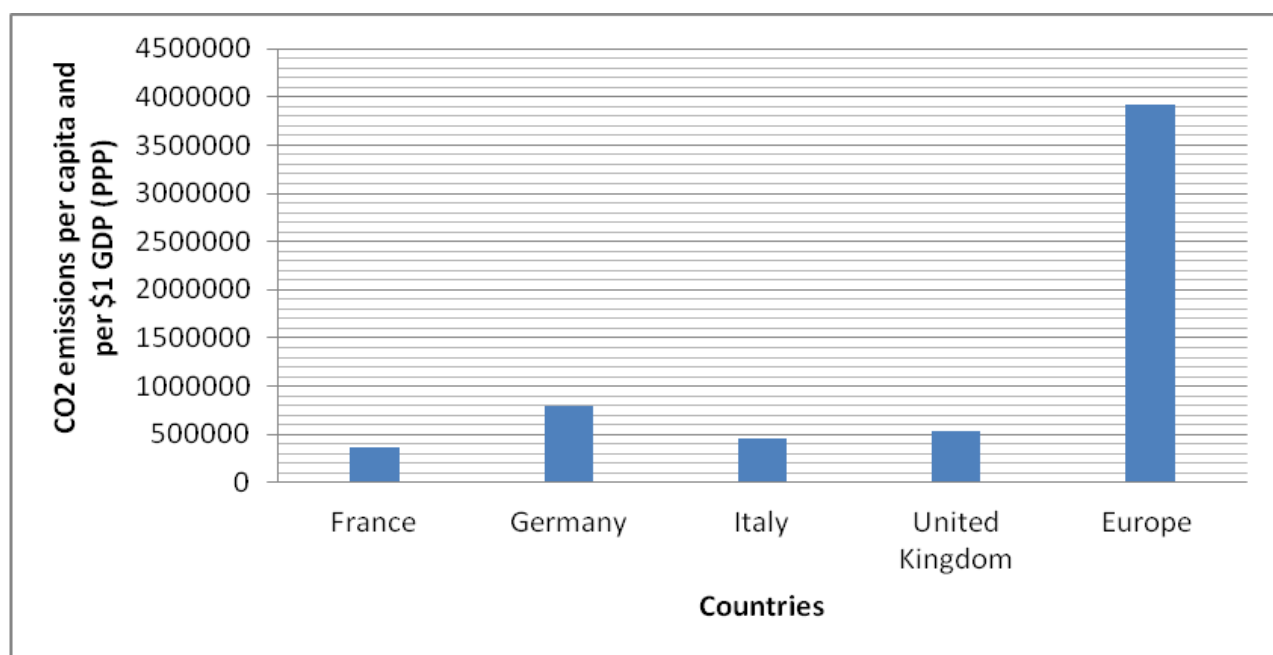
The choice of the four European countries, namely France, Germany, Italy and the UK, is justified by the fact that these countries are the largest European polluters (as per 2007 estimates) and they have the highest GDP in Europe (covering four years from 2005 to 2008). **Table 3** below lists CO<sub>2</sub> emissions due to human activity for the four countries according to the [United Nations Statistics Division \(2010\)](#). As illustrated in **Figure 9**, in 2007 France, Germany, Italy and the UK were the largest European carbon polluters, with Germany (787,936 MCO<sub>2</sub>) being the biggest CO<sub>2</sub> emitter, followed by the UK (539,617 MCO<sub>2</sub>), Italy (456,428 MCO<sub>2</sub>) and France (371,757 MCO<sub>2</sub>), respectively. Together, the four countries emit 55% of Europe's CO<sub>2</sub> emissions and 7.35% of the world total.

**Table 3. Countries by CO<sub>2</sub> Emissions due to Human Activity (2007)**

Country	Annual CO <sub>2</sub> emissions (in thousands of metric tons)	Percentage of Europe's total CO <sub>2</sub> emissions	Percentage of the world total CO <sub>2</sub> emissions
France	371,757	9.49%	1.27%
Germany	787,936	20.11%	2.69%
Italy	456,428	11.65%	1.56%
UK	539,617	13.77%	1.84%
Total	2,155,738	55.03%	7.35%
Europe	3,917,512	100%	13.36%
World	29,321,302	n/a	100%

Source: [United Nations Statistics Division \(2010\)](#)

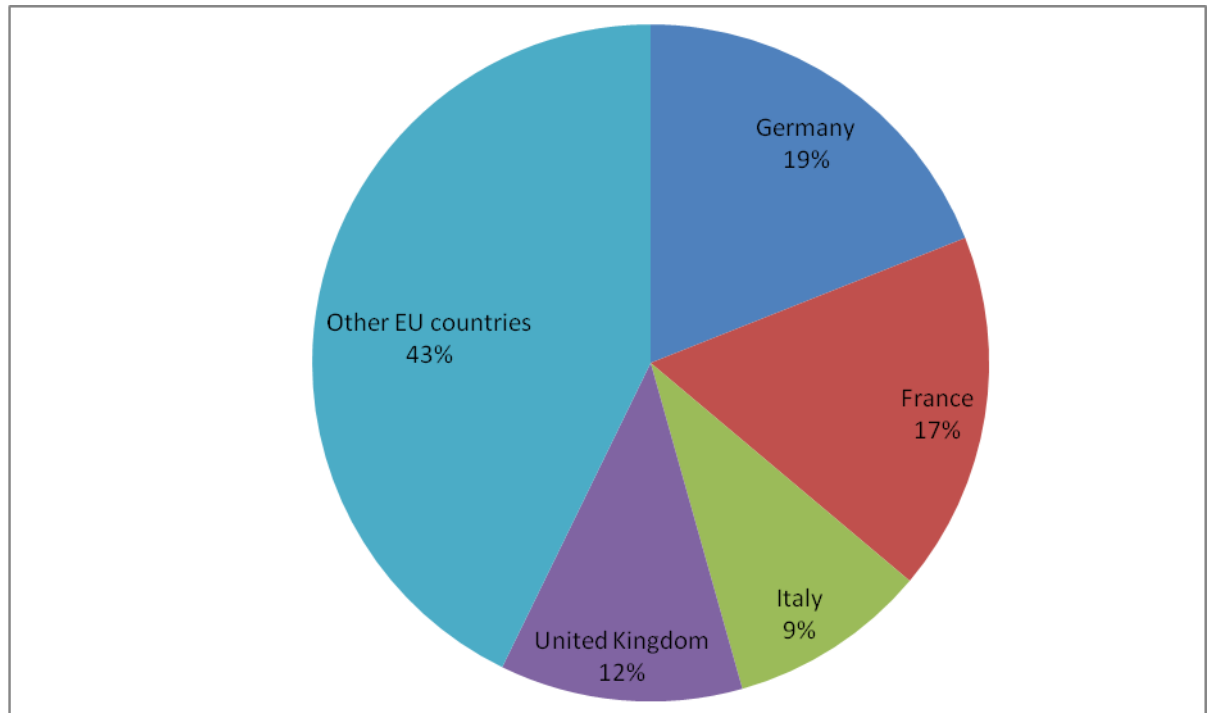
**Figure 9. Europe's Four Largest Emitters (2007)**



Source: [United Nations Statistics Division \(2010\)](#)

As per [Eurostat \(2010\)](#), as illustrated in **Figure 10**, in 2008 57% of the EU–27 gross electricity generation was produced by Germany (19%), France (17%), the UK (12%) and Italy (9%).

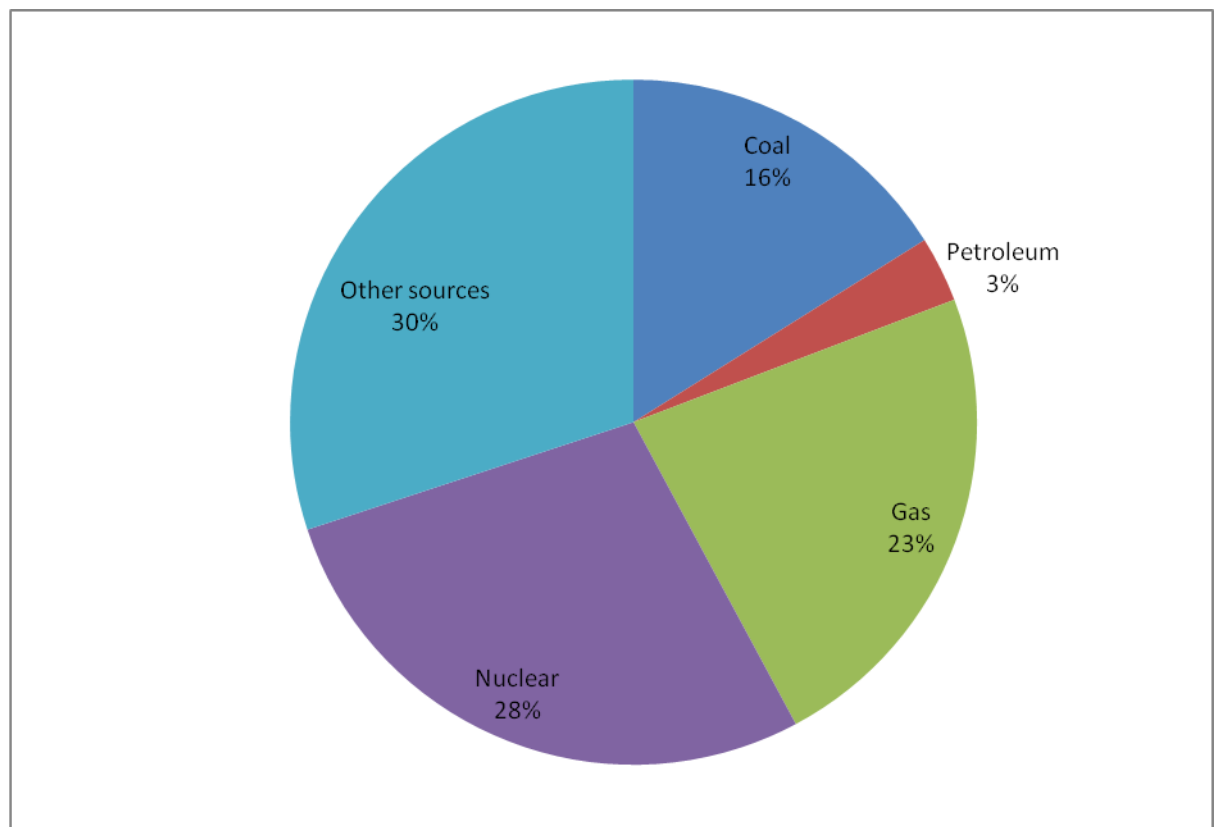
**Figure 10. Total EU–27 Gross Electricity Generation (2008)**



Source: [Eurostat \(2010\)](#)

When examining electricity production by source, it is evident that in 2008 most of the European energy was generated from other sources (30%) such as hydroelectricity and wind; followed by nuclear energy (28%), gas (23%), coal (16%). Results show that, in fact, very little electricity was sourced from petroleum products (3%) in 2008 (Eurostat, 2010). *Figure 11* below provides a graphical representation of the discussion above.

**Figure 11. EU–27 Electricity Production by Source (2008)**



Source: Eurostat (2010)

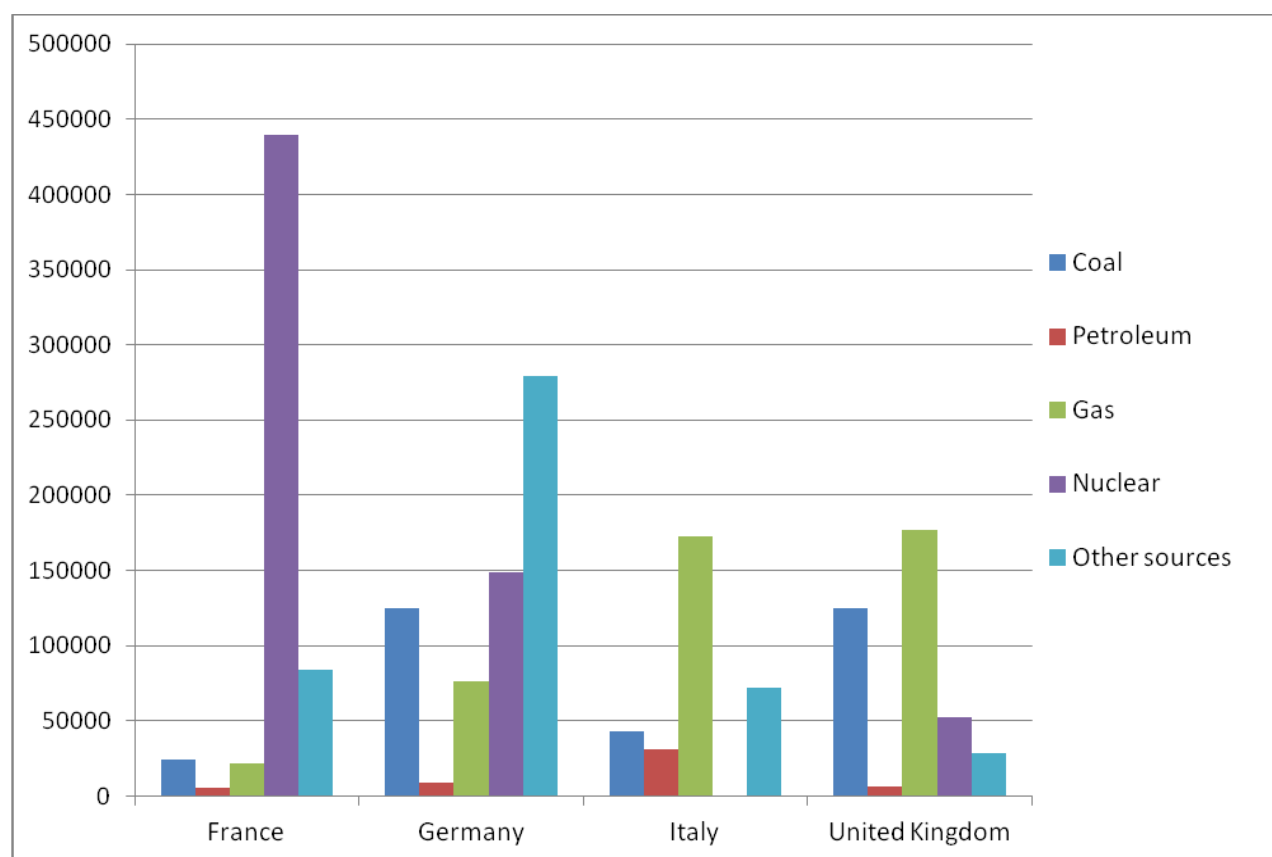
We then dig deeper to see how much electricity was produced by each country and from which sources it was generated (*Table 4* and *Figure 12*).

**Table 4. Electricity Production in Individual Countries by Source (2008)**

	EU-27	France	Germany	Italy	UK
<b>Coal</b>	16.1%	4.2%	20.0%	13.5%	32.2%
<b>Petroleum</b>	3.1%	1.0%	1.4%	9.9%	1.6%
<b>Gas</b>	23.0%	3.8%	11.9%	54.1%	45.4%
<b>Nuclear</b>	27.8%	76.3%	23.3%	0.0%	13.5%
<b>Other sources</b>	30.1%	14.6%	43.9%	22.5%	7.4%

Source: [Eurostat \(2010\)](#)

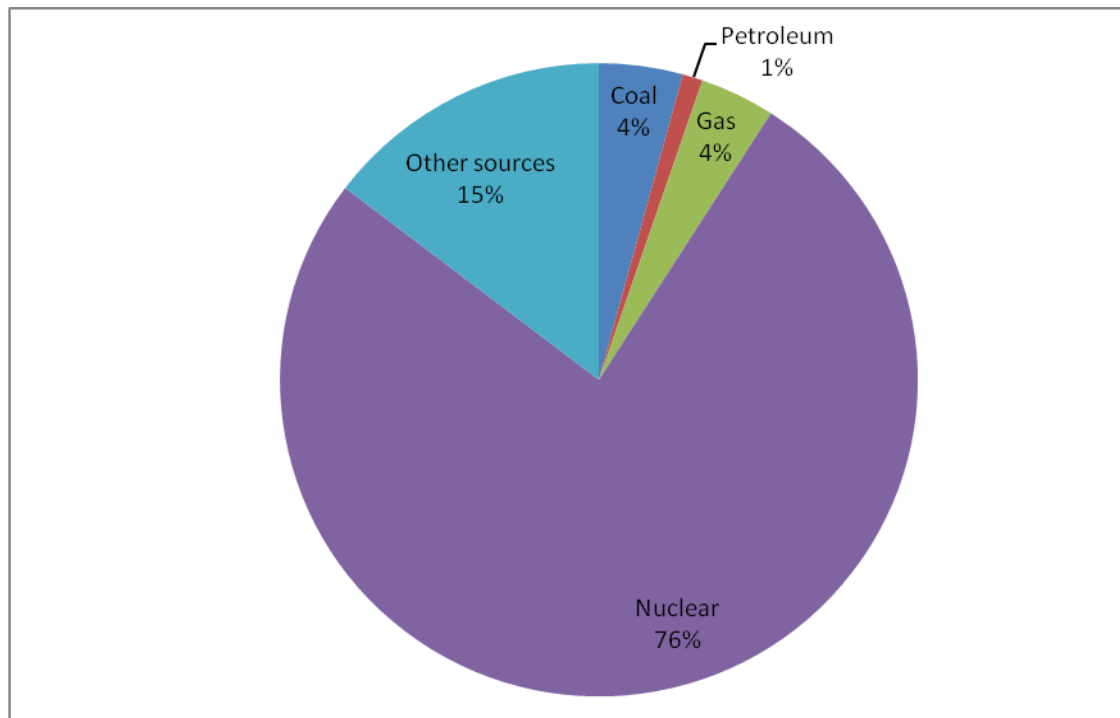
**Figure 12. Electricity Production in Individual Countries by Source (2008)**



Source: [Eurostat \(2010\)](#)

As shown on **Figure 13**, when evaluating electricity production in individual countries by source, in 2008 most of France's electricity came from nuclear energy (76%); other sources constituted 15%; and in fact very little of France's electricity was generated from coal (4%), gas (4%) and petroleum products (1%) ([Eurostat, 2010](#)).

**Figure 13. Electricity Production by Source – France (2009)**

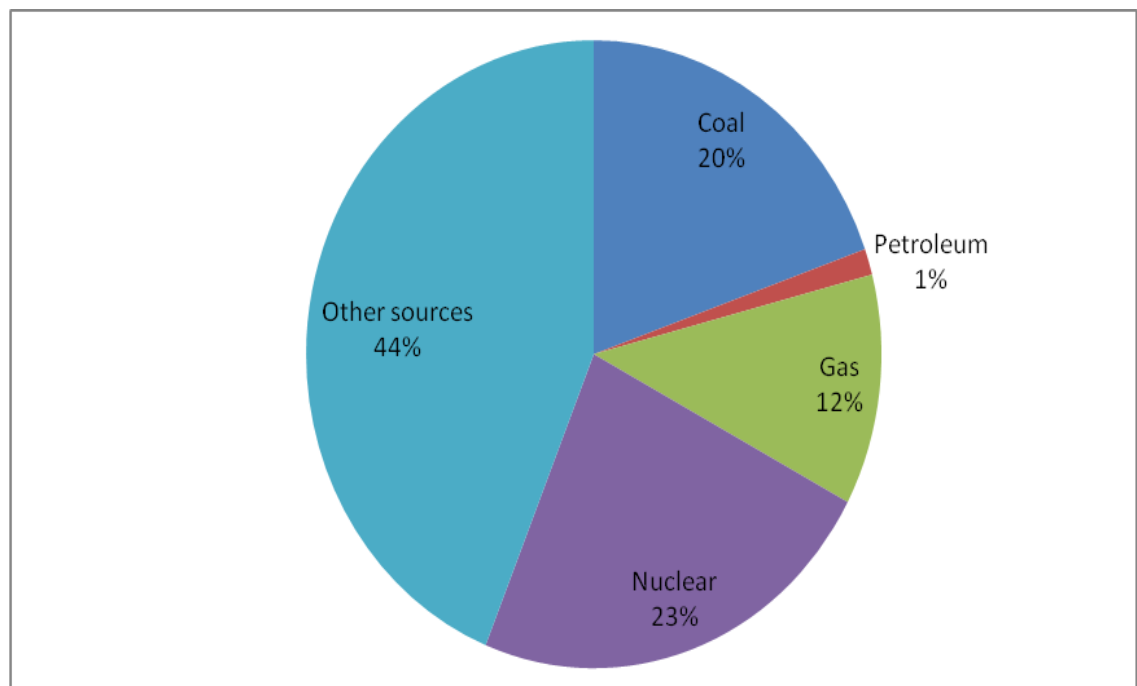


Source: [Eurostat \(2010\)](#)



On the other hand, as illustrated on **Figure 14**, the majority of Germany's electricity was generated from other sources (44%), followed by nuclear energy (23%), coal (20%), gas (12%) and petroleum products (1%) made up an insignificant contribution (Eurostat, 2010).

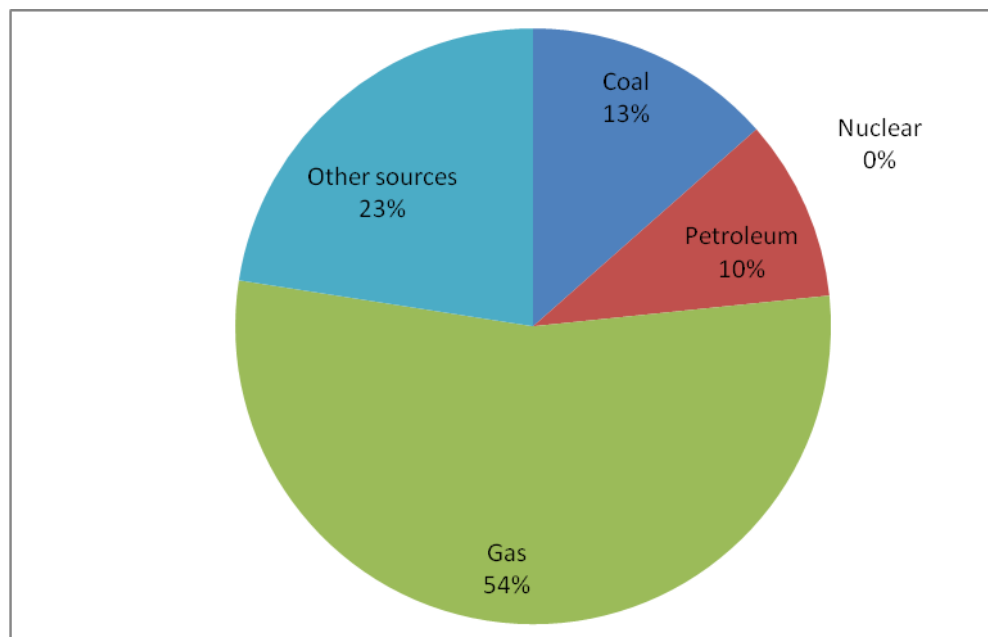
**Figure 14. Electricity Production by Source – Germany (2008)**



Source: Eurostat (2010)

Notably, as shown on **Figure 15**, the Italian electricity power stations sourced most their energy from gas (54%), followed by reliance on other sources (23%), coal (13%) and petroleum products (10%) ([Eurostat, 2010](#)). It is interesting to note that in 2008 none of Italy's electricity was sourced from nuclear energy ([Eurostat, 2010](#)).

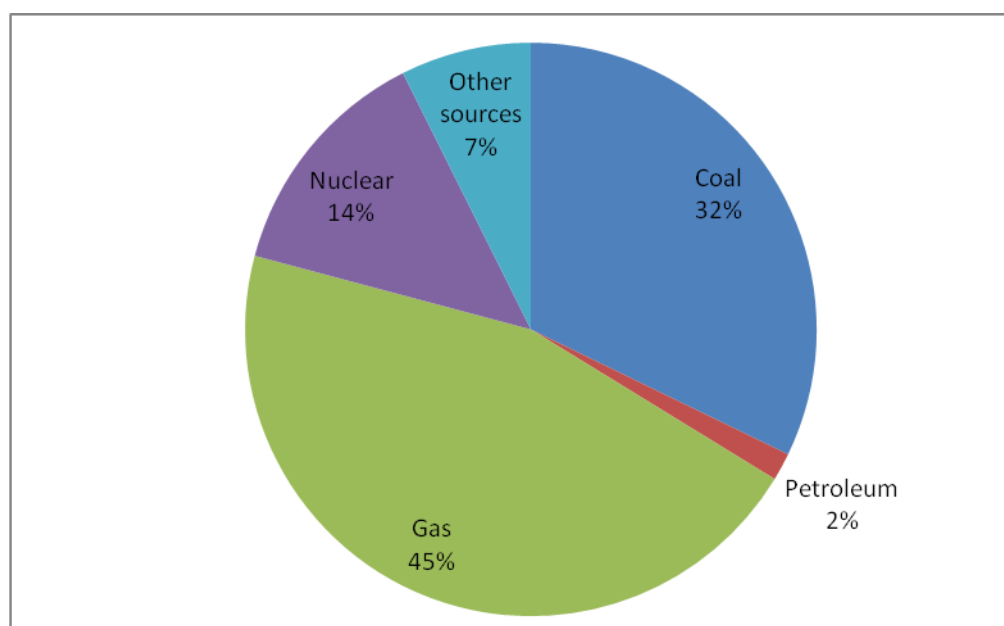
**Figure 15. Electricity Production by Source – Italy (2008)**



Source: [Eurostat \(2010\)](#)

Finally, as per **Figure 16**, the United Kingdom showed heavy reliance on gas (45%) and coal (32%) in their electricity production. In contrast, the country's dependence on nuclear energy (14%) was lower than that of France or Germany. Lastly, an insignificant amount of energy came from other sources (7%) and petroleum products (2%) ([Eurostat, 2010](#)).

**Figure 16. Electricity Production by Source – UK (2008)**



Source: [Eurostat \(2010\)](#)

Besides being Europe's four largest emitters, France, Germany, Italy, and the UK also had the highest GDP (current \$US)<sup>17</sup> during the time frame covering 2005 – 2008, with Germany having the largest GDP, followed by the UK, France and Italy. Together, the four countries contribute around 60% to the EU aggregate GDP.

---

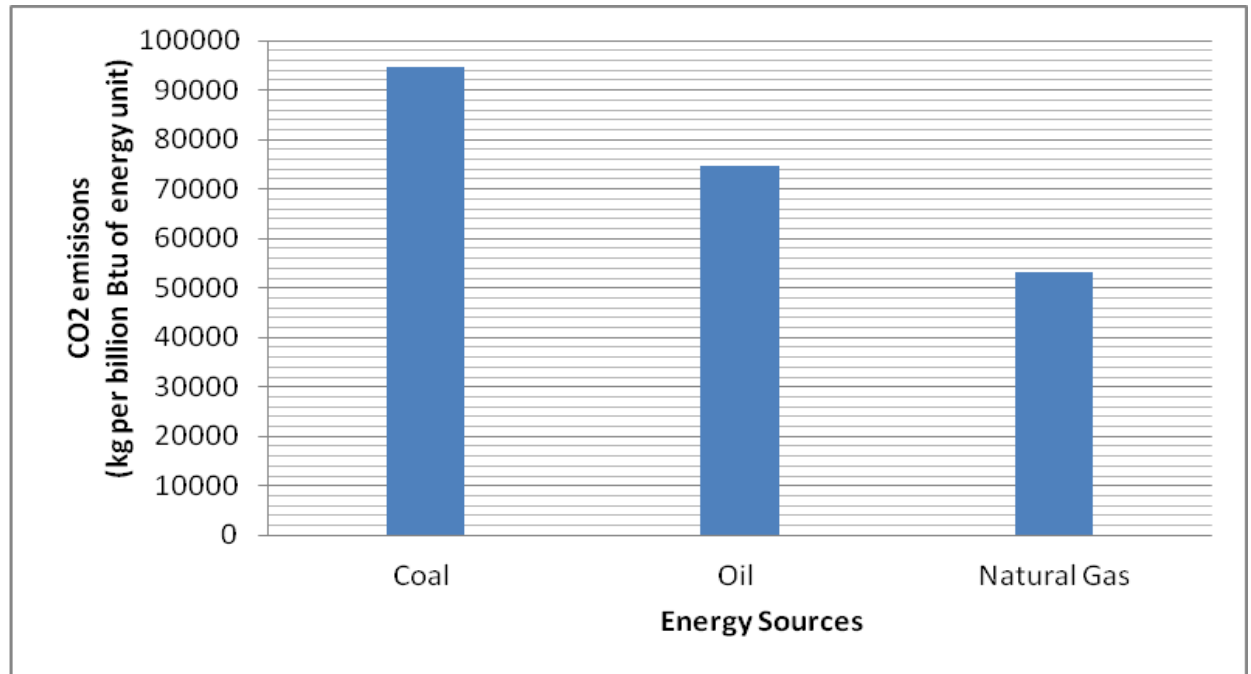
<sup>17</sup> **GDP at purchaser's prices** is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Data are in current US dollars; i.e. dollar figures for GDP, and are converted from domestic currencies using single year official exchange rates.

*The price of carbon* was extracted as a daily price of carbon permits from the European Climate Exchange (ECX) permit price history database (ECX Emissions Index) and converted into monthly estimates for the period from January 2006 until December 2009. At present there are several carbon exchanges operating in Europe. For the purpose of our research, the price of carbon was obtained from the ECX, since it is the largest European carbon exchange in number of transactions. In fact, the ECX attracts over 80% of the exchange-traded volume in the European CO<sub>2</sub> market, thus making it the leading marketplace for trading carbon dioxide emissions in Europe (ECX, 2010). Similarly, Mizrach and Otsubo (2010) name the European Climate Exchange the largest EU ETS trading venue. In fact, “the ECX captures 2/3 of the screen traded market in EUA and more than 90% in CER” (Mizrach and Otsubo, 2010, p.1). More than 65 leading businesses, including major global companies such as ABN AMRO, Barclays, BP, Calyon, Fortis, Goldman Sachs, Morgan Stanley and Shell, have signed up for membership to trade ECX products (ECX, 2010). In addition, several hundred clients can access the market daily via banks and brokers (ECX, 2010).

*The price of natural gas* represents the price of UK Natural Gas (NBPI) and was extracted from the ICE (Intercontinental Exchange) database. In addition to being a secure source of energy, the use of natural gas also offers a number of environmental benefits over other sources of energy, particularly other fossil fuels. In terms of emissions, natural gas is the cleanest of all the fossil fuels, as evidenced by the Energy Information Administration (EIA, 1998) as well as Lustgarten and ProPublica (2008). In fact, the combustion of natural gas emits almost 25-30% less CO<sub>2</sub> than oil, and about 45% less than good quality thermal coal (Naturalgas.org, 2010; Lustgarten and ProPublica, 2008). *Figure 17* further illustrates the carbon footprint of the three

energy sources discussed in this thesis.

**Figure 17. Carbon Footprint of Various Energy Sources**



Source: [Spaccavento \(2009\)](#)

Besides being cleaner, natural gas is also abundant: assuming steady levels of production, the world's supply of natural gas will last 65 years, and that is higher than oil's 41 years ([Wikinvest, 2010](#)). As illustrated in **Figure 8**, prior to mid-2008, natural gas prices were skyrocketing. However, the financial crisis of 2008, along with a global economic slowdown and excess supply, has caused demand growth for natural gas to fall into the negative ([Seeking Alpha, 2008](#)). "In December of 2009, the Independent Energy Agency (IEA) stated that by 2030 world natural gas demand will increase from 3TCM<sup>18</sup> in 2007 to 4.3TCM" ([Al Fathi, 2009](#)), thus signifying a 30% growth rate.

---

<sup>18</sup> TCM stands for *trillion cubic meters*

Among the most potent drivers of natural gas prices are: economic conditions, weather and seasonal fluctuations, as well as political arrangements. Because of the recent financial crisis, natural gas demand had started to fall since the summer of 2008 ([Seeking Alpha, 2008](#)). Given weather and seasonal fluctuations, natural gas demand observably fluctuates on a cyclical basis, falling in summer months and rising in winter months ([Money, 2008](#)). The need for heat during winter compared to summer is the primary factor responsible for these fluctuations ([Money, 2008](#)). Seasonal anomalies, such as cooler summers or warmer winters, can dampen this effect and change the amount of gas demanded on a large scale, thereby affecting natural gas prices ([Wikinvest, 2010](#)). Utilities that purchase gas when prices are lower during the summer months in order to keep inventories ready for the winter have a muting effect on natural gas seasonality ([Long, 2005](#)). Around 23% of European energy production is generated from natural gas ([EIA, 2006](#)).

*The price of oil* is the average of UK Brent, Dubai and West Texas Intermediate and was sourced from the IMF database. The majority of scientists tend to agree that there will be no traditional oil commercially available by 2030, and traditional oil reserves would be unlikely by 2040, unless adequate fuel alternatives are discovered ([BBC News, 2008](#)). There are also theories that the peak of the global oil production may occur in the next 2 – 3 years, while others postulate that it has already occurred around 2004. In fact, from 2005 to 2008 world crude oil production decreased by 3% ([EIA, 2010](#)). In a stated goal of increasing oil prices to \$75, which had fallen from a high of \$147 to a low of \$40, OPEC announced decreasing production by 2.2 million barrels per day from January 2009 ([BBC News, 2008](#)). This indicated a clear intention to influence oil prices by OPEC and casts doubt on the randomness of movements in oil prices. According to the data provided by [IMF \(2010\)](#), this would very well explain an

immense increase in the price of oil starting from January 2009. Peak oil research shows that about half of the available petroleum resources have been produced, and predicts a decrease of production in future. Around 40% of European energy production comes from oil combustion ([EIA, 2006](#)).

*The price of coal* is based on the price of Australian thermal coal for export. The data on coal prices was extracted from the IMF database. Arguably, coal is the dominant driver of CO<sub>2</sub> pollution. Coal is the most abundant and the fastest growing fossil fuel and its large reserves make it a popular candidate to meet the energy demand of the global community, short of global warming concerns and other pollutants ([Bradsher and Barboza, 2006](#)). According to the International Energy Agency ([IEA, 2006](#)), proven reserves of coal are around 909 billion tonnes, which could sustain the current production rate for 155 years, although at a 5% growth per annum this would be reduced to 45 years, or until 2051. In Europe some 17% of energy generation comes from burning coal ([EIA, 2006](#)).

***Temperature*** is the average of the mean temperature for four European capital cities representing each country: France – Paris, Germany – Berlin, Italy – Rome, UK – London. The data on temperature was extracted from the website [www.wunderground.com](http://www.wunderground.com).

***Gross domestic product (GDP)*** is one the primary indicators used to measure the health and size of a country's economy. It represents the total dollar value of all goods and services produced over a specific time period. As stated by [Enerdata \(2010\)](#), in 2009, world energy consumption decreased for the first time in 30 years and shrank by 1.1%, as a result of the financial and economic crisis (GDP drop by 0.6% in 2009). While energy consumption in the OECD was cut by 4.7% in 2009 and was thus almost

down to its 2000 levels; in Europe energy consumption shrank by 5% due to the slowdown in economic activity ([Enerdata, 2010](#)).

The GDP figures for the data analysis have been extracted from the OECD quarterly national accounts database and have been expressed as the growth rate compared to the previous year, seasonally adjusted. However, due to the deficiency in monthly GDP data, it should be noted that quarterly GDP figures tend to be approximate estimates.

***Global Financial Crisis and Europe.*** A dummy variable of 1 is used to designate the effects of the GFC, and zero indicating a period without any such effects. Overall, the GFC is considered by many economists to be the worst financial crisis since the Great Depression of the 1930s ([Elstone, 2008](#); [Hilsenthrath et al., 2008](#); [Stewart, 2008](#); [Bernanke, 2009](#); [Altman, 2009](#)). Among some of the consequences brought by the global financial crisis is the collapse of major businesses including banks, weakening consumer confidence and declining wealth estimated in trillions of U.S. dollars, large financial liabilities incurred by national governments, and a considerable fall in economic activity ([Brookings, 2009](#)).

One of the big risks here is the fact that the United States appears to be very connected to the rest of the world ([Baily and Elliott, 2009](#)). As stated by [Ivry \(2008, Sep 24\)](#), “credit markets froze in August 2007 after two hedge funds run by New York-based Bear Stearns, the fifth-largest US securities firm, collapsed due to the deteriorating value of its mortgage-related holdings”. It was the inability to determine the price on such securities that had frozen the market ([Ivry, 2008](#)).

Thus, it appears that the GFC has been in effect in Europe since September 2007 until the end of 2009. Also, an important implication here is that the term *global financial*



*crisis* is regarded as an Australian term. Among the most widely used other terms describing the events of 2007 – 2009 are the subprime crisis, the global credit crisis, or the liquidity crisis.

## **4.2. Methodology and Methods**

In order to achieve my research objectives, the present study includes two analytical methodologies: first, empirical and statistical analyses of trends in prices of carbon permits and major fossil fuels, as well as fluctuations in temperature and GDP over the period of January 2006 – December 2009; and second, a survey of the theoretical and empirical literature, notably on the determinants of the price of carbon and the impact of such interrelationships on emissions trading under the EU ETS.

The scientific method demonstrates that a theory is a unifying and self-consistent explanation of fundamental natural processes or a phenomenon that is totally constructed of corroborated hypotheses ([Schafersman, 1994](#)). Scientific research methodology is objective, reliable and verifiable ([Neuman, 2006, chapter 4](#)). There are other methodologies associated with research usually more attributable to social sciences. The two most common approaches to forecasting are qualitative and quantitative forecasting methods ([Berenson et al., 2010](#)). Qualitative forecasting methods are mainly used when historical data are unavailable and are considered highly subjective and judgmental in nature ([Berenson et al., 2010](#)); whereas quantitative forecasting methods normally involve a time series and a causal analysis. Time series generally use past data to predict future values. Whereas causal analysis involves a statistical study such as for example multiple regression analysis. This

study will main rely on both the types of quantitative forecasting methods discussed above – a time series and a causal analysis.

Regression has been used as the main tool for conducting the data analysis. Specifically, the study relies on a multiple linear regression since it involves one *dependent variable* – price of carbon permits, and multiple *independent variables* – price of coal, oil, and natural gas, as well as temperature and the level of GDP growth. As pointed out by [Berenson et al. \(2010\)](#), multiple linear regression has only one *dependent variable*, the relationship between several  $X_j$  and  $Y$  is described by a linear function, and changes in  $Y$  are assumed to be caused by changes in  $X_j$ . The general purpose of multiple regression is to investigate the relationship between several independent, or predictor variables, and a dependent, or criterion variable ([StatSoft, n.d.](#)). Generally, multiple regression allows a researcher to ask (and hopefully answer) a broad question "what is the best predictor of ..." ([StatSoft, n.d.](#)).

The regression equation used is depicted below. The regression analysis was conducted using Eviews software, using the ordinary least squares method (OLS), in which  $p < 10\%$  level of significance would indicate a significant result.

$$\ln(\text{Carbon Price})_t = \alpha + \beta_1 \ln(\text{Gas})_t + \beta_2 \ln(\text{Oil})_t + \beta_3 \ln(\text{Coal})_t + \beta_4 \ln(\text{Temperature})_t + \beta_5 (\text{GDP})_t + \text{dummy}_t + e_t$$

$$H_0 = \text{there is no relationship}$$

$$H_1 = \text{there is a relationship}$$

Here  $t$  is year; the dummy variable which controls for the period-specific effects of the global financial crisis (September 2007 – December 2009). As mentioned earlier, the data are drawn primarily from a number of sources, including the European Climate Exchange (ECX) carbon permit price history database, the Intercontinental Exchange

(ICE), International Monetary Fund (IMF), [www.wunderground.com](http://www.wunderground.com) (weather database), and the OECD statistical records.

The prices of carbon, natural gas, oil and coal as well as temperature are all logged to the natural logarithm ( $\ln$ ) so as to adjust for positive skew and to obtain a normal distribution (Bewick et al., 2003). The growth rate of the real GDP was already expressed in percentage terms and therefore there was no need to convert its values to the natural logarithm ( $\ln$ ). It should also be noted that all the price estimates described in this thesis are expressed in US dollars.

## **Chapter 5**

### **5. Empirical Results of Pricing Relationship from the EU ETS**

Carbon permit prices are determined by a multitude of physical conditions such as weather, as well as fuel costs, economic growth and the impact of environmental policies and measures, for example emissions trading, and by market factors such as the demand-supply curve and investment needs ([International Energy Agency, 2007](#)). This multiplicity of factors coupled with the novacity of this commodity makes it somewhat difficult to forecast EUA prices ([International Energy Agency, 2007](#)).

#### **5.1. Correlation**

Correlation is the degree of association between the two variables. Consequently, “*coefficient of correlation is a measure of the degree of association between the two variables*” ([Gujarati, 2003, p.85](#)). “The most commonly used techniques for investigating the relationship between two quantitative variables are correlation and linear regression” ([Bewick et al., 2003](#)). “Correlation quantifies the strength of the linear relationship between a pair of variables, whereas regression expresses the relationship in the form of an equation” ([Bewick et al., 2003](#)). The problem of *multicollinearity* arises when independent variables  $X_1$  to  $t$  are highly correlated. Then it is not possible to separate the effects of these variables on the dependent variable  $Y$  – carbon price. The slope coefficient estimates will tend to be unreliable, and often are not significantly different from zero. Therefore, the simplest solution is to delete one of the correlated variables.

The following discussion focuses on the calculation and interpretation of the sample product moment correlation coefficient denoted by  $r$ . As **Table 7** below reports, there is a 0.6328 correlation between Natural Gas and the Carbon Price, indicating a moderate positive linear relationship between the two variables. The notion of this relationship will be further discussed in the regression analysis. Interestingly, the correlation between Coal and Oil is 0.7147. This case is an illustration of a positive linear relationship. Stemming from this correlation outcome, it appears that one should be rather careful in terms of reliability when Oil and Coal are incorporated into the same regression equation, so as not to distort the results and the underlying data analysis.

**Table 5. Correlation Output**

	<b>Carbon Price</b>	<b>Natural Gas</b>	<b>Oil</b>	<b>Coal</b>	<b>Temperature</b>	<b>GDP growth rate</b>
<b>Carbon Price</b>	1					
<b>Natural Gas</b>	0.6328	1				
<b>Oil</b>	0.1228	0.1472	1			
<b>Coal</b>	0.2532	0.3568	0.7147	1		
<b>Temperature</b>	-0.2180	-0.4770	0.3731	0.1297	1	
<b>GDP growth rate</b>	-0.2065	-0.42956	0.1117	-0.5458	0.1820	1

---

This is based on longitudinal time series monthly data for four years from year 2006 to 2009 of 48 observations that covers France, Germany, Italy and the UK. All variables except for real GDP growth rate are logged to the natural logarithm ( $\ln$ ).

*Correlation between the Price of Natural Gas and Carbon Price.* According to [Roques et al. \(2006\)](#), there is a high correlation between gas and carbon prices. Clearly such strong correlation cannot be ignored. The authors also note that the winter of 2005/6 has seen threats of gas supply disruptions in Europe and very high gas prices and point to the uncertainty over the evolution of gas and carbon prices in the future ([Roques et al., 2006](#)). In conducting their study, [Roques et al. \(2006\)](#) drew random trajectories for gas and carbon prices for a series of Monte Carlo simulations. As recapped by [Roques et al. \(2006\)](#), the long-term gas and carbon price trajectories follow similar patterns. Another interesting point brought out by the authors is the fact that most new power plants built in the liberalised European electricity markets since the 1990s have been gas-fired power stations. This is why the increase in the share of gas in the power industry has raised concerns among policy-makers about the resulting increased exposure to gas price fluctuations ([Roques et al., 2006](#)).

This finding is further reinforced by [Koenig \(2011\)](#) who also found that prices of natural gas and carbon prices move in the same direction. According to [Koenig \(2011\)](#), this co-movement between prices for input fuels and the price of CO<sub>2</sub> emission allowances is the result of the ability to switch between input fuels in power generation, especially between coal and natural gas. However, [Koenig \(2011\)](#) also notes that the relationship between the prices of natural gas and carbon emission allowances is not constant. In his study [Koenig \(2011\)](#) shows that there are periods in which the carbon and natural gas prices tend to decouple. Namely, these are times when the absence of an economic incentive to switch input fuels leads to a decoupling of prices and a resulting reduction in correlation.

So from the correlation analysis alone we can already see that the price of natural gas

and the carbon price are interrelated. Consequently, an implication of such finding for the regression analysis would be that due to a fairly high correlation of the variable with the price of carbon, the price of Natural Gas should not be left out of any such regression model.

*Correlation between the Prices of Coal and Oil.* Simple logic along with the laws of economics dictates that as the price of oil goes up, there will be more demand for alternative sources, thus creating shortages of those alternatives and pushing their price upward. As a result, the price of coal would go up and a report by [ANZ Commodities \(2010\)](#) points to a strong correlation between thermal coal and oil prices. In addition, [Standard Capital Securities \(2011\)](#) also note that coal prices, as based on this analysis, tend to follow oil prices in many instances. This indicates that one should be rather careful when generalising from regression results containing both variables simultaneously.

*Correlation between the Prices of Petroleum and Oil.* Initially, the price of Petroleum was also included into the analysis. However, as the correlation test reveals, there is a correlation of almost +1 between the price of petroleum and oil, which signifies a perfect positive linear relationship and therefore gives a signal that either petroleum or oil needs to be excluded from the regression equation. This suggests that because petroleum is the derivative of oil, their respective prices appear to be very closely associated with each other. In addition, significant here would be the fact that the market for petroleum tends to be rather small when compared to the market for crude oil (in terms of quantities bought and sold). Therefore, oil prices are more likely to drive petroleum prices than vice-versa.

Adding to the above discussion on the outcomes of correlation analysis, we can so far

see that there is a linear relationship between the price of natural gas and the carbon price. Further, because petroleum has been excluded from the regression analysis in favour of oil, and because of their high correlation one should be rather careful when drawing conclusions from regression results containing both oil and coal.

## **5.2. Autocorrelation or Serial Correlation**

Autocorrelation or serial correlation is a problem that may arise in time-series data. It occurs when successive observations of the dependent variable  $Y$  are not independent of each other. So in this case if we are examining the price of carbon over time, and it appears to be particularly high in one period, it is likely to be high in the next period as well. Therefore, the residuals tend to be correlated among themselves (autocorrelated) rather than independent.

According to Gujarati (2003), the most popular method for identifying serial correlation is the Durbin–Watson  $d$  statistic ([Gujarati, 2003, p.467](#)). A significant “advantage of the  $d$  statistic is that it is based on the estimated residuals, which are routinely computed in the regression analysis” ([Gujarati, 2003, p.467](#)).

Having conducted some of the regression analyses I have often encountered the problem of autocorrelation, as detected by the Durbin–Watson statistic. That prevented me from further conducting the study until the autocorrelation problem was fixed. There are a few techniques for handling autocorrelation problems. The one that I used in my data analysis was the Newey–West approach. The Newey–West estimator is used in statistics and econometrics to provide an estimate of the covariance matrix of the parameters of a regression-type model when this model is applied in situations



where the standard assumptions of regression analysis do not apply ([Quantitative Finance Collector, 2010](#)). The estimator is used to overcome autocorrelation, or correlation, and heteroskedasticity in the error terms in the models. This is often used to correct the effects of correlation in the error terms in regressions applied to time series data. The problem in autocorrelation, often found in time series data, is that the error terms are correlated over time. The problem is that as the time between error terms increases, the correlation between the error terms tends to decrease. Thus, the estimator can be used to improve the ordinary least squares (OLS) regression when the variables have heteroskedasticity or autocorrelation. Therefore, when using a Newey–West approach, one may disregard the meaning of the Durbin–Watson statistic and proceed to interpret the regression output.

To conclude, during some of the regression analyses the problem of autocorrelation was encountered, as detected by the Durbin–Watson  $d$  statistic. The technique for handling autocorrelation problems used in the data analysis was the Newey–West approach. Importantly, when using a Newey–West approach, one may disregard the meaning of the Durbin–Watson statistic and proceed to interpret the regression output. In total, I ran four regression models ( $A$ ,  $B$ ,  $C$ ,  $D$ ), the results of which will be discussed in the next section, each adjusted using the Newey–West technique.

### **5.3. Regression Results**

“Energy is central to our lives. We rely on it for transport, for heating and cooling our homes, and running our factories” ([EUROPA, 2010](#)). Theoretically, the price of fossil fuels is most likely to have a direct impact on the carbon price, as evident from the studies by [Point Carbon](#) and the [Chicago Climate Exchange \(2004\)](#), the [European](#)

[Climate Exchange \(2004\)](#), Redmond and [Convery \(2006\)](#) and [Retamal \(2009\)](#). This notion is further amplified by the fact that 57% of the EU gross electricity generation () was produced by the four countries considered in our study – Germany (19%), France (17%), the UK (12%) and Italy (9%) ([Eurostat, 2010](#)).

The regression analysis consists of four regression models *A*, *B*, *C*, *D* each adjusted using the Newey–West technique, and each necessarily containing the price of natural gas and the dummy variable [GFC]. Underpinning the regression analysis was unit root testing which checked for stationarity. ***Appendix*** provides a detailed overview of the stationarity analysis. The regression analysis for each respective model is provided in the following paragraphs accompanied by ***Tables 6, 7, 8 and 9***.

## Regression A

$$\ln(\text{Carbon Price})_t = \alpha + \beta_1 \ln(\text{Gas})_t + \beta_2 \ln(\text{Oil})_t + \beta_3 \ln(\text{Coal})_t + \beta_4 \ln(\text{Temperature})_t + \beta_5 (\text{GDP})_t + \text{dummy}_t + e_t$$

**Table 6. Regression A – Eviews Output**

Dependent Variable: CARBON

Method: Least Squares

Sample: 2006M01 2009M12; Included observations: 48

Newey–West HAC Standard Errors & Covariance (lag truncation=3)

	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.240665	2.896112	-1.464261	0.1507
***GAS	3.508095	0.754006	4.652610	<b>0.0000</b>
OIL	-1.568157	2.220418	-0.706244	0.4840
COAL	-0.615760	2.104801	-0.292550	0.7713
* TE MP ER AT UR E				
	0.695915	0.380776	1.827624	<b>0.0749</b>
**GDP	1.963716	0.750175	2.617677	<b>0.0123</b>
DUMMY (GFC)	1.749839	1.073715	1.629705	0.1108
R-squared	0.508122	Mean dependent var		1.997345
Adjusted R-squared	0.436140	S.D. dependent var		1.739736
Sum squared resid	69.97159	Akaike info criterion		3.506432
Log likelihood	-77.15437	Schwarz criterion		3.779315
F-statistic	7.059009	Hannan-Quinn criter.		3.609555
Prob(F-statistic)	0.000033	Durbin-Watson stat		0.473414

In *regression A*, carbon price is the dependent variable, while the independent variables are the prices of natural gas, oil, and coal as well as temperature, GDP and the dummy variable [GFC]. It is quite interesting to report this regression, as it

includes all the hypothesised drivers of carbon price. With the number of explanatory variables excluding the constant term [being carbon price]  $k' = 6$ , this regression analysis reveals that the only factors that influence changes in the price of carbon are the price of natural gas\*\*\* (0.0000), fluctuations in temperature\* (0.0749) and changes in the level of GDP\*\* (0.0123). Given the 0.10 level of significance, the above regression results can be considered as statistically significant.

## Regression B

$$\ln(\text{Carbon Price})_t = \alpha + \beta_1 \ln(\text{Gas})_t + \beta_2 \ln(\text{Coal})_t + \beta_3 \ln(\text{Temperature})_t + \beta_4 (\text{GDP})_t + \text{dummy}_t + e_t$$

**Table 7. Regression B – Eviews Output**

Dependent Variable: CARBON

Method: Least Squares

Sample: 2006M01 2009M12; Included observations: 48

Newey–West HAC Standard Errors & Covariance (lag truncation=3)

	Coefficient	Std. Error	t-Statistic	Prob.
C	-5.483285	3.672419	-1.493099	0.1429
***GAS	3.365345	0.647167	5.200116	<b>0.0000</b>
*COAL	-1.679560	0.913373	-1.838855	<b>0.0730</b>
TEMPERATURE	0.564174	0.350592	1.609202	0.1151
*GDP	1.169818	0.630802	1.854494	<b>0.0707</b>
*DUMMY (GFC)	1.806039	1.062013	1.700581	<b>0.0964</b>
R-squared	0.500624	Mean dependent var		1.997345
Adjusted R-squared	0.441175	S.D. dependent var		1.739736
Sum squared resid	71.03823	Akaike info criterion		3.479894
Log likelihood	-77.51746	Schwarz criterion		3.713794
F-statistic	8.420997	Hannan-Quinn criter.		3.568285
Prob(F-statistic)	0.000014	Durbin-Watson stat		0.445735

In *regression B*, carbon price is the dependent variable, while the independent

variables consist of the prices of natural gas and coal, temperature, GDP and the dummy variable [GFC]. With the number of explanatory variables excluding the constant term [being carbon price]  $k' = 5$ , this regression equation demonstrates that changes in the prices of natural gas\*\*\* (0.0000) and coal\* (0.0730), as well as fluctuations in GDP\* (0.0707) and the occurrence of the GFC\* [dummy] (0.0964) have an effect on changes in the price of carbon. Interestingly, fluctuations in temperature (0.1151) also seem to be an important determinant of changes in the price of carbon; however, given the 0.10 level of significance, the results for temperature cannot be considered as statistically significant.

### Regression C

$$\ln(\text{Carbon Price})_t = \alpha + \beta_1 \ln(\text{Gas})_t + \beta_2 \ln(\text{Oil})_t + \beta_3 \ln(\text{Temperature})_t + \beta_4 (\text{GDP})_t + \text{dummy}_t + e_t$$

**Table 8. Regression C – Eviews Output**

Dependent Variable: CARBON

Method: Least Squares

Sample: 2006M01 2009M12; Included observations: 48

Newey–West HAC Standard Errors & Covariance (lag truncation=3)

	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.176455	2.953749	-1.413950	0.1647
***GAS	3.501156	0.762119	4.593976	<b>0.0000</b>
**OIL	-2.198564	0.822904	-2.671712	<b>0.0107</b>
* TEMPERATURE	0.711109	0.377041	1.886027	<b>0.0662</b>
***GDP	2.268830	0.740203	3.065144	<b>0.0038</b>
**DUMMY (GFC)	1.626399	0.722952	2.249665	<b>0.0298</b>
R-squared	0.506378	Mean dependent var		1.997345
Adjusted R-squared	0.447613	S.D. dependent var		1.739736
Sum squared resid	70.21979	Akaike info criterion		3.468306
Log likelihood	-77.23935	Schwarz criterion		3.702206
F-statistic	8.617053	Hannan-Quinn criter.		3.556697
Prob(F-statistic)	0.000011	Durbin-Watson stat		0.478869

In *regression C*, carbon price is the dependent variable, while the independent variables consist of the prices of natural gas and oil, as well as temperature, GDP and the dummy variable [GFC]. With the number of explanatory variables excluding the constant term [being carbon price]  $k' = 5$ , this regression equation demonstrates that fluctuations in the prices of natural gas\*\*\* (0.0000) and oil\*\* (0.0107), as well as changes in temperature\* (0.0662), variations in GDP\*\*\* (0.0038) and the onset of the GFC\*\* [dummy] (0.0298) – all have a significant impact on changes in the price of carbon, given the 0.10 level of significance.

## Regression D

$$\ln(\text{Carbon Price})_t = \alpha + \beta_1 \ln(\text{Gas})_t + \beta_2 \ln(\text{Oil})_t + \beta_3 (\text{GDP})_t + \text{dummy}_t + e_t$$

**Table 9. Regression D – Eviews Output**

Dependent Variable: CARBON

Method: Least Squares

Sample: 2006M01 2009M12; Included observations: 48

Newey–West HAC Standard Errors & Covariance (lag truncation=3)

	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.411452	3.458460	-1.275554	0.2090
***GAS	2.838385	0.704446	4.029242	<b>0.0002</b>
OIL	-1.141838	0.755261	-1.511846	0.1379
**GDP	1.782400	0.804914	2.214397	<b>0.0322</b>
DUMMY (GFC)	1.339823	0.844559	1.586416	0.1200
R-squared	0.472318	Mean dependent var		1.997345
Adjusted R-squared	0.423231	S.D. dependent var		1.739736
Sum squared resid	75.06495	Akaike info criterion		3.493363
Log likelihood	-78.84072	Schwarz criterion		3.688280
F-statistic	9.622102	Hannan-Quinn criter.		3.567023
Prob(F-statistic)	0.000012	Durbin-Watson stat		0.350575

In *regression D*, carbon price is the dependent variable, while the independent variables consist of the prices of natural gas and oil, as well as GDP and the dummy variable [GFC]. With the number of explanatory variables excluding the constant term [being carbon price]  $k' = 4$ , this regression shows that changes in the price of carbon are affected by movements in the price of natural gas\*\*\* (0.0002) and fluctuations in the level of GDP\*\* (0.0322). Assuming the 0.10 level of significance and stemming from the results obtained from running this regression model, changes in the price of oil and the GFC [dummy] have no impact on fluctuations in the price of carbon.

**Table 10** below presents a brief summary of the discussion of the regression results and their significance above.

**Table 10. Regression Output Summary (in terms of probabilities)**

	<i>Regression A</i>	<i>Regression B</i>	<i>Regression C</i>	<i>Regression D</i>
<b>Gas</b>	0.0000***	0.0000***	0.0000***	0.0002***
<b>Oil</b>	0.4840	n/a	0.0107**	0.1379
<b>Coal</b>	0.7713	0.0730*	n/a	n/a
<b>Temperature</b>	0.0749*	0.1151	0.0662*	n/a
<b>GDP</b>	0.0123**	0.0707*	0.0038***	0.0322**
<b>Dummy (GFC)</b>	0.1108	0.0964*	0.0298**	0.1200
<b>R-squared</b>	0.5081	0.5006	0.5064	0.4723

Notes:

\*\*\* 0.01;    \*\* 0.05;    \* 0.10

n/a Variable not included in the regression model being considered

---

This is based on longitudinal time series monthly data for four years from year 2006 to 2009 of 48 observations that covers France, Germany, Italy and the UK. Carbon price is a *dependent* variable.



*Natural Gas.* Most of the EU electricity generated from non-renewable sources comes from natural gas (23%), thus making it the most important non-renewable source of energy in Europe (Eurostat, 2010). In addition, most new power plants built in European electricity markets since the 1990s have been gas-fired power stations (Roques et al., 2006), presumably because natural gas is the least polluting fossil fuel. This has substantially increased the EU reliance on natural gas in energy production. The regression analysis has provided evidence that the price of natural gas is very closely correlated with the price of carbon. Indeed, the price of natural gas has proven to be the largest driver of the price of carbon out of all the independent variables studied. The price of natural gas appears significant in all four regression models, at a 99% confidence level. This is consistent with the findings of Retamal (2009), who also recognised that the price of natural gas had an influence on the price of permits under the EU ETS.

The study indicates that changes in the price of natural gas appear to have a positive relationship with changes in the price of carbon, showing an average coefficient of 3.30. In the context of the EU ETS carbon market, this means that if the price of natural gas increases by 1%, the price of carbon permits will correspondingly increase by 3.3%, *ceteris paribus*<sup>20</sup>. Notably, most European power plants can run on either coal or natural gas. So the decision to use natural gas may largely depend on its price. When gas is expensive, power plants may switch to coal, which creates more pollution and thus increases the demand for carbon permits. Given the constancy of the supply of carbon allowances, this drives the price of carbon upwards.

---

<sup>20</sup> **Ceteris paribus** means “all other things being equal or held constant”

**Oil.** When examining electricity production by source, it is evident that in 2008 very little of the EU electricity was produced from oil (only 3%) (Eurostat, 2010). This is why changes in the price of oil do not appear to be an important driver of changes in the price of carbon, being significant in only one regression model (C), at a 95% confidence level. However, in a university working paper, Redmond and Convery (2006) examined the effect of changes in the price of oil and gas and found that increases in the price of oil appeared to have the greatest impact on the price of permits. This is not consistent with the findings of this study, where changes in the price of natural gas have been found to be the most important influence upon changes in the price of carbon. Amongst the possible reasons for such discrepancy in research outcome could be the different time periods and the number of variables being studied as well as the EU's increased reliance on the usage of gas since Redmond and Convery's (2006) paper.

The regression analysis shows that changes in the price of oil have a negative relationship with changes in the price of carbon, with an average coefficient of  $-1.65$ . Practically, this implies that if the price of oil increases by 1%, the price of carbon will fall by 1.65%. Given rising oil prices, one would reasonably expect energy demand to fall, which would reduce power consumption, leading to lower emissions. Under a carbon trading scheme, when the level of emissions falls, then the price of carbon permits will fall too (Williams-Derry, 2008).

**Coal.** As mentioned earlier in the dissertation, coal is the major driver of CO<sub>2</sub> pollution, so it could be expected that changes in the price of EU ETS permits would be affected by movement in the price of coal. However, this study shows that coal only appears significant in one regression model (B), at a 90% confidence level. In fact,

according to the [Encyclopedia of Earth \(2010\)](#), over the past decade, there has been a significant decline in the use of coal, and natural gas has been the fastest growing fuel source in the EU. Arguably, environmental concerns are a major reason for the decline in the use of coal, most evident in the EU's Directive 2001/80/EC, which seeks to limit air pollutants produced from large coal-fired combustion plants ([Encyclopedia of Earth, 2010](#)). The EU ETS aims to limit the amount of CO<sub>2</sub> that power generators can emit by placing a price on the amount of carbon emissions generated via a cap-and-trade scheme, thus further decreasing the probability of coal use in the EU member countries.

Similar to the oil scenario, this study indicates that changes in the price of coal appear to have a negative relationship with changes in the price of carbon, showing an average coefficient of  $-1.15$ . In the context of the EU ETS carbon market, this notion would suggest that if the price of coal goes up by 1%, then the price of carbon permits would fall by 1.15%. The rationale behind such a trend is that higher coal prices increase the likelihood of power utilities switching to using natural gas. This would, in turn, result in lower emissions, thus reducing the demand for carbon permits and having a dampening impact on the price of carbon. As mentioned earlier in the dissertation, most power plants can run on either coal or gas, so the decision to use coal primarily depends on its price. Accordingly, when coal is expensive, power plants tend to switch to using gas, which pollutes less than coal, thus creating fewer emissions and reducing the demand for carbon permits, therefore, driving the price of carbon allowances downwards.

**Temperature.** Notably, temperature is significant at a 90% confidence level in two (*A* and *C*) of the four regression models tested. This provides enough confidence to

suggest that weather fluctuations is a significant driver of changes in carbon price, which should be related to earlier findings in the literature. After studying various carbon price determinants under the EU ETS, [Kruger \(2008\)](#), [Point Carbon and the Chicago Climate Exchange \(2004\)](#), [the European Climate Exchange \(2004\)](#), [Retamal \(2009\)](#), [Betz \(2006\)](#) and [Koenig \(2011\)](#) – all found that weather had a significant impact on the level of emissions by the major covered installations in the power and heat sector. This finding pinpoints the importance of seasonal effects and the influence of extreme weather conditions on carbon price volatility.

The regression analysis conducted indicates that variations in temperature have a positive relationship with changes in the price of carbon, showing an average coefficient of 0.66. In the context of the European carbon market, this would imply that if temperature rises by 1%, the price of carbon permits will correspondingly increase by 0.66%, *ceteris paribus*. The legitimacy of this relationship seems rather obvious, given the impact temperature tends to have on the demand for and supply of electricity; i.e. the more it deviates from the average, the greater the likelihood that consumers will turn to using heating or cooling devices.

**GDP.** Interestingly, the level of GDP, which represents the level of economic activity, shows as statistically significant in all four regression models, although at varying levels of significance, ranging from 90% to 99%. This research finding corresponds with the view expressed by [Point Carbon and Chicago Climate Exchange \(2004\)](#) as well as [the European Climate Exchange \(2004\)](#), which suggested that the price of carbon will depend on a number of factors, including economic growth. According to [Energy Brainpool \(2007\)](#), power demand changes due to economic growth. Practically, such dependence of changes in the price of permits on the level of economic activity

can be explained by the fact that the more prosperous the economy becomes, the greater the output of production it generates, the greater the level of pollution it emits.

The study indicates that changes in the level of real GDP growth rate prove to have a positive relationship with changes in the price of carbon, showing an average coefficient of 1.80. Practically, this means that if the level of real GDP increases by 1%, the price of carbon permits will correspondingly increase by 1.8%, *ceteris paribus*. Such dependence of the price of permits on the level of economic activity can be explained by the fact that a more prosperous economy spawns greater output of production which generates a greater level of emissions. This would in turn create a higher demand for EUAs, thus resulting in the higher price of carbon permits. In particular, as pinpointed by [Chan \(2009\)](#), the sharp economic downturn in the EU led to a drop in greenhouse gas emissions, resulting in less need for the EU allowances (EUAs) mandated under the EU's cap-and-trade programme, thus driving the price of carbon permits downwards.

***Global Financial Crisis.*** Finally, the effects of the global financial crisis have had statistical significance (90% and 95%) in two (*B and C*) of the four regression models examined. Considering the dampening impact of the GFC on the EU levels of production as well as its close interrelation with major commodity markets, it is no surprise that this variable has played an important role in shaping the price of carbon under the EU ETS.

To summarise, all of the independent variables considered in this thesis have had an impact on the price of carbon, although each to a different extent. It appears that the price of natural gas, oil and coal, as well as changes in the level of GDP, fluctuations in weather and the onset of the global financial crisis together explain about half of the

changes in the price of carbon. This is likely to become more significant for the valuation of derivatives in the future as the carbon market matures.

## **Chapter 6**

### **6. Discussion and Conclusion**

As mentioned in earlier chapters of this thesis, in January 2005, the EU ETS was launched, establishing a price for CO<sub>2</sub> emissions. Due to its large share in total EU CO<sub>2</sub> emissions, the power generation industry in particular has been significantly impacted by carbon pricing. The cost of producing one unit of electricity (based on fossil fuel generation) is now a function of the fuel price and the power plant's thermal efficiency and the carbon price together with the fuel's carbon density (Koenig, 2011).

According to EUROPA (2010), in the twenty-first century, energy plays a key role in delivering some of the most crucial necessities in our lives. In fact, economic growth, stability and well-being are all underpinned by access to affordable and sustainable energy sources for electricity and transport. Notably, a substantial amount (57%) of the EU gross electricity generation was produced by the four countries considered in this thesis; i.e. France, Germany, Italy and the UK. Theoretically, the price of fossil fuels is most likely to have a direct impact on the carbon price.

The statistical analysis conducted as part of this thesis provides evidence that changes in the price of natural gas are very closely correlated with changes in the price of carbon. Indeed, from the regression analysis it appears that fluctuations in the price of natural gas are the largest driver of changes in the price of carbon out of all the independent variables studied. The price of natural gas appears significant in all four regression models. Importantly for this study, most EU electricity generated from non-renewable sources comes from natural gas (23%), thus making it the most important non-renewable source of energy in Europe. In addition, most new power

plants built in European electricity markets since the 1990s have been gas-fired power station, presumably because natural gas is the least polluting fossil fuel. This has substantially increased the EU reliance on natural gas in energy production. This indicates that it is profitable for the company to switch to natural gas for power production, as the cost of production using coal and the cost of compliance are higher.

When examining electricity production by source in 2008, it is evident that only 3% of the EU electricity was produced from oil. This is why the price of oil appears not to be a considerable driver of the price of carbon, being significant in only one regression model. Given rising oil prices, one would reasonably expect energy demand to fall, which would reduce power consumption, leading to lower emissions. Under a carbon trading scheme, when the level of emissions falls, then the price of carbon permits will fall too.

As mentioned earlier in the thesis, coal is the major driver of CO<sub>2</sub> pollution, so it could be expected that the price of EU ETS permits would be affected by the price of coal. However, it only appears significant in one regression model perhaps because the coal industry has been declining since the 1960's in Europe. Over the past decade, there has been a significant decline in the use of coal, and as a result natural gas has been the fastest growing fuel source in the EU. As a matter of fact, there have been no new coal-fired plants in the EU-15 since 2000 and environmental concerns are arguably a major reason for the decline in the use of coal. This is evident in the EU's Directive 2001/80/EC that aims to limit air pollutants generated by large coal-fired plants. The EU ETS explicitly limits the amount of CO<sub>2</sub> that power generators can emit, thus further decreasing the probability of expanded coal use in EU member countries. "Coal is environmental enemy number one" was written on the cover of the Economist



in July 2002 ([The Economist, 2002](#)). This seems to be an accurate assessment of the European position and according to [Lundberg \(2003, p.3\)](#), “coal is a major contributor to greenhouse gases and to other pollutants”. About 37% of the world’s emissions of carbon dioxide come from coal ([Lundberg, 2003](#)). What is imperative is that gas can fairly easily substitute for coal. [Lundberg \(2003\)](#) points out that there are several other methods to produce electricity and to use it more efficiently. The costs for phasing out coal power stations are often very low, as many plants are old, inefficient and in need of large reinvestments to comply with modern environmental demands ([Lundberg, 2003](#)).

According to [Chakravarthy \(2010\)](#), weather is expected to impact the EUA prices mainly in the short term. Notably, temperature is significant in two of the four regression models studied. This suggests that weather has a significant impact on the level of emissions by the major covered installations in the power and heat sector. The legitimacy of this relationship seems rather obvious, given the impact temperature tends to have on the demand for and supply of electricity – the more it deviates from the average, the greater the likelihood that consumers will turn to using heating or cooling devices. Therefore, increased emissions due to adverse weather conditions increase the demand for EUAs. Cold weather increases energy consumption, resulting in an increase in CO<sub>2</sub> emissions.

Interestingly, the level of GDP shows as statistically significant in all four regression models, although at varying levels of significance. Practically, such dependence of the price of permits on the level of economic activity can be explained by the fact that the more prosperous the economy, the greater the output of production, the greater the level of emissions.

Finally, the effects of the global financial crisis had statistical significance in two of the four regression models we have examined. Considering the dampening impact of the GFC on the EU levels of production, it is no surprise that this variable has played such a considerable role in shaping the price of carbon under the EU ETS.

To summarise, all of the independent variables considered in this thesis have had an impact on the price of carbon, although each to a different extent. It appears that the price of natural gas, oil and coal, as well as changes in the level of GDP, fluctuations in weather and the onset of the global financial crisis together explain about half of the changes in the price of carbon. Being able to estimate the price of carbon is likely to become more significant for the valuation of derivatives in the future as the carbon market matures. Otherwise, we have a very good chance of facing the problem of a subprime carbon derivatives bubble.

Today, derivatives are commonly used as risk-management tools and speculative instruments. According to [ECX \(2010\)](#), 96% of carbon trading takes place in derivatives: 86% in futures contracts and the remaining 10% in options. Following [Bodie et al \(2007\)](#), active derivative markets are also considered a source of danger to the overall stability of financial markets. In particular, carbon derivatives are highly complex in nature and easily misunderstood in the sense that they are much more difficult to value than the more ‘generic’ derivative instruments. It is likely that carbon investors who believe they are reducing their risk exposure (i.e. hedging) might in fact be increasing their exposure to different sources of risk. Derivatives will continue to play an important role in portfolio management and the financial system, and the carbon market is no exception.

Effectively, in an ETS, the total number of permits issued (either auctioned or

allocated) determines the price of carbon. But the actual carbon price is essentially determined by the market. If we fail to understand how the carbon price works, then the emissions level would not be reduced, thus defeating the primary aim of establishing and running a carbon trading scheme. As mentioned in earlier chapters of this thesis, the evident failure of the EU ETS in the pilot phase of its operation (Phase One) was marked by the apparent failure of a market based approach, resulting in a 2% increase in the level of emissions compared to a business-as-usual scenario. As **Figures 5 and 6** from Phase One and Two show, the carbon market is largely imperfect and extremely volatile. It is a young market that is still under construction. Hence, it is very important for both buyers and sellers to know the price and be able to estimate the value of their EUAs.

If the price of carbon remains low, then polluters would be tempted to purchase carbon credits instead of implementing green measures in plants or factories. Therefore, major emitters will be less interested in developing low-carbon initiatives if the expected financial income for doing so is not sufficiently rewarding. Therefore, if we do not get the price of carbon right, the level of emissions will not be reduced, thus abandoning the initial purpose of an ETS. So far during Phase One of the EU ETS verified emissions rose by 2%. This notion further establishes the need for determining a reasonable price level of an EUA. After several years in Europe, it is known that carbon price must be sufficient enough to bring a positive environmental impact. It has been shown by [Retamal \(2009\)](#) that if the price of carbon remains below €25–30, coal will remain more attractive than gas in price terms, thus completely undermining the initial idea of reducing pollution unless there are other incentives. Therefore, it is most likely that under a benchmark price of €25–30, the global carbon-constraint economy will fail to substantially reduce its GHG emissions. Then we also have the chance of

prices remaining volatile due to financial speculation and probably regulation mistakes. Clearly, the lack of transparency is another contributing factor to carbon market failures.

On a final note, some of the main price drivers in the EU ETS are political and regulatory decisions, and emissions levels which are determined by weather, the wider energy complex and economic growth. Building a fundamental understanding of the functioning of the carbon market is essential in order to meet emissions reduction targets. This thesis is a step in the direction of getting a clearer view of the factors that drive carbon prices within the EU ETS. It is my hope that this study provides some useful guidelines for determining the hypothetical price of carbon in both established and proposed carbon trading schemes.

One of the substantial limitations of this thesis is that Phase Two (2008-2012) of the EU ETS is not fully observable, as it is expected to last till December 2012; whereas this thesis is expected to be completed by April 2012. Second, one should be rather careful when generalising from the findings obtained from this study. As mentioned earlier in the dissertation, because the EU ETS is a relatively immature market, with a rather short history of trading, caution needs to be exercised when attempting to hypothesise future trends in the price of carbon. Third, there may also be some potential statistical implications to this study. Parametric statistics have been used throughout the study, which rely on the presence of a normal distribution and involve a big sample, such as monthly and even daily observations. In addition, whenever relevant, I have also conducted tests using non-parametric statistics, which implies lack of a normal distribution and usually small populations, in this case carbon permits essentially being one commodity with four or five annual observations, as emissions

trading tends to take place in phases. The non-parametric results are not reported here as they are not significantly different to the parametric results

## 7. Appendix. Stationarity and Cointegration

Although time series data are heavily used in studies in explaining and predicting price movements, it is important to note that such data may present some problems for researchers. In particular, most empirical work based on time series data assumes that the underlying time series is stationary. A time series is said to be stationary, if its mean and variance are constant and do not vary systematically over time (Gujarati, 2003, p.26). Alternatively, if the mean and variance change, then the series is non-stationary. Statistically speaking, this can be put as:

*If  $\lambda - 1 = 0$ , then the series is not stationary (the series contains a unit root)*

*If  $\beta > 0$ , then the series contains a trend*

*If  $\beta = 0$  and  $\lambda - 1$  is not zero, then the series is stationary*

Given the daily figures, all the values designating independent variables were initially converted to both monthly and quarterly estimates. However, due to non-stationarity present in the time series, quarterly figures have been excluded from this regression study and therefore from our data analysis too. **Table 11** below further elaborates on this matter.

**Table 11. Unit Root Probabilities – Eviews Output (quarterly data)**

	Level – intercept	Level – trend & intercept	First difference – intercept	First difference – trend & intercept
<b>Carbon price</b>	0.3534	0.3418	0.0542*	0.1725
<b>Natural Gas</b>	0.0125**	0.0323**	0.0357**	0.1412
<b>Oil</b>	0.0600*	0.2185	0.0296**	0.3001
<b>Coal</b>	0.3595	0.5366	0.1939	0.4605
<b>Temperature</b>	0.0000***	0.0060*	0.0007***	0.0359**
<b>GDP</b>	0.2250	0.1502	0.0444**	0.0277**

Notes:

\*\*\* less than 0.01;      \*\* less than 0.05;      \* less than 0.10

---

This is based on longitudinal time series **quarterly** data for four years from year 2006 to 2009 of 48 observations that covers France, Germany, Italy and the UK with all variables [except for real GDP growth rate] logged to the natural logarithm ( $\ln$ ).

The above table illustrates that when analysing quarterly data under the 95% confidence level, in the level form (trend & intercept), only the price of natural gas and temperature appear to stationary; whereas carbon price, as well as the prices of oil and coal, and GDP are all non-stationary. This implies that the latter set of variables cannot be incorporated in the regression analysis.

In addition, for the purpose of this study, monthly figures were deemed to be more statistically significant than the quarterly ones. The justification for such reasoning relies on the assumption that time series data would tend to be less volatile on a quarterly basis, thus showing a smoothing effect, which would likely make our results rather futile. Consequently, further focus of this thesis is on analysing the data based using the monthly estimates for the period from January 2006 until December 2009. **Table 12** below depicts unit root probabilities tested in both their level and first difference forms, and included in the test equation are intercept and trend & intercept data. Therefore, the table discusses the stationarity outcomes for level – intercept, for level – trend & intercept, first difference – intercept, as well as first difference – trend & intercept. All stationarity outcomes are based on monthly  $\ln$  data with a 95% confidence level.

**Table 12. Unit Root Probabilities – Eviews Output (monthly data)**

	<b>Level – intercept</b>	<b>Level – trend &amp; intercept</b>	<b>First difference – intercept</b>	<b>First difference – trend &amp; intercept</b>
<b>Carbon price</b>	0.2203	0.4260	0.0006***	0.0038***
<b>Natural Gas</b>	0.2314	0.5590	0.0000***	0.0002***
<b>Oil</b>	0.0219**	0.0911*	0.0043***	0.0222**
<b>Coal</b>	0.5512	0.9177	0.0001***	0.0008***
<b>Temperature</b>	0.0010***	0.0029***	0.0000***	0.0002***
<b>GDP</b>	0.1339	0.2631	0.0308**	0.1080

Notes:

\*\*\* less than 0.01;      \*\* less than 0.05;      \* less than 0.10

---

This is based on longitudinal time series monthly data for four years from year 2006 to 2009<sup>21</sup> of 48 observations that covers France, Germany, Italy and the UK with all variables [except for real GDP growth rate] logged to the natural logarithm (*ln*).

**Table 12** above demonstrates that in the level form (trend & intercept) under the 90% confidence level, only oil and temperature are stationary, whereas all other variables appear to be non-stationary. This means that carbon price as well as the prices of natural gas and coal,

---

<sup>21</sup> The EU ETS officially commenced in January 2005. However, because no trading occurred on ECX prior to 9 January 2006, the time series for all variables begins from the latter date and covers a four-year period until 31 December 2009.



temperature as well as GDP cannot be included in the regression model due to their non-stationarity.

Stationarity is an aspect to consider when doing empirical studies involving time series data (Gujarati, 2003, p.792). First, when the underlying time series are non-stationary, this may lead to autocorrelation (i.e. characterised by a low Durbin-Watson score). Second, the estimation of parameters of the OLS model produces statistically significant results between time series that contain a trend and are otherwise random. This finding led to considerable work on how to determine what properties a time series must possess if econometric techniques are to be used. The basic conclusion was that any times series used in econometric applications must be stationary. Namely, one should be cautious in inserting time series figures into a regression equation. When regressing one time series variable on (an)other time series variable(s), if there is a trend (upward or downward) in the underlying time series, then one may often get a very high  $R^2$  even though there actually may be no significant relationship between the two variables. This is likely to exemplify the problem of spurious or nonsense regression. Otherwise stated, spurious regressions caused by high  $R^2$  can arise provided time series are non-stationary, which was the case with the quarterly figures. Third, some financial time series, such as stock prices for example, reveal a trend called the random walk phenomenon (Gujarati, 2003, p.792). Under the random walk phenomenon, the best prediction of a carbon price tomorrow is equal to its daily price today plus a purely random shock (or error term). If this were indeed the case with carbon pricing, then predicting or aiming to explain the price of carbon permits would be deemed a fruitless exercise. Fourth, considering that regression models involving time series data are often used for forecasting, and given the implications under point four mentioned above, it is important to find out if such prediction is legitimate provided the underlying time series are non-stationary. Finally, because causality tests assume that the time series incorporated into the analysis are stationary, tests of stationarity should precede tests of causality (Gujarati, 2003, p.792-793).

There are different tests of stationarity. However, due to popularity and the importance

attached to the unit root test in the recent past amongst the econometricians ([Gujarati, 2003](#)), the unit root test has been used in this data analysis. In statistics, a unit root test is used to investigate whether a time series variable is non-stationary using an autoregressive model. The most famous test is the augmented Dickey–Fuller test, which is parametric and assumes some sort of normal distribution of data. In statistics and econometrics, an augmented Dickey–Fuller test (ADF) is a test for a unit root in a time series sample ([Greene, 1997](#)). The augmented Dickey–Fuller (ADF) statistic, used in the test, is a negative number and the more negative it is, the stronger the rejection of the hypothesis that there is a unit root at some level of confidence ([Greene, 1997](#)). This test uses the existence of a unit root as the null hypothesis. The ADF unit root testing was performed using Eviews software. Firstly, I tested for unit root in the level form on intercept, and then in level form on trend and intercept. Afterwards, I repeated this testing for unit root in the first difference and then on level on trend and intercept. I did not proceed to testing for unit root in the second difference.

When the Eviews analysis shows that there is a unit root, then the data are non-stationary. If the calculated Dickey–Fuller test statistic is greater than the critical value, one should reject the null hypothesis of non-stationarity because the variable being examined presents stationary series and can be further integrated into the regression analysis. However, when the variable is non-stationary, it cannot be incorporated into a regression model. *Tables 11 and 12* mentioned earlier present an output of the analysis on stationarity.

Yet, if the time series is not stationary, in many cases a series can be transformed from non-stationary to stationary by taking the first difference. Statistically, this can be expressed in the manner described below:

Rather than using  $z_t$  as a dependent variable, the dependent variable becomes  $z_t - z_{t-1}$ . A series that is stationary without any transformation is designated as  $I(0)$ , or integrated of order 0, while a series that has stationary first differences is designated  $I(1)$ , or integrated of order 1.

In particular, we can often transform it by initially trying the first difference (intercept and/or trend and intercept) test and then, if necessary, the second difference (intercept and/or trend and intercept) test. Stemming from this postulation, as depicted in **Table 12**, some of the data under the level-intercept test on a monthly basis were stationary (such as petroleum price, oil price and temperature) and some turned out to be non-stationary (such as carbon price, price natural gas, coal price and GDP). However, as **Table 12** shows, having conducted the first difference-intercept test, all the data without exception became stationary. Interestingly, the level – trend and intercept test showed that most variables (except for temperature) were non-stationary and then again once the first difference – trend and intercept test has been performed, all the data except for GDP turned out to be stationary.

Generally, if the first difference testing makes the data stationary, then the values included in a regression equation should also be entered in their first-difference form unless the variables are cointegrated. However, sing data in the first difference form is likely to add confusion and complexity to the interpretation and usefulness of the output obtained from the regression analysis. That is because it would make it more difficult to pick up significant relationship and would be likely to deliver low  $R^2$ . Therefore, to avoid this problem, a concept in econometrics known as cointegration suggests that if the residuals from regression in their level form prove stationary (i.e. are cointegrated), then data can be incorporated into the regression equation in its level, or original form ([Engle and Granger, 1987](#)). Having conducted such a test, I found that indeed the residuals in their level form proved stationary (0.0884\*) at a 10% confidence level and so I included original data in the regression analysis.

If there is a stationary linear combination of non-stationary random variables, the variables combined are said to be cointegrated. Statistically speaking, if two or more times series are individually integrated but some linear combination of them has a lower order of integration, then the series are said to be cointegrated ([Engle and Granger, 1987](#)). A common example is where the individual series are first-order integrated  $I(1)$  but some (cointegrating) vector of coefficients exists to form a stationary linear combination of them ([Engle and Granger, 1987](#)).

The notion of cointegration arose out of the concern about spurious or nonsense regressions in time series. Specifying a relation in terms of levels of the economic variables often produces empirical results in which the  $R^2$  is quite high, but the Durbin-Watson statistic is quite low. This happens because economic time series are dominated by smooth, long term trends. That is, the variables behave individually as nonstationary random walks. Importantly, as highlighted by [Engle and Granger \(1987\)](#), the possible presence of cointegration must be taken into account when choosing a technique to test hypotheses concerning the relationship between two variables having unit roots (i.e. integrated of at least order one). In addition, cointegration provides more powerful tools when the data sets are of limited length, as most financial time-series are ([Engle and Granger, 1987](#)).

## 8. References

- Abadie, L. M. and Chamorro, J. M. 2008. 'European CO<sub>2</sub> prices and carbon capture investments'. *Energy Economics*, Vol. 30, pp. 2992–3015.
- Affalo, J. 2010. 'The economics of climate change'. *The Analyst*, No. 1. Available: <http://issuu.com/lseanalyst/docs/lseanalyst1> [Accessed May 28, 2011].
- Agritrade, 2004. 'Analysis of price volatility'. Available: <http://agritrade.cta.int/en/Key-topics/Market-access-and-developmets/News/Analysis-of-price-volatility> [Accessed September 18, 2009].
- Alberola, E. And Chevallier, J. 2009. 'European Carbon Prices and Banking Restrictions: Evidence from Phase I'. *The Energy Journal*, Vol. 30, No. 3.
- Andrew, B. 2009. 'Price Volatility in the EU'. Informal discussion on October 10, 2009.
- Andrew, J. and Cortese, C. 2011. 'Accounting for climate change and the self-regulation of carbon disclosures'. *Accounting Forum*, forthcoming.
- Andrew, J., Kaidonis, M. A. and Andrew B. 2010. 'Carbon tax: Challenging neoliberal solutions to climate change'. *Critical Perspectives on Accounting*, Vol. 21, pp. 611–618.
- Australian Bureau of Statistics, 2009. 'Australian Demographic Statistics'. Available: <http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0> [Accessed October 28, 2009].
- Australian Centre for Environmental Law (ACEL) 2007. 'Carbon trading and the derivatives market'. Available: [http://sydney.edu.au/law/acel/docs/carbon\\_trading\\_June%2007.pdf](http://sydney.edu.au/law/acel/docs/carbon_trading_June%2007.pdf) [Accessed January 11, 2011].
- Australian Government, Department of Climate Change, 2008–09. 'Pollution Reduction Scheme'. Available: <http://www.climatechange.gov.au/emissionstrading/index.html> [Accessed September 9, 2009].
- Avgouleas, E. 2009. 'The global financial crisis, behavioural finance and financial regulation: in search of new orthodoxy'. *Journal of Corporate Law Studies*, Vo. 1, pp. 23–58.
- Bartlet Brebner, J. 1948. 'Laissez Faire and State Intervention in Nineteenth-Century Britain'. *Journal of Economic History*, Vol. 8, pp. 59–73.
- Beder, S. 2001. 'Neoliberal think tanks and free market environmentalism'. *Environmental Politics*, Vol. 10, No. 2, pp.128–133.
- Beder, S. 2002. 'Agenda setting for environmental protection policies'. In Kerr, S.,

- Buhrs, T. and Dann, C. (editors), *Green governance: From periphery to power* (pp. 22–25). Christchurch: Lincoln University.
- Beder, S. 2006. *Suited themselves: How corporations drive the global agenda*. London, Earthscan.
- Beder, S. 2006. 'Emissions Trading: A principal Approach'. *Environmental Principles and Policies*, UNSW Press, Sydney.
- Bessec, M. and Fouquau, J. 2007. 'The non-linear link between electricity consumption and temperature in Europe: a threshold panel approach'. Available: [https://editorialexpress.com/cgi-bin/conference/download.cgi?db\\_name=NASM2008&paper\\_id=21](https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=NASM2008&paper_id=21) [Accessed April 7, 2010].
- Bettelheim, E. and Janetos, G. 2010. 'Survey of Carbon Exchanges'. Available: <http://www.exchange-handbook.co.uk/index.cfm?section=articles&action=detail&id=78451> [Accessed April 14, 2010].
- Betz, R. 2006. 'What is driving Price Volatility in the EU ETS?' Centre for Energy & Environmental Markets, the University of NSW. Available: [http://www.ceem.unsw.edu.au/content/userDocs/PagesfromAETFRReviewOctNov06\\_web-2-1.pdf](http://www.ceem.unsw.edu.au/content/userDocs/PagesfromAETFRReviewOctNov06_web-2-1.pdf) [Accessed September 17, 2009].
- Betz, R. 2009. 'The governance challenge for implementing effective, efficient and fair market-based climate policies: Case studies of the EU Emissions Trading Scheme (EU ETS) and the Carbon Pollution Reduction Scheme (CPRS)'. Available: [http://www.ceem.unsw.edu.au/content/userDocs/RB\\_presentation-1.pdf](http://www.ceem.unsw.edu.au/content/userDocs/RB_presentation-1.pdf) [Accessed September 16, 2009].
- Blogocrats, 2009. 'Criticisms of the CPRS and calls for a carbon tax'. Available: <http://blogocrats.wordpress.com/2009/02/20/criticisms-of-the-cprs-and-calls-for-a-carbon-tax/> [Accessed October 11, 2009].
- Bodie, Z., Arif, M., da Silva Rosa, R., Kane, A. and Marcus, A. J. 2007. *Investments*. McGraw–Hill, Irwin.
- Brealey, R. A., Myers, S. C. and Allen, F. 2008, *Principles of Corporate Finance: Chapter 13: Corporate Financing and the Six Lessons of Market Efficiency* (p.354), 8<sup>th</sup> edition, McGraw–Hill, Irwin.
- Brook, B. 2008. 'Science must prevail'. The Australian, 30 April 2008. Available: <http://www.theaustralian.com.au/higher-education/opinion-analysis/science-must-prevail/story-e6frgcko-1111116197972> [Accessed March 20, 2010].
- Brook, B. 2009. 'Rapid roundup: Senate rejects Carbon Pollution Reduction Scheme – Experts respond'. Available: <http://www.aussmc.org/SenaterejectsCPRS.php> [Accessed September 9, 2009].
- BusinessLine, 2008. Carbon emissions market: A bubble in the boom?' Available: <http://www.thehindubusinessline.com/2008/08/08/stories/2008080850260900.htm>

[Accessed September 16, 2009].

Cahill D. 2009. 'The end of neoliberalism'. *Z Magazine*; January 2009, pp. 35–38.

Carbon Market Data, 2009. Available: <http://www.carbonmarketdata.com> [Accessed September 16, 2009].

Carbon Offsets Daily, 2009. 'The Coming Carbon Bubble'. Available: <http://www.carbonoffsetsdaily.com/usa/the-coming-carbon-bubble-9835.htm> [Accessed September 10, 2009].

Carbon Positive 2006. 'EUA prices flatten in October'. Available: <http://www.carbonpositive.net/viewarticle.aspx?articleID=459> [Accessed May 11, 2011].

Carbon Positive 2007. 'EUA price rally short-lived'. Available: <http://www.carbonpositive.net/viewarticle.aspx?articleID=938> [Accessed May 11, 2011].

Carbon Positive 2008. 'Europe's CO<sub>2</sub> emissions rise in 2007'. Available: <http://www.carbonpositive.net/viewarticle.aspx?articleID=1040> [Accessed December 19, 2010].

Carden, A. 2008. 'Price Controls Create Man-Made Disasters'. Available: <http://mises.org/story/3025> [Accessed October 30, 2009].

Carmona, R., Fehr, M., Hinz, J. and Porchet, A. 2010. 'Market Design for Emission Trading Schemes'. *SIAM Review*, Vol. 52, No. 3, pp. 403–452.

Chakravarthy, K. 2010. 'European Emissions Trading Market: Price Determinants of European Union Allowance (EUA)'. Available: [http://www.growthconsulting.frost.com/web/images.nsf/0/106BA97297245B02652575F9003EC77E/\\$File/European%20Emissions.htm](http://www.growthconsulting.frost.com/web/images.nsf/0/106BA97297245B02652575F9003EC77E/$File/European%20Emissions.htm) [Accessed August 3, 2011].

Chan, M. 2009. 'Subprime Carbon? Re-thinking the World's Largest New Derivatives Market'. Available: [http://urbanhabitat.org/files/SubprimeCarbonReport\\_0.pdf](http://urbanhabitat.org/files/SubprimeCarbonReport_0.pdf) [Accessed March 13, 2011].

Chan, Y. 2009. 'Australia tops global per capita carbon emissions'. Available: <http://www.businessgreen.com/business-green/news/2249385/australia-tops-global-per> [Accessed October 28, 2009].

Chua, W. 1986a. 'Radical Developments in Accounting Thought. *The Accounting Review*, Vol. LXI, No. 4, pp. 601–632.

Climate Institute and E3G, 2009. 'G20 low carbon competitiveness' Available: <http://www.climateinstitute.org.au/images/carboncompreport.pdf> [Accessed October 28, 2009].

Climate Change Law Practice Group Blog, 2007. 'EU learns from cap-and-trade

mistakes'. Available:  
<http://www.davis.ca/en/blog/Climate-Change-Law-Practice-Group/2007/10/31/EU-le-arns-from-cap-and-trade-mistakes> [Accessed September 16, 2009].

Cohen, J. N. 2007. 'The Impact of Neoliberalism, Political Institutions and Financial Autonomy on Economic Development, 1980–2003'. Dissertation, Department of Sociology, Princeton University. Available: <http://www.getcited.org/pub/103436872> [Accessed June 16, 2011].

Colong Bulletin, 2009. 'Carbon Polluters Reward Scheme?' Available:  
[http://www.colongwilderness.org.au/bulletin/Bulletin231\\_screen.pdf](http://www.colongwilderness.org.au/bulletin/Bulletin231_screen.pdf) [Accessed September 9, 2009].

Considine, J. T. 2000. 'The impacts of weather variations on energy demand and carbon emissions'. *Resource and Energy Economics*, Vol. 22, pp. 295–314.

Convery, F. and Redmond, L., 2007. 'Market and Price Developments in the European Union Emissions Trading Scheme'. *Review of Environmental Economics and Policy*, Vol. 1, No. 1, pp. 88–111.

Cowen, T. and Crampton, E. 2002. *Market Failure or Success: The New Debate*.

Cultural Dictionary, 2005. 'Laissez-faire'. Available:  
<http://dictionary.reference.com/browse/laissez+faire> [Accessed October 30, 2009].

Daskalakis G. and Markellos R.N. 2008. 'Are the European Carbon Markets Efficient?' *Review of Futures Markets*, Vol. 17, No. 2, pp. 103–128.

Davis, M. and Monk, D. B. 2007. *Evil Paradises: Dreamworlds of Neoliberalism*. New Press.

Dictionary.com, 2009. 'Laissez-faire'. Available:  
<http://dictionary.reference.com/browse/laissez+faire> [Accessed October 30, 2009].

Diesendorf, M. 2009. 'Rapid roundup: Senate rejects Carbon Pollution Reduction Scheme – Experts respond'. Available:  
<http://www.aussmc.org/SenaterejectsCPRS.php> [Accessed September 9, 2009].

Dollar, D. and Kraay, A. 2001. *Growth Is Good for the Poor*. Washington, DC, The World Bank.

Duncan, E. 2009. 'Getting Warmer'. *The Economist*. 5 December 2009, p. 57.

Ebeling, R. M. 2004. 'Democracy, Freedom and the Market'. *The Freeman: Ideas on Liberty*, Vol. 54, No. 9, pp. 8–15.

Ellerman, A. D. and Buchner, B.K., 2007. 'The European Union Emissions Trading Scheme: Origins, Allocation and Early results'. *Review of Environmental Economics and Policy*, Vol. 1, No. 1, pp. 66–87.



Ellerman, A. D. and Montero, J-P, 2002 'The Temporal Efficiency of SO<sub>2</sub> Emissions Trading'. Available: [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=337142](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=337142) [Accessed September 9, 2009].

Energy Brainpool 2007. 'Effects of Temperature, Precipitation and Wind on the EUA Prices of the Second Phase'. Available: <http://www.ifs-italia.it/site/media/file/132.pdf> [Accessed July 10, 2011].

Engle, R. F. and Granger, C. W. J. 1987. 'Co-integration and error correction: Representation, estimation and testing'. *Econometrica*, Vol. 55, No. 2, pp. 251–276.

Engle, R. F., Granger, C. W. Rice, J. and Weiss, A. 1986. 'Semi-parametric estimates of the relation between weather and electricity sales'. *Journal of the American Statistical Association*, Vol. 81, No. 394, pp. 310–320.

EurActiv, 2009. 'EU Emissions Trading Scheme'. Available: <http://www.euractiv.com/en/climate-change/eu-emissions-trading-scheme/article-133629> [Accessed September 15, 2009].

European Climate Exchange, 2004. 'What determines the price of carbon in the European Union?' Available: [http://www.chicagoclimatex.com/news/publications/pdf/EU\\_CO2\\_price\\_drivers.pdf](http://www.chicagoclimatex.com/news/publications/pdf/EU_CO2_price_drivers.pdf) [Accessed September 15, 2009].

European Climate Exchange, 2009. Available: <http://www.ecx.eu/> [Accessed September 13, 2009].

European Environment Agency, 2009. 'EU ETS data viewer'. Available: <http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=1078> [Accessed September 15, 2009].

Eurostat, 2010. 'Energy Statistics – Quantities'. Available: [http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main\\_tables](http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables) [Accessed September 27, 2010].

Fama, E. F. 1970. 'Efficient Capital Markets: a Review of Theory and Empirical Work'. *The Journal of Finance*, Vol. 25, No. 2, pp. 383–417.

Fama, E. F. 1998. 'Market Efficiency, Long–Term Returns, and Behavioural Finance'. *Journal of Financial Economics*, Vol. 49, No. 3, pp. 283–306.

Filippini, M. 1995. 'Swiss residential demand for electricity by time–of–use'. *Resource and Energy Economics*, Vol. 17, No. 3, pp. 281–290.

Friedman, M. 1962. *Capitalism and Freedom*. The University of Chicago Press.

Friedman R. M., Downing D., Gunn, E. M. 2005. 'Environmental Policy Instrument Choice: The Challenge of Competing Goals'. *Duke Environmental Law & Policy Forum*, Vol. 10, p. 327.

Frino, A., Kelly, S., Comerton-Forde, C., Cusack, T. and Wilson, K. 2004. *Corporate Finance: Chapter 8: Australian Equities Market*. Pearson, Australia.

Gaffikin, M. 2008. 'Accounting Theory: Research Regulation and Accounting Practice'. Pearson Education, Australia.

Garnaut Climate Change Review, 2008. 'Interim Report to the Commonwealth, State and Territory Governments of Australia: *Climate change in Australia – current and future*'. Available: <http://www.garnautreview.org.au> [Accessed October 15, 2009].

Gettler, L. 2008. 'Carbon Loading'. *Business Review Weekly*, Vol. 30, No. 32, pp. 30–31.

Gettler, L. 2009. 'Without control, carbon market will bubble'. Available: <http://www.theage.com.au/business/without-control-carbon-market-will-bubble-2009-0722-dtm1.html?page=-1> [Accessed September 16, 2009].

Gordon, A. B. 2003. "University presses" in James W. Guthrie. *Encyclopedia of Education*, Vol. 7, p. 2601.

Gordon, P. 2004. 'Top-down Planning, Market Failures and Spontaneous Orders'. Available: <http://time.dufe.edu.cn/article/petergordon/12.pdf> [Accessed May 25, 2011].

Harvey D. 2005. *A brief history of neoliberalism*. New York, Oxford University Press.

Hayek, F. A. 1991. *The Fatal Conceit: The Errors of Socialism*. The University of Chicago Press.

Henley, A. and Peirson, J. 1997. Non-linearities in electricity demand and temperature: parametric versus non-parametric methods. *Oxford Bulletin of Economics and Statistics*, Vol. 59, pp. 1149–1162.

Henley, A. and Peirson, J. 1998. 'Residential energy demand and the interaction of price and temperature: British Experimental Evidence'. *Energy Economics*, Vol. 20, pp. 157–171.

Hoeller, P. and Wallin, M. 1991. Energy Prices, Taxes and Carbon Dioxide Emissions'. *OECD Economic Studies*, Vol. 17. Available: <http://www.oecd.org/dataoecd/33/26/34258255.pdf> [Accessed May 2, 2011].

Houston, T. C., Crighton, E. and Williams, H. 2010. 'Gaming the EU ETS. Market Failure in the 2005 – 2007 Trial Trading Round'. Available: <http://www.pomona.edu/academics/departments/international-relations/theses/houston-2010.pdf> [Accessed April 20, 2011].

Immordino, G., Pagano, M. and Polo, M. 2011. 'Incentives to innovate and social harm: Laissez-faire, authorization or penalties?' *Journal of Public Economics*, Vol. 95, No. 7/8, pp. 864–876.

International Energy Agency 2007. 'CO<sub>2</sub> Allowances and Electricity Price Interaction – Impact on Industry's Electricity Purchasing Strategies in Europe'. Available: [http://www.iea.org/papers/2007/jr\\_price\\_interaction.pdf](http://www.iea.org/papers/2007/jr_price_interaction.pdf) [Accessed July 10, 2011].

Isenegger, P. and von Wyss, R. 2009. 'The Valuation of Derivatives on Carbon Emission Certificates – a GARCH Approach'. Available: [http://www.docstoc.com/docs/DownloadDoc.aspx?doc\\_id=68868664](http://www.docstoc.com/docs/DownloadDoc.aspx?doc_id=68868664) [Accessed January 11, 2011].

Johnsen, T. A. 2001. 'Demand, generation and price in Norwegian Market Electric Power'. *Energy Economics*, Vol. 23, pp. 227–251.

Joyce, H. 2001. 'Adam Smith and the Invisible Hand'. Available: <http://plus.maths.org/issue14/features/smith/> [Accessed October 30, 2009].

Kahneman, D. and Tversky, A. 1979. 'Prospect Theory: An Analysis of Decision under Risk'. *Econometrica*, Vol. 47, No. 2, pp. 263–292.

Kahneman, D. and Tversky, A. 1996. 'On the Reality of Cognitive Illusions'. *Psychological Review*, Vol. 103, No. 3, pp. 582–591.

Kahneman, D. and Tversky, A. 2000. *Choices, Values, and Frames*. Cambridge: Cambridge University Press.

Kharecha, P. A. and Hansen, J. E. 2008. 'Implications of "peak oil" for atmospheric CO<sub>2</sub> and climate'. *Global Biogeochemical Cycles*, Vol. 22, pp. 1–10.

Kirat, D. and Ahamada, I. 2009. 'The impact of the European Union Emission Trading Scheme on electricity generation sectors'. Available: <http://www.parisschoolofeconomics.eu/IMG/pdf/Djamel.pdf> [Accessed September 21, 2010].

KMAfrica Knowledge Hub, 2009. 'Critical Discourse Analysis (CDA) – social and political domination through text and talk'. Available: <http://www.isivivane.com/kmafrica/?q=group.pkm.critical.discourse.analysis> [Accessed October 16, 2009].

Kruger, J., Oates, W. E. and Pizer, W. A. 2007. 'Decentralization in the EU Emissions Trading Scheme and Lessons for Global Policy'. *Review of Environmental Economics and Policy*, Vol. 1, No. 1, pp. 112–133.

Kruger, D. 2008. 'Lessons Learned from EU Emissions Trading Scheme (ETS)'. Available: <http://www.narucmeetings.org/Presentations/Kruger%2520NARUC%2520EU%2520ETS%2520Lessons%2520Feb%252019.ppt+eu+ets+lessons+learned&cd=1&hl=en&ct=clnk&gl=au> [Accessed September 16, 2009].

Kyoto Protocol, 2009. 'Status of Ratification'. Available: [http://unfccc.int/files/kyoto\\_protocol/status\\_of\\_ratification/application/pdf/kp\\_ratification.pdf](http://unfccc.int/files/kyoto_protocol/status_of_ratification/application/pdf/kp_ratification.pdf) [Accessed October 20, 2009].

Lackner, K. S., Grimes, P. and Ziock, H.– J. n.d. ‘Capturing Carbon Dioxide from Air’. Available: [http://www.netl.doe.gov/publications/proceedings/01/carbon\\_seq/7b1.pdf](http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/7b1.pdf) [Accessed June 10, 2011].

Laurini, M. P., Gustavo, L., Furlani, C. and Portugal, M. S. 2008. ‘Empirical market microstructure: An analysis of the BRL / US\$ exchange rate market’. *Emerging Markets Review*, Vol. 9, No. 4.

Leys, C. 2010. ‘The Dictatorship of the Market’. *E-Bulletin*, No. 365. Available: <http://www.socialistproject.ca/bullet/365.php> [Accessed April 10, 2011].

Li, X. and Sailor, D. J. 1995. ‘Electricity use sensitivity to climate and climate change’. *World Resource Review*, Vol. 7, No. 3, pp. 334–346.

Lundberg, F. 2003. ‘To Phase Out Coal: The structure of the coal industry, its environmental effects, and the possibilities of phasing out the use of coal’. Available: <http://www.airclim.org/reports/apc16.PDF> [Accessed April 15, 2011].

MacKenzie, D. 2008. ‘Making things the same: gases, emission rights and the politics of carbon markets’. *Accounting, Organizations and Society*, Vol. 34, No. 3–4, pp. 440–455.

McKinsey & Company 2009. ‘Pathways to a Low–Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve’. Available: <http://www.worldwildlife.org/climate/WWFBinaryitem11334.pdf> [Accessed July 19, 2011].

McNeil, B. 2009. ‘Rapid roundup: Senate rejects Carbon Pollution Reduction Scheme – Experts respond’. Available: <http://www.aussmc.org/SenaterejectsCPRS.php> [Accessed September 9, 2009].

Minsky, H. P. 1991. ‘The Financial Instability Hypothesis’. Working Paper No. 74. Available: <http://www.levyinstitute.org/pubs/wp74.pdf> [Accessed May 28, 2011].

Montagnoli A. and de Vries F.P. 2010. ‘Carbon trading thickness and market efficiency’. *Energy Economics*, Vol. 32, No. 6, pp. 1331–1336.

Montero, J – P 2002. ‘Testing the Efficiency of a Tradeable Permits Market’. Available: [http://www.cuadernosdeeconomia.cl/Pdf/DT\\_224.pdf](http://www.cuadernosdeeconomia.cl/Pdf/DT_224.pdf) [Accessed November 21, 2009].

Montgomery, W. D. 1976. ‘Markets in Licenses and Efficient Pollution Control Programs’. *Journal of Economic Theory*, Vol. 5, pp. 395–418.

Neuman, W. L. 2006. ‘Social Science Methods’, Pearson International Edition, Pearson Education Inc.

Ng, T. 2010. ‘Endemic instability in the inefficient markets’. *The Analyst*, No. 1. Available: <http://issuu.com/lseanalyst/docs/lseanalyst1> [Accessed May 28, 2011].

- Nova, J. 2009. 'The Skeptics Handbook'. Available: [http://jonova.s3.amazonaws.com/sh1/the\\_skeptics\\_handbook\\_2-3\\_lq.pdf](http://jonova.s3.amazonaws.com/sh1/the_skeptics_handbook_2-3_lq.pdf) [Accessed March 15, 2010].
- Pardo, A., Meneu, V. and Valor, E. 2002. 'Temperature and seasonality influences on Spanish electricity load'. *Energy Economics*, Vol. 24, pp. 55–70.
- Pew Center on Global Climate Change, n.d. 'Global Warming Basics'. Available: <http://www.pewclimate.org/global-warming-basics> [Accessed September 14, 2009].
- Point Carbon, 2004. 'What determines the price of carbon?' Available: <http://www.pointcarbon.com/> [Accessed October 14, 2009].
- Poon, S. P. 2005. *A Practical Guide to Forecasting Financial Market Volatility*, Wiley, England.
- Prasad, M. 2006. 'The Politics of Free Markets: The Rise of Neoliberal Economic Policies in Britain, France, Germany, and the United States'. University of Chicago Press.
- Redmond, L. and Convery, F. J. 2006. 'Determining the price of carbon in the EU ETS'. *Planning and Environmental Policy Research Series Working Paper*. School of Geography, University College in Dublin, Ireland.
- Reisman, G. 2006. 'Freedom Is Slavery: Laissez-faire Capitalism Is Government Intervention: a Critique of Kevin Carson's Studies in Mutualist Political Economy'. *Journal of Libertarian Studies*, Vol. 20, No. 1, pp. 47–86.
- Retamal, C. 2009. 'Understanding CER Price Volatility'. Carbon Management Consulting Group, Latin Carbon Forum, Panama.
- Reuters, 2008. 'Factbox: Carbon trading schemes around the world'. Available: <http://uk.reuters.com/article/idUKL2189304520080521?pageNumber=4&virtualBrandChannel=0&sp=true> [Accessed October 20, 2009].
- RGGI 2011. 'Regional Greenhouse Gas Initiative – an initiative of the Northeast and Mid-Atlantic States of the US'. Available: <http://www.rggi.org/home> [Accessed October 22, 2009].
- Rotfuss, W., Conrad, C. and Rittler, D. 2009. 'The European Commission and EUA Prices: A High Frequency Analysis of the EC's Decisions on Second NAPs'. Discussion Paper No. 09–045. Available: <ftp://ftp.zew.de/pub/zew-docs/dp/dp09045.pdf> [Accessed June 12, 2010].
- Roy, R. K., Denzau, A. T. and Willett, T. D. 2007. *Neoliberalism: national and regional experiments with global ideas*. New York, Routledge.
- Sandbag, 2010. 'The Carbon Rich List: The companies profiting from the EU Emissions Trading Scheme'. Available: [http://www.sandbag.org.uk/site\\_media/pdfs/reports/carbon\\_fat\\_cats\\_march2010.pdf](http://www.sandbag.org.uk/site_media/pdfs/reports/carbon_fat_cats_march2010.pdf)

[Accessed November 2, 2010].

Sanin, M. E. and Violante, F. 2009. 'Understanding volatility dynamics in the EU–ETS market: lessons from the future'. Available: [http://www.uclouvain.be/cps/ucl/doc/core/documents/coredp2009\\_24.pdf](http://www.uclouvain.be/cps/ucl/doc/core/documents/coredp2009_24.pdf) [Accessed November 20, 2009].

Seifert, J., Uhrig-Homburg, M. and Wagner, M. 2008. 'Dynamic Behavior of CO<sub>2</sub> Spot Prices', *Journal of Environmental Economics and Management*, Vol. 56, No. 2, pp.180–194.

Sewell, M. 2010. 'Behavioural Finance'. Available: <http://www.behaviouralfinance.net/behavioural-finance.pdf> [Accessed March 15, 2010].

Sewell, M. 2011. 'BF or BS?' Available: <http://bs.behaviouralfinance.net/> [Accessed March 11, 2010].

Slattery, L. 2010. 'Climate wars give science bad name'. The Australian, February 24, 2010. p. 23. Available: <http://www.theaustralian.com.au/higher-education/climate-wars-give-science-bad-name/story-e6frgcjx-1225833598122> [Accessed March 1, 2010].

Standard Capital Securities 2011. 'Correlation between global coal and oil prices'. Available: <http://www.scstrade.com/scstradenew/research/Research%20Reports/General/Correlation%20between%20global%20coal%20and%20oil%20prices.pdf> [Accessed February 8, 2010].

Stockholm Environment Institute and Greenhouse Gas Management Institute 2011. 'Western Climate Initiative: Overview'. Available: <http://www.co2offsetresearch.org/policy/WCI.html> [Accessed February 18, 2010].

Stoll, H. R. 1993. *Microstructure of World Trading Markets*, Kluwer, London, reprinted from the *Journal of Financial Services Research*, Vol. 6, No. 4.

Tan, A. 2009. 'Design and Settings of the Carbon Market'. Informal discussion on October 9, 2009.

Taylor, J. B. and Frost, L. 2009. *Microeconomics*, 4<sup>th</sup> edition, Wiley, Chapter 7, pp.135–151.

Thaler, R. H. and Johnson, E. J. 1990. 'Gambling with the House Money and Trying to Break Even: The Effects of Prior Outcomes on Risky Choice'. *Management Science*, No. 36, pp. 643–660.

The Australian 2009. 'When world views collide'. 12 December. Available: <http://www.theaustralian.com.au/news/opinion/when-world-views-collide/story-e6frg71x-1225809548866> [Accessed March 8, 2010].

The Australian 2010. 'A wholesale climate fraud?' Not here. 16 January 2010. Available:  
<http://www.theaustralian.com.au/news/opinion/a-wholesale-climate-fraud-not-here/story-e6frg6zo-1225819884224> [Accessed March 8, 2010].

The Christian Science Monitor, 2007. 'Key climate question: What's the cost of carbon?' Available: <http://www.csmonitor.com/2007/0412/p03s01-uspo.html> [Accessed September 18, 2009].

*The Economist* 2002. Cover page. Vol. 364, No. 8280, p.1.

The Ministry for the Environment of New Zealand, 2011. 'Price range in the international emissions trading market. Pricing in the EU ETS'. Available: <http://www.mfe.govt.nz/publications/climate/issues-international-carbon-market-oct07/html/page3.html> [Accessed July 8, 2011].

Trouson, A. 2010. 'Science a victim of climate wars'. The Australian, 5 March 2010. Available:  
<http://www.theaustralian.com.au/news/nation/science-a-victim-of-climate-wars/story-e6frg6nf-1225837140418> [Accessed March 8, 2010].

Unites States (US) History, 2010. 'Laissez Faire: A Conservative Approach to the Industrial Revolution'. Available: <http://www.u-s-history.com/pages/h844.html> [Accessed May 15, 2010].

University of Wisconsin – Stevens Point, 2010. 'Nonparametric Statistics'. Available: <http://www.uwsp.edu/psych/stat/14/nonparm.htm> [Accessed January 31, 2010].

US Department of State, 2010. 'Laissez-faire Versus Government Intervention'. Available: <http://www.state.gov/r/pa/ei/rls/dos/221.htm> [Accessed May 18, 2010].

Valor, E., Meneu, V. and Caselles, V. 2001. 'Daily Air Temperature and Electricity Load in Spain'. Available: <http://journals.ametsoc.org/doi/pdf> [Accessed April 6, 2010].

Viney, C. 2007. *Financial Institutions, Instruments and Markets*. Chapter 7: Forecasting Share Price Movements (pp. 309–311), 5<sup>th</sup> edition, McGraw–Hill.

White Paper, 2008. 'Carbon Pollution Reduction Scheme: Australia's Low Pollution Future'. Available: <http://www.climatechange.gov.au/whitepaper/foreword.html> [Accessed September 10, 2009].

Williams-Derry, C. 2008. 'Oil Prices vs. Carbon Prices'. Available: [http://daily.sightline.org/daily\\_score/archive/2008/03/14/easyblogentry.2008-03-13.2565187452](http://daily.sightline.org/daily_score/archive/2008/03/14/easyblogentry.2008-03-13.2565187452) [Accessed January 16, 2011].

World Bank, 2008. 'State and Trends of the Carbon Market 2008'. Available: <http://siteresources.worldbank.org/NEWS/Resources/State&Trendsformatted06May10pm.pdf> [Accessed September 10, 2009].

Yan. K. 2009. 'Getting Out of the Carbon Derivatives Market'. Available:  
<http://www.internationalrivers.org/blog/katy-yan/eu-rushes-get-out-carbon-derivatives-market> [Accessed March 13, 2011].