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A Study of the Determinants of Emissions Unit Allowance Price in the European Union Emissions Trading Scheme

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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. In its second phase which began in 2008 the EU ETS now applies to all 27 members of the EU together with Norway, Iceland and Lichtenstein, the members of the European Economic Area (EEA) which are not members of the Union. In the first phase of the EU ETS permits to emit carbon into the atmosphere known as European Union Allowances (EUA) were traded in a market where the price rose to €30 and eventually fell to well below 10 Euro cents as the imperfections of the market became obvious. In the second phase which began in 2008 the price has fluctuated between €30 and €8. EUA 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 growing market dominated by a few large players.

This paper reports some 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. Over the last decade a number of environmental products have been developed alongside the EUA, 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. A better understanding of the determinants of these markets will help regulators manage these new markets and this paper aims to enhance our knowledge of the market.

Keywords

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A Study of the Determinants of Emissions Unit Allowance Price in the European Union Emissions Trading Scheme

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Keywords: Carbon market, permit price, EU ETS.

JEL Classification: M40.

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Introduction

There is a clear move around the world to develop emissions trading schemes (ETS). The EU scheme is probably the best known, but now New Zealand has one, Japan has tabled the outline of one and many US states and Canadian provinces have moved to develop one. The North Eastern regional Greenhouse Gas Initiative (RGGI) in the USA is now in operation and it applies to emissions in ten US states. The Western Climate Initiative (WCI) has established a trading mechanism that could apply to eight Western states and four Canadian provinces. Political changes have limited the introduction of this scheme but it has become the basis of a scheme which will start in California next year. 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 applies in 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).

Market-based solutions to solving the global warming problem are increasing around the world as it is believed that an ETS in the form of 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, as there are likely to be many problems in establishing a top-down market for an artificial scarcity (emissions permits) created by government. A different market-based approach that exists in many countries is to impose a carbon tax on polluters as there is plenty of evidence that directly increasing the price of a pollutant through a tax has the effect of reducing demand, this approach has been used in many places to discourage the use of plastic bags and bottles.

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.

This paper reports some research which has attempted to assess the main drivers of the price of an emissions permit. Obviously demand and supply factors determine price in the short-run but this paper is concerned with the factors which may influence price in the medium term as some understanding of this is essential for a rational trade in derivatives. Currently the markets offer futures which guarantee the delivery of numbers of permits at various times in the future, and the valuation model used for these futures is not clear at the moment. The purpose of the futures 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.

The paper proceeds with a discussion of the theory which informs the establishment of emissions trading markets. The third section provides a summary of some relevant literature, results are presented in the fourth section, followed by a conclusion in the final section.

Theory

For the purpose of this paper, theory mainly comes from two broad areas: economic theory and finance theory. While economic theory essentially involves the theory of perfect competition; finance theory is principally concerned with the concept of the Efficient-Market Hypothesis (EMH).

Theory of Perfect Competition and the Efficient Market Hypothesis (EMH)

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. Amongst some of the key assumptions of a perfectly competitive market are the existence of a large number of buyers and sellers, and the homogeneity of the goods traded. In addition, buyers and sellers also need complete information and businesses must be completely free to enter or exit the market without transaction costs. This model is fundamentally related to the supply and demand model, and presumes utility maximisation for buyers and profit maximisation for sellers (Taylor & Frost 2009).

Nevertheless, 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 differ somewhat from each other, or consumers and producers are not able to acquire comprehensive information about prices, or transaction costs are high. This seems to be exactly the case with the carbon market where we have a limited number of both buyers and sellers, where there are several exchanges and only one commodity is traded [being the carbon permit] and where both parties to the transaction are unable to obtain adequate information about prices and the underlying value of carbon permits. However, the model of perfect competition enables one to take a broad view of how markets operate and whether they operate efficiently and it makes it possible for one to comprehend what happens when markets fail (Taylor & 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 & Frost 2009). The perfect competition model, which incorporates the behaviour of buyers and sellers, aims to explain the price, the quantity consumed by each buyer and the quantity produced by each seller. It also explains the marginal benefit of consumption for each buyer and marginal cost for each seller.

Even though the idea of upward and downward price movements to achieve equilibrium between the quantity supplied and the quantity demanded makes some 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. The legitimacy of the model depends upon its performance in explaining or forecasting prices and quantities in markets where market participants conduct various transactions through buying and selling products and services (Taylor & Frost 2009). In conclusion, the discussion presented above highlights the role of theory of perfect competition as an analytical tool used to describe the principles of market mechanism.

The EMH is closely related to the theory of perfect competition but 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 constantly superior returns (Brealey, Myers & Allen 2006; Viney 2007). The weak form of the efficient–market hypothesis occurs when prices efficiently impound all the information in the past series of stock prices, which makes it impossible for market participants to make superior returns simply by following patterns in stock prices (Brealey et al. 2006; Viney 2007). The semi-strong form of the efficient–market hypothesis suggests that prices are inclusive of all publicly available information, while the strong form of the efficient–market hypothesis requires that stock prices reflect all available information, including data from private sources (Brealey et al. 2006; Viney 2007). 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 (Daskalakis & Markellos 2008; Montagnoli & de Vries 2010; Seifert Uhrig-Homburg & Wagner 2008).

Relevant Literature

The literature review for this paper revolves around the three key areas of the influence of regulatory processes and government intervention on the design and settings of the scheme, carbon price volatility, and the factors that affect the price of carbon.

Influence of Regulatory Processes and Government Intervention on the Design and Settings of the Scheme

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, p.6), “carbon credits are a new type of immaterial commodity, highly dependent on political decisions”. In fact, as outlined by the European Climate Exchange (2004), the EU emissions trading market has been operating in an environment dominated by political and regulatory influence. The European Climate Exchange (2004) and Agritrade (2004) proposed that policy and regulatory issues are amongst the key drivers that are likely to have an impact on the design and settings of the carbon market.

The study by Bettelheim and Janetos (2008, p.1) found that the “structural flaws in the EU ETS are quickly reflected in exchange traded prices”. Clearly, the disclosure 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 (Bettelheim & Janetos 2008; Kirat & Ahamada 2009). This sudden collapse of the carbon price followed the disclosure of the 2005 verified emissions by the European authorities (Kirat & Ahamada 2009). The results revealed a net long position of the carbon market with more allowances than actual emissions (Kirat & Ahamada 2009). Similarly, the recent announcement by the European Commission of its intention to curtail use of CERs in Phase Three (beginning in 2012) had an almost immediate depressive effect on both carbon prices and exchange activity. This is clearly a manifestation of poor market regulation (Bettelheim & Janetos 2008). A further issue highlighted by the authors is, is that the uncertainty created by repeated political and regulatory interference is a key problem for markets (Bettelheim & Janetos 2008). Under the EU ETS, this interference is further facilitated by 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 & Janetos 2008). Evidence from phase one and phase two so far suggests that such an environment prevents carbon markets from functioning efficiently.

Carbon Price Volatility

According to Poon (2005), volatility refers to the "spread of all likely outcomes of an *uncertain variable*", in this case, price (2005, p.1). 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.

Kruger (2008) looked into some of the general factors that contribute to price volatility and argued 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 one of the research questions addressed here, 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 realise real price discovery. It is unlikely that a market structured like the EU ETS, with a small number of large players being 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 Daskalis 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) used a series of variance ratio tests to find that:

> "For the sample periods 27 June 2005 to 28 December 2007 (Phase I) and 26 February 2008 to 4 April 2009 (Phase II) the EMH is tested through variance-ratio tests while adjusting for thin trading. The results show that the EU ETS was inefficient during Phase I but efficient during the first period of Phase II. This suggests that the carbon market shows the first signs of maturation after the learning and trial period of Phase I (Montagnoli & de Vries, p.6)."

However, they are aware of the problems created by this trading and advise "some caution in the interpretation of the results" (p.5). Their published information on trading volumes certainly raises questions about the study and the use of non-parametric statistics is an interesting departure from the earlier studies.

Though the carbon market is clearly still at a pilot stage of development, there is evidence to suggest that the carbon permit market is starting to show some signs of efficiency as a centre of price discovery and dissemination and that in the near future it is likely to grow in size and scope of complexity (Bettelheim & Janetos 2010).

Factors that Affect the Price of Carbon

The paper aims to present a picture as to what factors influence 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_2 emissions, gas, oil and coal prices, and weather conditions (indicated by temperature) in the UK, Germany, France and Italy; as well as conduct a cross-sectional analysis of movements in 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_2 markets. Official EU data published in May 2006, when the carbon price halved overnight, showed that a group of countries, including large polluters such as Germany, were left with 44.1 million tonnes of extra CO_2 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) emphasises 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).

Convery and Redmond (2007, p.88) argued that “in the case of climate change and other environmental challenges, the market will not produce the ‘right’ carbon price”. The authors refer this to “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 & Redmond 2007, p.88). Nevertheless, “in regard to climate change, none of these conditions has applied” (Convery & 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”.

Point Carbon and Chicago Climate Exchange (2004) along with 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 here. 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 the winter of 2005/06 was very cold and led to a clear increase in energy requirements. Effectively, weather (temperatures) can affect the price of carbon due to its impact on the demand for, and supply of, electricity.

However, an analysis of the carbon market between December 1, 2004 and July 31, 2006 by Redmond and Convery (2006) revealed 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. 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.

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.

Empirical Analysis of Price Determinants

In this paper, empirical testing is conducted to determine 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[2] and covering four European countries, France, Germany, Italy and the UK. Hence, this paper 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. Appendix 1 plots movements in the price of carbon permits, natural gas, oil and coal, as well as fluctuations in temperature and changes in GDP.

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 1 below lists CO_2 emissions due to human activity for the four countries. According to the United Nations Statistics Division (2010), as illustrated in ***Figure 1,*** in 2007 France, Germany, Italy and the UK were the largest European carbon polluters, with Germany (787,936 MCO_2) being the biggest CO_2 emitter, followed by the UK (539,617 MCO_2), Italy (456,428 MCO_2) and France (371,757 MCO_2), respectively. Together, the four countries emit 55.03% of Europe's CO_2 emissions and 7.35% of the world total.

Table 1

Countries by CO_2 Emissions Due to Human Activity (2007)

Country	**Annual CO_2 emissions** (in thousands of metric tons)	**Percentage of Europe's total CO_2 emissions**	**Percentage of the world total CO_2 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)

Besides being Europe's four largest emitters, France, Germany, Italy, and the UK also had the highest GDP (current $US)[3] during the time frame covering 2005-2008, with Germany having the greatest GDP, followed by the UK, France and Italy, accordingly. Together, the four countries contribute around 60% to the EU aggregate GDP. Figure 1 further illustrates the individual contribution of each of the four countries to Europe's overall GDP between 2005 and 2008.

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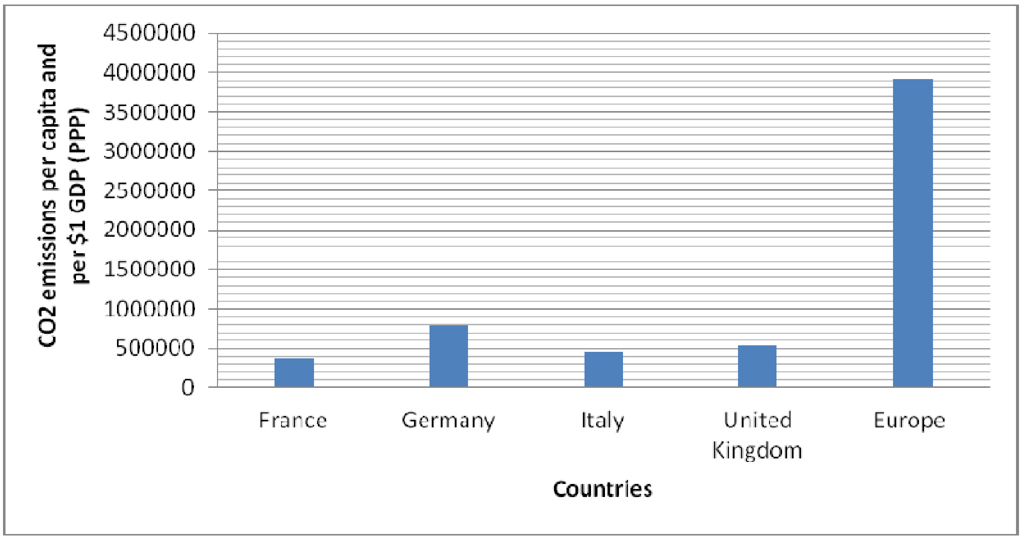
[2] The EU ETS officially commenced in January 2005. However, because no trading occurred on ECX prior to 9 January 2006, the time series for all variables begins from the latter date and covers a four-year period until 31 December 2009.

[3] 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.

Figure 1
Europe's Four Largest Emitters (2007)



Source: United Nations Statistics Division (2010)

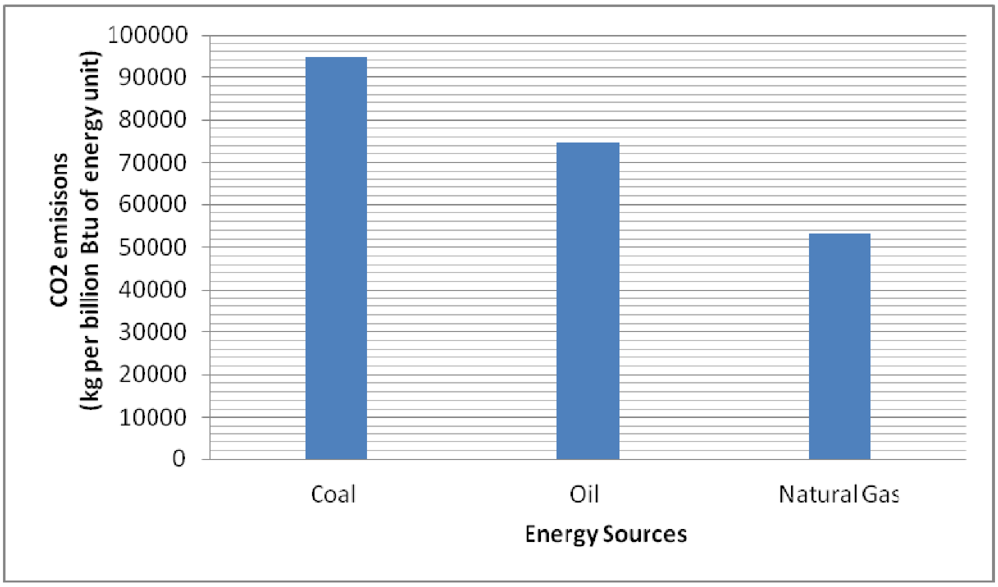
The Price of Carbon

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_2 market, thus making it the leading marketplace for trading carbon dioxide emissions in Europe (ECX 2010a). 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 & Otsubo 2010, p.1). More than 65 leading businesses, including global companies such as ABN AMRO, Barclays, BP, Calyon, E.ON UK, 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

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_2 than oil, and about 45% less than good quality thermal coal (Lustgarten & ProPublica 2008; Naturalgas.org 2010). Figure 2 further illustrates the relative carbon footprint of the three energy sources discussed in the paper. Besides being cleaner, natural gas is also more 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 Appendix 1, 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 negatives (Seeking Alpha 2008). "In December of 2009, the Independent Energy Agency (IEA) stated that by 2030 world natural gas demand will increase from 3TCM[4] in 2007 to 4.3TCM" (Al Fathi 2009), thus signifying a 30% growth rate.

Figure 2
Relative Carbon Footprint of Various Energy Sources



Source: Spaccavento (2009)

Amongst 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). Concerning 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, like 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).

The Price of Oil

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 oil commercially available by 2030, and no oil reserves left at all by 2040, unless adequate alternatives are discovered. There are also theories that the peak of the global oil production may occur in the next 2–3 years. From 2005 to 2008 world crude oil production decreased by 3% (Energy Information Administration [EIA] 2009). According to peak oil theory,

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[4] TCM stands for *trillion cubic meters*

increasing production will lead to a more rapid collapse of production in the future, while decreasing production will lead to a slower decrease. 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 beginning January 2009 (BBC News 2008), This indicates 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. In fact, around 40% of European energy production comes from oil combustion (EIA 2006a).

The Price of Coal

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_2 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 & Barboza 2006). According to the International Energy Agency (EIA 2006a), 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.

Temperature

Temperature is the average of the Mean Temperature for four European capital cities representing each country: France – Paris, Germany – Berlin, Italy – Rome, UK – London[5].

Gross domestic product (GDP)

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. One metric of efficiency is energy intensity. This is a measure of the amount of energy it takes a country to produce a dollar of gross domestic product (EIA 2006b). Figure 3 below shows the ratio between energy usage and GDP for the selected countries, being France, Germany, Italy and the UK and provides a comparison of overall European and world energy consumption.

The GDP figures for our 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 only be approximate estimates.

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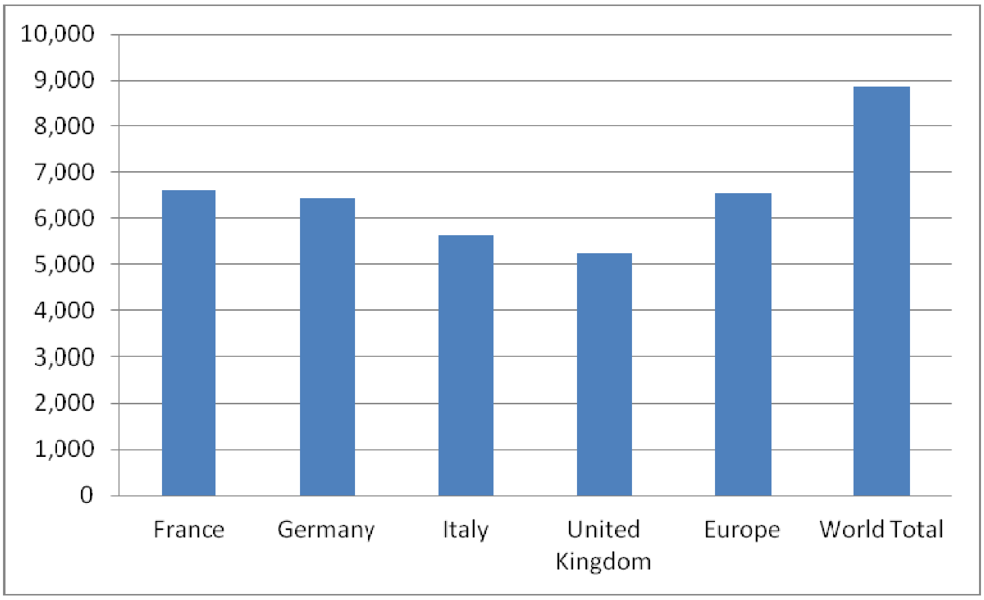
[5] The data on temperature was extracted from the website www.wunderground.com.

Figure 3
World Energy Intensity in 2006

(total primary energy consumption per dollar of GDP using PPP, Btu per (2000) US Dollars)



Source: Energy Information Administration (2006)

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 (Altman 2009; Bernanke 2009; Elstone 2008; Hilsentrath & Paletta 2008; Stewart 2008). Amongst some of the consequences brought by the global financial crisis are 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 & Elliott 2009). As stated by Ivry (2008), “credit markets froze in August 2007 after two hedge funds run by New York-based Bear Stearns Cos., the fifth-largest U.S. 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 term describing the events of 2007-2009 are the *subprime crisis, global credit crisis, liquidity crisis* etc.

Methodology

In order to achieve the 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 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.

Regression

Regression has been used as the main tool for conducting the data analysis. A multiple linear regression has generally been relied on since this study 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. The regression equation used is depicted below. The regression analysis has been conducted with the help of Eviews6 software, using the ordinary least squares method (OLS), in which <10% level of significance would indicate a significant result.

$$\mathit{Ln\ PRICE\ OF\ CARBON}_t = \alpha + \beta_1 \text{ NATURAL GAS}t + \beta_2 \text{ OIL}t + \beta_3 \text{ COAL}t + \\ + \beta_4 \text{ TEMPERATURE}t + \beta 5\text{GDP}t + \mu t$$

Here *t* is year; whereas μ is a dummy variable which controls for the period-specific effects of the global financial crisis (September 2007 –December 2009). 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, Cheek & Ball 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 this paper are expressed in US dollars.

Correlation

The following discussion focuses on the calculation and interpretation of the sample product moment correlation coefficient denoted by *r*. As Table 2 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 fairly positive linear relationship. Stemming from this correlation outcome, it appears that oil and coal should not be incorporated into the same regression equation so as not to distort the results and the underlying data analysis.

Table 2
Correlation Output (based on monthly figures)

	Carbon Price (ln)	**Natural Gas (ln)**	**Oil (ln)**	**Coal (ln)**	**Temperature (ln)**	**GDP growth rate**
Carbon Price (ln)	1					
Natural Gas (ln)	0.6328	1				
Oil (ln)	0.1228	0.1472	1			
Coal (ln)	0.2532	0.3568	0.7147	1		
Temperature (ln)	-0.2180	-0.4770	0.3731	0.1297	1	
GDP growth rate	-0.2065	-0.42956	0.1117	-0.5458	0.1820	1

CORRELATION BETWEEN NATURAL GAS AND CARBON PRICE

According to Roques et al. (2006), there is a high correlation between gas and carbon prices. The authors also note that the winter of 2005/6 saw threats of gas supply disruptions in Europe and very high gas prices, and they 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 and the long-term gas and carbon price trajectories followed similar patterns. Another interesting point brought out by the authors is the fact that most new power plants built in liberalised European electricity markets since the 1990s have been gas-fired power stations (Roques et al., 2006). So from the correlation analysis alone it can be sees that the price of natural gas and the carbon price are interrelated. Concluding, it can be seesn that there is a linear relationship between the price of natural gas and the carbon price.

CORRELATION BETWEEN 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 also points to a very strong correlation between thermal coal and oil prices (ANZ Commodities 2010).

AUTOCORRELATION OR SERIAL CORRELATION

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 that was 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, four regression models (*A, B, C, D*) were run, the quick summary of which is provided in Appendix 2, each adjusted using a Newey-West technique, and each necessarily containing the price of natural gas and the dummy variable.

Discussion and Conclusion

"Energy is central to our lives. We rely on it for transport, for heating and cooling our homes, and running our factories" (EUROPA [the official European Union website] 2010a). Theoretically, the price of fossil fuels is most likely to have a direct impact on 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 a substantial amount of the EU gross electricity generation (57%) was produced by the four countries considered in our study – Germany (19%), France (17%), the UK (12%) and Italy (9%), as stated by Eurostat (2010). 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 (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) that also recognised that the price of natural gas had an influence on the price of permits under the EU ETS.

When examining electricity production by source, it is evident that in 2008 only very little of the EU electricity was produced from petroleum products, essentially oil (3%) (Eurostat 2010). 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 (*C*), at a 95%-confidence-level. However, Redmond and Convery (2006), who examined the effect of changes in the price of oil and gas, found that increases in the price of oil appeared to have the greatest impact on the price of permits. This is inconsistent with the findings of this study, where the price of natural gas was the driving force of changes in the price of carbon.

As mentioned earlier in the paper, coal is the major driver of CO_2 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 (*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 explicitly limits the amount of CO_2 that power generators can emit, thus further decreasing the probability of expanded coal use in EU member countries.

Notably, temperature is significant at a 90%-confidence-level in two (*A and C*) of the four regression models devised. This does not give the authors enough confidence to suggest that weather is a significant driver of the 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) – all found that weather had 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 turn to using heating or cooling devices. Finally, Valor, Meneu & Caselles (2001) have indicated that weather also had a considerable effect on various segments of the economy. In fact, a lot of economic activities are influenced by changes in weather and business revenues may be seriously affected by a deviation from typical weather conditions (Valor et al. 2001).

Interestingly, the level of GDP 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. 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 have had statistical significance (90% and 95%) in two (*B and C*) of the four regression models we have examined. Considering the dampening impact of the GFC on 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 paper 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 market matures.

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Appendices

Appendix 1 – Regression Output Summary

Regression A: *carbon price & natural gas + oil + coal + temperature + GDP + GFC [dummy].* It is quite interesting to report this regression, as it includes all the hypothesised variables, 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 the price of carbon are natural gas*** (0.0000), temperature* (0.0749), and GDP** (0.0123). This regression also suggests that such variables as oil (0.4840) and coal (0.7713) are not the primary determinants of the price of carbon. Interestingly, the GFC [dummy] (0.1108) also seems to be an important determinant of the price of carbon; however, given the 0.05 level of significance, it cannot be considered as statistically significant.

Regression B: *carbon price & natural gas + coal + temperature + GDP + GFC [dummy].* With the number of explanatory variables excluding the constant term [being carbon price] *k'* = 5, this regression equation demonstrates that changes in the price 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 a considerable effect on changes in the price of carbon. Interestingly, temperature (0.1151) also seems to be an important determinant of the price of carbon; however, given the 0.05 level of significance, it cannot be considered as statistically significant.

Regression C: *carbon price & gas + oil + temperature + GDP + GFC [dummy].* With the number of explanatory variables excluding the constant term [being carbon price] *k'* = 5, this regression equation demonstrates that natural gas*** (0.0000), oil** (0.0107), temperature* (0.0662), GDP*** (0.0038) and the GFC** [dummy] (0.0298) – all have a significant impact on the price of carbon.

Regression D: *carbon price & natural gas + oil + GDP + GFC [dummy].* With the number of explanatory variables excluding the constant term [being carbon price] *k'* = 4, this regression shows that the price of carbon is affected by changes in the price of natural gas*** (0.0002) and GDP** (0.0322). Stemming from the results obtained from running this regression model, the price of oil and the GFC [dummy] have no impact on the price of carbon.

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

Notes:

***	0.01
**	0.05
*	0.10
//////	variable not included in the regression model being considered

Appendix 2 – Relationship between Carbon price and Its Hypothesised Drivers