The Economic Geography of European Carbon Market Trading

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Abstract
The European Union Emissions Trading Scheme (EU ETS) is the world's first regional 10 carbon trading market. This article is a quantitative attempt to examine the temporal and spatial geography of European carbon trading. We show that carbon markets are especially sensitive to two factors: staging across time (Phase I versus II of the EU ETS) and across space (energy market structures in Europe). Carbon markets serve as a vehicle to better understand the economic geography of financial markets. Building on the theoretical vocabulary of the geography of finance, the article suggests that certain national factors (market structure) and institutional factors (regulatory phases) better explain how carbon markets operate than company level differences. These findings indicate that geographers have a key role to play in highlighting the local ramifications of carbon markets if and when the world moves towards its ambition for a global carbon market.

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1. Introduction

Climate change has been identified as one of the greatest economic and political challenges facing the world economy this century. The immensity of this challenge is in part due to reconciling the global nature of the problem with the need for action at the sub-global level, whether regional, national and/or local. This problem of collective action is an inherently geographical challenge. It requires coordinating action globally amongst a highly differentiated political, economic and social landscape.

In order to address this challenge, market based policy approaches have been argued to be a crucial part of achieving an international solution. Chief amongst these is the introduction of carbon markets. A carbon market is a market based solution designed to optimise the allocation of capital in the context of a carbon-constrained world by putting a price on carbon and letting the market operate efficiently around this price. This is in contrast to (although typically used in complement with) direct government interventions through, for example, environmental standards or direct investment in technologies where national or local governments make decisions on collective action. The ability of carbon markets to successfully address the collective action problem embedded in the climate challenge is in part contingent on how well carbon markets can be scaled up and inter-linked by governments globally (Grubb, 2009). The introduction of a carbon market within a single country or even region alone is arguably insufficient to create the radical transformations needed to effectively de-carbonize the global economy.

Faith in market based solutions to address global problems extends on the rise of financial markets as key institutions in the allocation and coordination of capital over the last half century. The ability of financial markets to create cross-border infrastructure which enables the allocation of capital for economic goods and services around the globe rapidly and seamlessly has been one of the defining characteristics of modern global economic development. Schmitter (1997) has argued that this may have shifted the locale of international economic integration away from national polities towards new institutional actors as the agents of international economic change. However, this issue remains an open question which economic geographers have sought to address in a number of areas within the economy including industrial relations, corporate governance, training systems and financial markets (Christopherson, 2002; Clark and Wójcik, 2007; Dunford, 2005; Wójcik, 2002). Clark and Wójcik (2007), for example, have argued that the notion of seamlessly operating global financial markets must be understood in the context of spatial and temporal specificity about the way capital flows within these markets.

The article turns the lens of economic geography on one of the emerging economic challenges of our time: the development of inter-linked carbon markets to address global climate change. Knox-Hayes (2009b) has examined the importance of complementarities in developing new global markets for carbon-linked products out of the existing financial market structures in New York and London. While Knox-Hayes' (2009b; 2009c) work examines the institutional setting to foster a nascent carbon market, it leaves open an examination into the economic impact of these new carbon-linked products on the underlying economies where carbon markets operate.

The article addresses this gap by empirically examining the operation of the European Union Emissions Trading Scheme (EU ETS) – the world's first regional carbon market. We examine how this carbon market impacted the stock performance of European energy utility companies, taking into account geographical dimensions of time and space. With respect to differentiation across time, we empirically examine whether investors responded to the operation of carbon markets differently for Phase I (2005-2007) compared to Phase II (2008-

2012). These two phases represent two distinct periods in the operation of the EU ETS in terms of regulatory and institutional structure. With respect to differentiation across space, we empirically examine whether the location of the majority of a company's installed capacity influenced the financial impact of carbon trading on that company.

The article contributes to the emergent carbon market literature as one of the first quantitative empirical the articles on the economic geography of carbon market trading. The importance of the time dimension through the phasing-in of carbon markets across distinctive regulatory blocks makes intuitive sense from a theoretical and policy perspective but has been empirically under-examined econometrically. Additionally, by using individual company data rather than pooling corporate data, we are able to draw conclusions albeit tentatively about the role of location and geography in the financial impact of carbon trading. Although the relatively limited amount of traded financial data for carbon markets restricts the depth and breadth of our findings, they leave scope for follow-up study as carbon markets develop to maturity in Europe and elsewhere.

The structure of the article is as follows: section 2 sets up the economic and policy context of carbon markets in Europe. Section 3 then ties these broader issues to a theoretical framework for research on the economic geography of European carbon markets. Section 4 presents the data used to empirically examine the effect of economic geography and market structures on carbon market operation and section 5 sets out the methodology used. Section 6 then discusses these results and section 7 concludes by drawing the potential implications of the findings for economic geography and policy makers addressing climate change.

2. Carbon markets in context

As the science of climate change places pressure on governments to urgently decarbonize the global economy, policy makers have turned to market based solutions to reduce the carbon intensity of the economy. Carbon markets have been promoted as a crucial policy intervention for addressing climate change, of which the cap and trade system is the most prevalent (Hasselknippe, 2003).

Under a cap and trade carbon market, companies within a national jurisdiction are given a limit (cap) on the volume of carbon emissions or their equivalent which they are allowed to emit annually. If they exceed this limit then they are legally obliged to purchase carbon emission allowances to offset their pollution. Each allowance purchased represents a volume of carbon emissions or their equivalent abated (one tonne per an allowance) from various approved projects. The cost of allowances is intended to act as a financial disincentive for carbon pollution.

The caps set for companies under the EU ETS regulation differ for Phase I compared to Phase II. This means that although the carbon market continues to trade year on year, Phase I and Phase II are institutionally distinctive. The policy intention behind this is to phase-in the financial impact of carbon gradually over time. Although the caps during Phase I were quite lenient, Phase II (and then Phase III, and so forth) are intended represent increasingly arduous carbon caps (Hepburn et al., 2006). This adds a time dimension to the operation of the EU ETS.

The price of carbon allowances is determined by the market price settled daily by participants in a financial market specifically for carbon emission allowances. During Phase I of the EU ETS, European carbon emissions allowances (EUAs) were traded on a number of platforms across Europe including London, Leipzig, Oslo, and Paris at a single arbitrage-free price (Daskalakis et al., 2009). Although the trading platforms are located within Europe, the financial intermediation involved in originating and trading carbon emissions allowances spawns an increasingly global financial network of bankers, lawyers, and project developers around the world (Knox-Hayes, 2009a; Knox-Hayes, 2009c). An emerging strand of literature in the economic geography of carbon markets examines the geography of the professional services market itself. Knox-Hayes (2009a) argues that the clustering of professional expertise in London and New York reflects the way in which the carbon market has emerged in complementarity with conventional capital markets. This clustering also suggests the potential for these cities to become hubs for new financial and technological innovation (Wójcik 2009).

While the financial infrastructure of carbon markets may be globally integrated, the question of whether the economic impact of carbon markets is geographically differentiated remains open and is the focus of the article. The relevance of economic geography for carbon market operation has important policy implications. If some economies are more negatively affected by the price of carbon compared to neighbouring economies then this may be grounds for increased government support for research and development investment in alternative technologies. Geographical differentiation may also impact multilateral negotiations to introduce a regional carbon market because governments will act in their self-interest to avoid the comparative disadvantage of their economies.

The relevance of economic geography in modern economic development has been developed in the varieties-of-capitalism literature which has emerged over the last decade and a half to offer a more delineated view on the contours of modern economic development. A key theoretical challenge in this literature has been to diagnose an appropriate analytical unit for examining economic variety (Peck and Theodore, 2007). While Soskice (1990; 1991) has argued for the on-going relevance of the nation as a constructive influence in the behaviour of firms and institutions in the presence of global economic forces, Hollingsworth and Boyer (1997) have argued that individual institutions have increasingly become nodes for economic coordination in their own right. This debate remains robust in the study of macro economies (Crouch, 2005; Hall and Soskice, 2001; Hollingsworth and Boyer, 1997), but it is still relatively unexplored within some sub-sections of the economy such as the development of carbon markets.

In order to examine the relevance of geography in the context of carbon market development, the article draws on the nation versus institution distinction within the varieties-of-capitalism literature and applies empirical methodologies from economic geography to examine the effect of geography on carbon market operation.[1] Clark and Wójcik (2007) have offered some direction on empirical approaches to examining the geography of finance.

One approach has been to map the flow and trade of capital around the world. This approach offers a complex topography of global finance, illustrating where capital pools and from where it runs away (Clark, 2005). A second approach has been to examine the role and significance of borders in affecting financial market operations. La Porta et al. (2002) made a seminal contribution to this inquiry by mapping differences in corporate governance regimes based on distinctive legal traditions. They showed that border distinctions remained deeply embedded in the functioning and structure of financial markets, with common law (such as Anglo-American) countries exercising different corporate governance structures to civil law (such as continental European) countries. A third approach has been to examine the spatial and temporal heterogeneity of information (Clark and O'Connor, 1997). This draws on the previous two approaches by examining how information and local knowledge can flow across borders in financial markets. Recent research in this area has mapped out the flow of

[1] The importance of methodological innovation between economic geography and the varieties-of-capitalism literature has been underscored by Peck and Theodore (2007).

publicly traded market data (Bauer et al., 2008; Gompers et al., 2003) in order to highlight the corporate governance geography identified in La Porta et al. (2002).

The article builds on the logic of the second and third approaches to economic geography by developing a new geographical lens to investigate the impact of carbon markets on the corporate performance of companies. We use as our measure of economic performance the quoted stock price of publicly traded energy companies.[2] These prices reflect investors' long-term assessments of the valuation of these companies taking into account all presently available information. With reference to economic geographic markers of space and time, we rely on information about the differences between Phase I and Phase II of the EU ETS to examine the impact of timing on investors' perceptions of carbon market operations. For location, we examine the role of market structure and company level characteristics as an explanatory variable for the financial impact of carbon markets. These are explained in greater detail in the following section.

3. Theoretical framework

According to economic theory, putting a price on carbon should impact the financial performance of companies obligated to purchase carbon emission allowances. However, the nature of this impact – whether it has a positive or negative effect on a company's cash flows – depends on whether a company bears the ultimate cost of carbon directly or whether it is able to pass it through to customers (Smale et al., 2006).

If a company is forced to bear the cost internally then we would expect to see a negative relationship between the carbon price and the company's traded stock price. However, if a company can pass the cost through to consumers, then the financial cost borne by the company is neutral (Sijm et al., 2006). In some cases, a company may pass on more than 100% of the carbon cost it incurs thereby profiteering from the carbon scheme. This would result in a positive relationship between carbon price and stock price.

In the econometric model set out in section 4 we empirically examine the sign and significance of the relationship between carbon pricing and European electricity stock prices. We examine the time dimension by comparing the spot prices for emissions allowances which are traded for compliance in Phase I of the EU ETS with future prices which are traded for compliance in Phase II of the EU ETS. Although traded concurrently, these products are linked to two distinct phases in the deployment of carbon markets and therefore provide an opportunity to examine how investors respond to the staging of carbon markets. We would expect to see different relationships emerging between stock prices, and spot and future carbon prices respectively.

However, we are interested in examining whether there is a latent geographical effect which explains differences in the way stock prices respond to carbon prices. The first hypothesis we develop (hypothesis one) posits that the energy market structure into which a company sells its electricity affects the way in which carbon liabilities impact cash flows and, by extension, stock price.

The reason why energy market structure might affect cash flows is because it impacts the ability of companies to pass the marginal cost of purchasing emissions allowances through to customers in the form of higher electricity prices. According to economic theory, Bonacina and Gulli (2007) argue that companies selling electricity into a purely competitive energy market ($N = \infty$) sell electricity at a the marginal cost of production: that is, the full cost of carbon is passed through to customers in the short-run. This means that rising carbon

[2] For alternative measures of economic performance in the context of carbon trading see (Anger and Oberndorfer, 2008; Demailly and Quirion, 2007; Zachmann and Von Hirschhausen, 2008).

prices will have a neutral impact on a company's balance sheet. Over the long-run, however, the increased price of electricity will result in reduced demand and a new equilibrium price will be set in which firms with the best technology will be able to profit. This will result in different firms having a mixture of a neutral or negative impact on their balance sheets from carbon liabilities depending on how well they have been able to adapt to changing market conditions.

At the opposite extreme, companies which sell into a monopolistic energy market structure (N = 1) are able to manipulate prices more easily. They are therefore able to either pass as much of the cost of carbon as they wish: most likely 100% or more than 100%. This will result in either a neutral or positive impact on cash flows from carbon prices in the short-term. In the long-run, however, even monopolistic firms will be required to respond to declining demand for electricity due to increased prices.

In practice, most European electricity market structures are oligopolies falling between these two extreme positions. In order to characterise the energy market structure within which our sample companies operate we used national borders as our unit of analysis. This is not an ideal assumption as the characteristics which define energy market structures are not always limited to national borders. Nevertheless, the highly nationally regulated nature of electricity markets in the EU as well as the concentrated ownership of electricity utilities in Europe where a number of companies own and operate a majority of their installed capacity within a single country suggests that country borders may be a suitable unit of analysis for the European energy market.

A second hypothesis (hypothesis two) which explains differences in the way stock prices respond to carbon prices posits that individual characteristics of energy companies influence investors' perception of corporate valuation. This hypothesis may exist in complement to hypothesis one.

The first aspect to this is the amount of free carbon emission allowances allocated to firms during Phase I of the EU ETS (Neuhoff et al., 2006; Smale et al., 2006). When companies were allocated free allowances, each free allowance offset the financial liability borne by that company when it purchased carbon emission allowances. The ratio of free allowances to amount obligated to purchase was different for each company but in theory this was not related to the country where the firm is located (Kettner et al., 2008).[3] We would expect that where the ratio is close to 1 then the impact on carbon liabilities on company balance sheets would be neutral whereas where the ratio is close to 0 then the impact is more likely to be negative.

The second aspect to hypothesis two is the carbon intensity of a company's electricity generation process. This may impact the financial cost of carbon for electricity utilities because companies which have more carbon intensive processes will be required to purchase more carbon emission allowances for each unit of electricity generated compared to their less carbon-intensive peers (Veith et al., 2009). Therefore the balance sheets of carbon intensive companies are morel likely to be negatively impacted by rising carbon prices than less carbon intensive companies.

Carbon intensity may be defined in two different ways. One definition of carbon intensity is the "capacity-weighted carbon intensity". This is the ratio of carbon emissions to generation capacity (kg/MWh) (Veith et al., 2009). In theory, companies which emit more carbon per a unit of electricity generated, such as coal-fired power stations, will have higher ratios then low carbon intensive companies, such as nuclear or renewable power stations. A second definition of carbon intensity is the turnover-weighted emission rate ("turnover

[3] In some extreme cases, companies received more free allowances than the number of carbon emissions they were obligated to purchase.

carbon intensity”). This is the ratio of carbon emissions to total turnover or revenues (tonnes/million USD) in the company.[4] An advantage of this definition is that it translates carbon emissions into a financial ratio which compares a company's sales to its direct financial liability in meeting its carbon compliance obligations.

In sum, our theoretical framework is intended to examine how time and space influences investors' valuation of carbon pricing on company returns. Differences across time would be exhibited by a statistically differentiated relationship to carbon pricing across Phase I (reflected in carbon spot prices) and Phase II (reflected in carbon future prices). Our theoretical framework then takes this analysis further by testing two hypotheses to explain what drives the increment to stock returns from carbon returns. Hypothesis one on market structure suggests that companies in more competitive energy market structures would experience a negative or neutral relationship with rising carbon prices whereas more monopolised market structures are more conducive to neutral or positive relationships. In hypothesis two we would expect companies with close to full free allocation to have a neutral financial impact for the cost of carbon, and companies with high carbon intensive processes to have a negative financial relationship with rising carbon prices compared to their less carbon intensive competitors.

4. Data and Descriptive Statistics

To examine the impact of economic geography on the operation of the European carbon markets, we take an empirical approach by building a time series econometric model using traded carbon data and the logarithmic daily stock returns of European energy companies from *Datastream*.

The European energy utility companies used in our sample are chosen by compiling a list of all publicly traded companies involved in electricity generation in Europe within the EU-25[5]. We then eliminated companies for whom there was a lack of information for the whole period. Because we are interested in examining market structure as delineated by national borders, we also eliminated companies which had less than 50% of their installed and operational capacity within a single country. Focussing on firms where the majority of installed capacity is within a single country is a proxy for studying national level effects sand represents a compromise, albeit imperfect, between larger sample size (by including companies with more geographically dispersed capacity) with degree of national embedded-ness. The resulting sample size of 19 companies was comparable to similar studies in the literature (Oberndorfer, 2009; Veith et al., 2009). However, unlike the econometric approach taken in Oberndorfer (2009) we do not pool the company data in our model. This enables a more differentiated approach to company and country level effects between carbon and stock pricing than in this approach.

To examine the price of carbon for spot trades we use the Bluenext (previously Powernext) EUA spot price (*P* in Euros/ton of CO_2e) between 24 June 2005 to 31 December 2007. This price series reflects the cost of carbon emission allowances purchased to meet regulatory commitments during Phase I of the EU ETS. For future trades in compliance with Phase II of the EU ETS we use the ECX future EUA carbon price between 22 April 2005 and

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[4] This definition is used by a number of private sector environmental consulting firms, including Trucost. Trucost is a private consulting company which collects company information from annual reports and aggregates this data in a proprietary database. Although the database is reliable and is used in the article, the relevance of the carbon intensity measure adopted by Trucost is open to debate. For this reason, the article uses alternative metrics for measuring carbon intensity in addition to the Trucost metric.

[5] The expansion of the EU to include Romania and Bulgaria (EU-27) only took place on 1 January 2007 so data from companies in these countries is limited to after that date.

31 December 2007. Comparing the relationship between stock prices and these two carbon price series respectively elucidates investors' perception of the two different phases of the carbon market. This facilitates an examination of how time features in the economic geography of carbon market operation.

In order to control for the effect of other influences on the stock returns of the sample companies, we used a number of control variables in order to make sure our econometric model is well specified. In accordance with the literature, we use the logarithmic daily returns of the one month forward prices of Brent Crude oil (Euros per barrel) and of natural gas from Intercontinentalexchange (ICE, London; Euros per 100 000 British Thermal Units) which controls for energy price fluctuations. Energy price fluctuations are statistically significantly correlated with electricity prices and by extension energy utility stock return. They are used in the literature for financial models to explain stock returns in the energy sector (El-Sharif et al., 2005). We also used large cap national market indices for each of the countries in our sample to control for domestic market effects such as economic or political news events. The choice of the appropriate index for each country was made based on whether the index had a broad industrial base and was exclusively composed of nationally listed stocks in order to capture idiosyncratic national economy factors. These indices are described in details in Appendix B. Where it was necessary to make currency conversions, the historical exchange rates recorded by the European Central Bank were used.

In order to example the effect of market structure and individual company characteristics as described in the theoretical framework in section 3, data was collected from a number of sources. Data on the carbon intensity of sample companies was collected from Trucost and from the publicly disclosed data in annual reports, as recorded on the Carbon Disclosure Project database.[6] These descriptive statistics are reported in Table 1.

[Insert Table 1]

Providing data to reflect the market structure of the European energy sector was more challenging. In economics, a traditional measure of market structure within a country is the Lerner Index (Lerner, 1934). However, due to insufficient publicly available data to calculate the Lerner Index in the countries in our sample, we considered market concentration measures as a proxy for national market structure characteristics. The CR4 ratio sums the market share of the four largest companies within a market. Typically, low CR4 reflects low levels of concentrated ownership in the market consistent with competitive market structures. CR4 of around 40% reflect competitive markets with low concentration, CR4 around 60% reflect oligopolies with moderate levels of ownership concentration, and monopolies have CR4 close to 100% with high levels of ownership concentration (Webster, 2003). The results of the four company concentration ratio (CR4) were calculated using (Domanico, 2007) and are recorded in Table 2.

[Insert table 2]

In order to improve the robustness of our market structure characterisation, we cross-check our CR4 rations with the Herfindahl-Hirschman Index (HHI) measure of market structure. This is also reported in Table 2 and is calculated as:

6 The Carbon Disclosure Project is a voluntary initiative to encourage companies to publicly disclose their environmental consumption data.

$$HHI = \sum_{n=1}^{n} s_i^2 < 1$$

where s_i is the market share of firm i in the market, and N is the number of firms. The index ranges between 0 and 1. Generally, if the HHI is below 0.1 the market is not concentrated, if it is between 0.1 and 0.18 it is moderately concentrated, and if the HHI is over 0.18 the market is regarded as concentrated (Webster, 2003). The HHI measures for the EU countries examined in the article are reported in Table 2 using data in Sijm et al. (2008).

The final characterisation of market structure relied upon in our model is an aggregate of both the CR4 and HHI measures and is reported in the last column of Table 2. As reported, there is a strong level of correlation between the CR4 and HHI measures for market structure even though these are calculated independently. This strengthens the reliability of our characterisations. Where low levels of ownership concentration are reflected in both the CR4 and HHI measures, we describe the market structure as competitive. We find that the most competitive energy markets are those in UK and Finland. By contrast where the CR4 and HHI both reflect high levels of concentration then we describe the market as monopolistic. Greece and France have more monopolised energy market structures because they each have a single dominant player which has dominant market share. Where concentration levels fall between these two poles or where the two measures suggest that the levels of ownership concentration are mixed (both moderate and high levels of concentration), we describe these markets as oligopolies. We find that the European energy markets of Germany, Spain, Italy, Portugal, and Austria fall within this category because they have a small number of firms which control a relatively large ownership stake.

5. Methodology

To investigate the effects of carbon returns on energy company stock returns, a two stage approach is followed. In the first stage, we estimate an expanded Capital Asset Pricing Model (CAPM) using OLS, while correcting for heteroskedasticity (White, 1980). The standard CAPM approach used in the econometric literature includes overall market returns as an explanatory variable for stock returns over time (Lintner, 1965; Sharpe, 1964). However, because we are interested in energy stock returns and the impact of carbon returns in particular under an efficient capital market assumption, we expand the standard CAPM to include oil, gas and carbon prices as control variables in the estimated equations. This is consistent with the literature on energy stock prices and is intended to avoid misspecification of the econometric approach (Boyer and Filion, 2007; Oberndorfer, 2009). The resulting first stage model is as follows:

$$R_{it} = \alpha_i + \gamma_{0i} R_{index,t} + \gamma_{1i} R_{carbon,t} + \gamma_{2i} R_{gas,t} + \gamma_{3i} R_{oil,t} + \varepsilon_t \qquad (1)$$

where R_{it} represents the logarithmic daily returns on company i . $R_{index,t}$ is the logarithmic daily return on the national stock market index and $R_{carbon,t}$ is the logarithmic daily return on the carbon price (spot; future). $R_{gas,t}$ represents the logarithmic daily return on the (one month) forward gas price, and $R_{oil,t}$ represents the logarithmic daily return on the (one month) forward oil price.

Two separate models are estimated for R_{carbon} using the carbon spot price and the carbon future price series respectively. This is to compare investors' different reactions to Phase I and Phase II of the EU ETS. In April 2006, the spot price of carbon crashed when it was revealed that there had been an over-allocation of free carbon allowances. As a result, a structural break (Chow, 1960) is used to break the model into two sub periods: 22 April 2005 – 24 April 2006 and 28 April 2006 to 31 December 2007. The results of the sub-period model are reported alongside the full period results. The carbon future price was unaffected by the over-allocation, but a similar structural break as been estimated for consistency. A positive coefficient for carbon returns can be interpreted as carbon returns moving in the same direction as a company's stock returns. This is consistent with the hypothesis that companies were able to profiteer from the carbon market. A negative relationship suggests that companies bear the cost of carbon internally.

While this first stage analysis is useful in understanding the direction of the relationship between carbon returns and stock returns, it does not indicate what factors motivate the increment to energy stock returns caused by carbon returns. In our theoretical model above we hypothesise why either country-level or company-level factors might explain this relationship. In order to examine these empirically a second stage analysis is undertaken. This second stage approach is an improvement on the methodology used in Veith et al. (2009) where dummy variables are used in the first stage OLS regression to account for various explanatory variables. By using individual firm and country level data we are able to examine underlying geographical and company-level trends in a more targeted and detailed manner than a cruder, dummy variable approach.

In the second stage analysis, the coefficient generated in equation (1) for the elasticity of carbon returns is regressed on data regarding the market structure for each company (Hanushek, 1974).[7] This model is estimated using generalized least-squares, incorporating the variance-covariance matrix of the parameters estimated in equations (1). It is represented by equation (2) below:

$$\hat{\gamma}_{1i} = \alpha_i + \eta_i M_i + \varepsilon_i \tag{2}$$

where M_i represents the market structure of the country where the company operates. The dependent variable in each case, $\hat{\gamma}_{1i}$, is estimated separately for carbon spot returns and carbon future returns respectively. To contrast the effect of market structure on stock returns with individual company (institutional) features, three variations on this model are estimated. In the first instance, the model in equation 2(a) is estimated:

$$\hat{\gamma}_{1i} = \alpha_i + \beta_{1i} M_i + \beta_{2i} FA_i + \varepsilon_i \tag{2a}$$

where FA_i represents the ratio of free carbon allowances given to the company during Phase I of the EU ETS. This examines the effect of free carbon allowances issued to each company as a decisive factor in stock returns compared to market structure. A second variation is equation 2(b):

[7] Following Hanushek (1974), this procedure is often used in the environmental economics literature, see for example Eichholtz et al. (forthcoming).

$$\hat{\gamma}_{1i} = \alpha_i + \varphi_{1i} M_i + \varphi_{2i} CTI_i + \varepsilon_i \qquad (2b)$$

where CTI_i represents the log of the carbon intensity of the company's turnover. This examines the effect of carbon intensity of each USD of turnover for each company in the sale compared to market structure. Finally equation 2 (c) is estimated:

$$\hat{\gamma}_{1i} = \alpha_i + \delta_{1i} M_i + \delta_{2i} CI_i + \varepsilon_i \qquad (2c)$$

where, CI_i represents the capacity weighted carbon intensity of the company's production process. This examines the effect of the carbon intensity of each company's technology as compared to market structure as an explanation for the financial impact of carbon markets on stock returns.

6. Results & Discussion

From the results of the first stage analysis reported in Table 3 we can see that carbon returns did impact the quoted stock returns of energy utility companies under the EU ETS. This relationship is not uniform and differs in size and statistical significance across companies in our sample.

[Insert Table 3]

The presence of a statistically significant relationship between carbon and stock returns for some companies at 5% confidence levels indicates that investors are responsive to carbon pricing in corporate valuation. However, in all cases the sign of this statistically significant coefficient is positive. This is interpreted as stock returns moving in the same direction carbon returns: as carbon returns rise so too do energy stock returns. A positive and statistically significant relationship is consistent with the view that a number of energy stocks were able to profit from the introduction of a carbon market in Europe by passing on more than the cost of purchasing carbon allowances. As the price of these allowances increased then these companies were able to sell these allowances as a windfall profit. From a policy perspective, this is problematic as it indicates that investors did not believe that the carbon market was a financial deterrent for energy utility companies emitting carbon. This means these companies had little or nor incentive to invest in new technology and innovation to reduce their future carbon emissions.

Comparing the number of statistically significant relationships for the carbon spot with carbon future price series it appears that investors were able to respond to the staging of the carbon market across time. The time dimension features in the significance of carbon markets on financial performance in two respects. Firstly, for emissions traded for compliance during Phase I of the EU ETS, we observe 6 out of 19 companies in our sample exhibit a statistically significant (positive) relationship between 22 April 2005 and 24 April 2006. However, after April 2006 carbon returns no longer exerted any significance on stock returns. This is what we would expect because the carbon spot price crashed towards zero when it was revealed that there was an excess of free allowances and therefore no demand for emission allowances. Investors' responsiveness to this announcement indicates that investors are responsive to news about carbon markets in their stock pricing and are efficient in factoring in sudden political events which change the trajectory of the carbon market.

The second way in which time is relevant is in the differentiation between Phase I and Phase II of the EU ETS. For Phase I, only 6 of 9 companies demonstrated any statistically significant reaction to the carbon markets and these were all clustered in the period to April 2006. However for Phase II there are statistically significant responses to the carbon market both before and after April 2006 as well as for the period as a whole. This means that investors were able to distinguish between the two stages of the carbon market and realize that these were two phases were differentiated. This is a promising policy outcome because it suggests that phasing in the introduction of a carbon markets can work. It also indicates that institutional factors – namely the regulatory construction of phases of the carbon market – are an important factor in explaining the economic behaviour of this new financial market. Investors are able to distinguish between the two phases and respond to the price of carbon according. In this sense, timing is an important factor in the way carbon markets influence equity pricing.

An important qualification which should be made is that the size of the coefficients reported is small. Therefore although these coefficients are positive they are also relatively close to zero with a range between 0.021 and 0.082. This means that the level of profiteering should not be overstated and in most cases the impact of other factors such as movements in the national indices or energy prices is relatively more important than carbon. Nevertheless, as carbon markets build momentum and grow beyond their current nascent stages, these coefficients may be expected to reverse sign and grow in magnitude.

In many instances, carbon pricing had no statistically significant impact on stock returns. Indeed 11 of the 19 companies in our sample demonstrated no relationship with carbon pricing in either the spot or future markets. This is also problematic from a policy perspective but is not entirely surprising. Indeed, the fact that the quantities of carbon allowances required to be purchased were so small may mean that investors simply did not think that carbon was relevant to a company's cash flow in many cases. Nevertheless, the fact that there is a difference between some companies where there is a significant relationship to carbon and some companies where there is not suggests that investors are aware of a carbon price and are relatively efficient in working out when carbon matters and when it does not. One extrapolation from this is that if carbon markets were developed to impose a stronger financial deterrent on pollution, then investors may be efficient in picking this up and responding to their corporate valuations accordingly.

In order to extend the analysis of these results beyond the relationship between carbon returns and stock returns across the Phase I and Phase II time periods, we undertake second stage regressions to examine the role of market structure and individual company characteristics in driving the financial significance of carbon. These results are reported separately for Phase I and Phase II with carbon spot returns (Phase I) reported in Table 4 and carbon future returns (Phase II) reported in Table 5. This distinction is intended to capture differences across time in the economic geography carbon market operation.

[Insert Table 4]

[Insert Table 5]

Turning first to carbon market operation during Phase I of the EU ETS, the results in Table 4 indicate that investors believe market structure is a strong driver behind the financial impact of carbon for energy stock valuations. Given that market structure is defined in the article by national borders, this suggests that national differences do influence the performance of an inter-national (regional) carbon market. Model (1) which reflects the regression output for equation 2 above indicates that market structure was statistically significant at 5% levels of confidence before 24 April 2006 but not afterwards. This is consistent with the results reported in the first stage regressions in Table 3 above and shows that investors are responsive to sudden, structural changes in the carbon market. Announcements made in April 2006 which resulted in the carbon spot price crash flowed through to the equities price valuations for energy stocks. The conclusion which can be drawn from this is that carbon markets do not operate in a vacuum but rather are a live feed into the functioning and operation of modern capital markets and the economy more generally. Notwithstanding the doubts identified above about the policy effectiveness of carbon markets in achieving the desired re-allocation of resources, investors do take carbon price information seriously and factor it into their pricing decisions.

The coefficient for market structure in model (1) is reported as -0.032. The interpretation of the negative sign here is that although market structures play an important role, the characterisation of this role is contrary to our hypothesis one. Hypothesis one posits that as companies move towards open and competitive market structures from closed and monopolistic structures, then the level of price manipulation decreases and therefore there is less profiteering from carbon pricing. However, a negative coefficient suggests the reverse is happening: that as companies move towards a competitive energy market there is a stronger, positive correlation between stock returns and carbon returns.

This result is highly paradoxical and difficult to explain. It is not at all clear why companies operating in more monopolised energy markets should experience less profiteering and price manipulation as a result of carbon market operations. One possible explanation for this might be that these results reflect the particular political environment in European energy markets in which governments with near-monopoly energy markets have pre-emptively acted to stop profiteering by regulating electricity pricing. There are numerous examples in Europe where these governments have regulated electricity prices often explicitly excluding carbon costs in the setting of electricity pricing. This creates a paradoxical situation in which near-monopoly energy markets in fact have less price manipulation around energy pricing than oligopolistic energy markets like Germany, the UK and Finland. Although these latter markets are more ‘open’ on the market structure spectrum, they still fall short of perfect competition because larger players are able to exert more force on the pricing of electricity.

There is some empirical evidence to support this explanation of the counter-intuitive results reported. In Greece, for example, which is reported in Table 2 as having the most monopolistic energy market structure in our sample, electricity prices are set by the Ministry of Development with advice from the Regulatory Authority for Energy (Iliadou, 2008; RAE, 2007). According to Law 2773/1999, so long as the Public Power Corporation (Greece’s monopoly energy company) continues to hold more than 70% market share, the Ministry sets the price of electricity in the wholesale and retail market on a ‘total cost plus’ basis. This means that although the cost of inflation, energy fuel prices, and other infrastructure costs may be passed through to consumers, the cost of purchasing carbon emission allowances is explicitly prohibited. This regulation clearly creates a situation in which price manipulation over carbon pricing is strictly. If markets for financial information are efficient around the knowledge of this regulation, then investors will correctly assume that there will be no profiting from carbon returns reflected in PPC’s stock price. Indeed, evidence to suggest investors are aware of this information is the investment research advice provided by one leading investment bank which identified this issue for PPC’s projected cash flows (HSBC, 2008). Electricity pricing restrictions and regulation in Europe’s near-monopoly energy markets can also be seen to a lesser extent in France. In France, the government is also solely responsible for electricity pricing upon periodic review rather than the nation’s monopoly entity, EDF, setting prices itself. However, unlike Greece, there is no strict prohibition on carbon cost pass through into electricity prices in France.

The possible higher prevalence of price manipulation in Europe's more open energy oligopolies has come to media attention in Germany, which is one of the more competitive energy markets in our sample. In December 2006, RWE (one of the companies in our sample) received a statement from the German Federal Cartel Office accusing it on improper methods in forming wholesale electricity prices for industrial customers. It was accused of passing on more than the full cost of carbon. Although RWE was able to avoid legal suit over this issue through legal settlement (RWE, 2007), our results in Table 3 show that RWE is a firm which exhibited a statistically significant positive relationship between carbon returns and stock returns.

These facts do not provide a comprehensive picture for why our results suggest that companies in oligopolistic energy market structures exhibit a stronger positive increment to their stock returns from rising carbon returns compared to monopolistic market structures. However, the regulation of electricity pricing does offer a possible albeit incomplete explanation for these counter-intuitive findings. Although it is difficult to robustly show empirically, there is a broad trend which can be observed as countries move from closed to open energy market structures in Europe. As countries move in this direction, there is generally less regulation of electricity pricing. A qualitative overview of this trend in electricity pricing regulation is described in more detail in Appendix A. Indeed, despite attempts to liberalise European energy markets through regulation reaching back to the 1990s, empirical evidence shows that opening up energy markets has been slow to follow.[8]

The importance of market structure described here in the Phase I grows in breadth and significance for Phase II as reflected in the second stage analysis for carbon future returns reported in Table 5. Unlike Phase I where the market after April 2006 falls flat, the statistical significance of market structure in driving the impact of carbon pricing remains across the entire second phase of the market. The coefficients are both in the same direction (negative) which suggests that investors thought that companies in our sample operating in oligopolistic energy markets would be more able to grow their stock returns from rising carbon returns.

This result has implications for the importance of time in the economic geography of carbon market operations. The fact that investors treated Phase II differently to Phase I indicates that investors are responsive to the notion of carbon markets as staged markets for compliance. This means that they treat each stage of the carbon market differently according to expectations around the particular institutional and regulatory settings for that market. Carbon markets are therefore more complicated than a single homogenous market for trading carbon but are rather highly differentiated according to the structural characteristics that are attributed to them by governments. This offers some hope for policy makers to isolate the structural mistakes in one phase of the carbon market from future phases in order to enable the proper staging or phasing in of carbon pricing and to control the impact on corporate investment.

The discussion of these results so far has captured the importance of time (staging of carbon markets) and space (market structure) in carbon market operation. However, it might be argued that there are unexplained variables driving these trends such as individual companies' characteristics like free allowances and carbon intensity. In order to examine this issue we build models (2), (3) and (4) in Table 4 and Table 5 to examine each of these factors in turn.

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[8] EU regulations to promote liberalisation of ownership and transmission within the EU include the Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity, O.J. L 27/20; 31.1.1997.

In model (2), we control for the effect of the ratio of free allowances given to firms. Hypothesis two suggests that firms with higher allocations of free allowances proportionate to purchased allowances would profiteer from rising carbon returns. Interestingly, the coefficient for free allocation is not statistically significant for either Phase I or Phase II. At the same time, the coefficient for market structure remains statistically significant for all cases. The conclusion we can draw from this is that the arrangement around electricity pricing and carbon cost pass-through is a much more important driver in investors' minds compared to free allocations when assessing the financial implication of carbon markets. The one exception to this is the over-allocation of free allowances in April 2006 for Phase I. Investors clearly acknowledged this changed the dynamics of the carbon market for that period, although this was an isolated case and did not apply equally to Phase II. The relative importance of market structure over free allocations makes intuitive sense because investors do not have information about the ratio of free allocations at any one time. Because investors do not know a company's carbon emissions until annual reports recording historical emissions are released, we would not expect this information to be reflected in the reactions of investors trading equities in real time.

Extending this analysis in models (3) and (4) to carbon intensity enables us to control for different energy production processes as well as different sized companies because our carbon turnover intensity measure uses turnover as a proxy for size. As we suggest in hypothesis two, firms with low carbon intensive processes might be expected to outperform their more carbon intensive competitors.

Once again, we find no statistical significance of note amongst our reported carbon intensity coefficients. At the same time, market structure prevails as a statistically significant (and negative) explanatory variable for excess carbon-related returns. This is also a surprising outcome and suggests that carbon costs as represented in the amount of carbon emissions allowances to be purchased is not closely correlated with the carbon intensity of companies' production processes. Indeed, data collected on companies' production processes was independent of the carbon market whereas the allocation of carbon allowances under the carbon market is a political process decided upon by national governments. This conclusion is also problematic from a policy perspective as it suggests that the metrics determining the financial implications of carbon markets are not based around the underlying carbon-intensity of production processes (and by extension the environmental credentials of various energy generating technologies) but rather other factors such as politics. A further explanation of the politics and economics around carbon allowance allocation deserves further examination beyond the current article.

7. Implications & Conclusion

The emergence of carbon markets offers a new vehicle through which to consider the economic geography of modern financial markets. The theoretical challenge in the literature on modern economic development since Soskice (1990; 1991) and Hollingsworth and Boyer (1997) has been to identify an appropriate unit of analysis to examine economic variety. This has varied from the relevance of national borders to the role firms and institutions play in shaping economic behaviour.

In the article, we find evidence that both institutional factors (in this case, the staging of carbon markets across Phase I and Phase II) and national boundaries (in this case, market structure) are influential in the way carbon pricing impacts economic activity. By contrast, company level variables (such as carbon intensity of production and free allocations of allowances) appear to play a relatively insignificant role in our sample.

The article represents an early but far from perfect attempt to empirically examine the operation of carbon market trading on the underlying economies involved. The conclusions and implications which can be drawn from the reported results is limited by the relatively short time period (just over two and half years), the small sample size (only 19 companies), and well as the thousands of unexplained factors and pieces of information which motivate investors in the efficient pricing of any listed equities. Yet these limited parameters are all that exist for a nascent market which is only beginning to take form and is still in its experimental stages in Europe as well as other jurisdictions around the world like North America, Asia and Australia. The implications of the article therefore need to be followed up as more data becomes available in the future in these regions.

Turning first to the institutional factor we examine, one implication which emerges is that carbon markets are a very time-specific market. Carbon allowances do not trade as a long-lived commodity in the way companies, for example, are traded. Rather carbon allowances have a finite life which expires with the end of each phase or stage of a carbon market's construction. This means that the financial implications of carbon for investors, corporations, and corporate innovation more broadly are closely tied to the institutional structures of the period in which carbon is traded. This may have important implications for policy makers wishing to stage the introduction of a fully-fledged carbon market without the mistakes of one period carrying into subsequent periods. But it also means that investors may not be making long-term investment decisions around the price of carbon. They know that the financial implications of carbon will change over time as new policies are formulated for each period and this may negatively impact the continuity of investors' long-term decision making. The efficiency of financial markets and information around the staging of carbon markets is evident in the marked statistical differences between the impacts of carbon on stock returns in Phase I compared to Phase II. In this respect, carbon markets add to our understanding of the sensitivity financial markets exhibit with respect to changes over time.

Turning next to the national factor we examine, a second important implication of our results for the geography of finance is the role market structure plays in defining the financial consequences of carbon markets. Clearly the assumptions we make about *national* market structures in Europe as well as the selection of our sample companies are open to re-interpretation in future academic studies in this field. However, following the assumptions we make it appears that the energy market within which companies operates differentiates the financial implications of carbon markets.

Our results are highly counter-intuitive, suggesting that companies in more closed energy markets are less able to profiteer from rising carbon prices via cost pass through and price manipulation compared to their oligopolistic counterparts. A possible explanation for this finding may be the deliberate regulation of electricity pricing in near-monopoly European energy markets which makes price manipulation around price more difficult. The European-specific nature of this explanation will qualify, but should not diminish, the significance of this finding. In essence, we argue that the institutional and national context around the pass through of carbon costs is important to the way carbon pricing feeds through the economy and corporate valuation. As the article shows, that context may be shaped by a unique mix of market structure and unusual restrictions on pricing regulation. However, this is far from a universal phenomenon and it is reliant upon researchers and policy makers in emerging carbon jurisdictions to better understand the empirical levers driving the financial implications of carbon trading in emerging jurisdictions like North America and elsewhere.

Aggregating our findings on timing and market structure, we believe there may be important implications for corporate innovation and investment in new technologies. If companies operate in a context in which they are able to pass through the cost of carbon then they may have little genuine incentive to invest in new technologies and production processes. While economic theory may suggest that over the long-term this problem may correct itself as electricity demand corrects to short-term price spikes, the episodic and time-sensitive nature of carbon market development suggests that such long-term consistency may be currently lacking. It appears that investors do not yet regard carbon as a long-term price point upon which to make their decisions. Rather, the price of carbon and its financial implications are closely tied to the institutional (time) and market structure (space) characteristics of the particular carbon market phase in play. The role of time and space in the geography of carbon markets is a recent observation in the economic geography literature (Knox-Hayes forthcoming) and the article contributes one of the first quantitative examinations into this phenomenon.

The importance of time and space in carbon market development is juxtaposed against our findings on the significance of company level factors like free allocations and carbon intensity. The statistical insignificance of free allocations may be explained by the relative inaccessibility of emissions information for real time trading. However, the statistical insignificance of carbon intensity is harder to explain. Although a possible explanation is an inconsistency between emissions caps and carbon-intensity of productive technologies, this is a problematic conclusion as it suggests that carbon markets may be susceptible to external political and lobbying interests rather than environmental considerations alone. However, the paucity of data prevents us from testing this hypothesis in great detail and deserves further research beyond the confines of the present article.

Looking beyond the findings of the article towards the broader implications for the future of carbon market development it is clear that carbon markets face a highly complex economic and political challenge ahead. On the one hand, governments under the United Nations Frame Convention of Climate Change continue to push for a global carbon market which is inter-linked across national borders. Indeed, some commentators have already begun to address design issues around an inter-linked North American and EU ETS carbon market (Sterk and Kruger, 2009; Tuerk *et al.*, 2009). However, whatever course such a market may take, it is clear that careful attention must be paid to how this market may operate differently across jurisdictions and across time. Our findings suggest that the institutional context of carbon cost pass-through will be an important issue in untangling the economic geography of a global carbon market, and that balancing short-term staging against the need for long-term price signals will be a significant economic challenge.

The economic geography of carbon markets might therefore be best understood as a raised relief map in which the cost of carbon flows across the contours of economies in a highly uneven manner. Although we have used market structure to analyse the EU ETS, further research might investigate how carbon costs aggregate differently across different sectors in the economy, or across economies with different industrial bases. In terms of international competitiveness, for example, it might be interesting to consider how carbon-intensive coal economies like Australia and Canada respond differently to carbon pricing compared to more technology-led economies like Japan and Europe.

Whichever direction future research on the economic geography of carbon markets take, it is clear that geography must play a key role in understanding the emergence and development of this new market. Rather than placing blind faith in a global carbon price as the panacea of international climate policy, carbon markets must be understood in all their complexity across physical and spatial geographies, however defined. The inherent tension between global solutions and local economies makes climate change a natural area for economic geography to make an important contribution.

Table 1. *Company level characteristics of sample companies*

Companies	*Country*	*Free allowance ratio*[a]	*Capacity-weighted carbon intensity (g/kwh)*[b]	*Turnover carbon intensity (tonnes/million EUR)*[c]
EVN	Austria	0.670	469	2906.67
Verbund	Austria	0.918	121	1335.16
Fortum	Finland	0.927	100	1931.79
EDF	France	0.938	90	1465.59
ENBW	Germany	1.000	250	1361.68
EON	Germany	0.916	520	2264.71
RWE	Germany	0.905	750	3790.43
Vattenfall Europe	Germany	1.027	416	4722.09
PPC	Greece	1.020	945	11483.22
Edison	Italy	0.933	547	2656.35
Enel	Italy	0.839	520	2024.04
Enipower	Italy	1.133	389	774.23
Electricidate de Portugal	Portugal	0.910	475	3055.10
Endesa	Spain	0.800	430	3068.39
Iberdrola	Spain	0.747	289	1863.50
Union Fonesa	Spain	0.660	477	4298.62
British Energy	UK	0.600	110	2177.89
Centrica	UK	1.190	394	462.83
Scottish & Southern	UK	0.772	868	1827.04
Sample Average		0.693	328.18	1945.79

Note: [a]The free allowance ratio is the proportion of carbon emission allowances which were issued for free to companies compared to the amount they were required to purchase according to their national allocation during Phase I of the EU ETS. Ratios greater than 1 indicate an excess of free allowances issued.

[b]The capacity-weighted carbon intensity measures the CO2 emissions (g) emitted for each unit of electricity generated (kwh).

[c]The turnover carbon intensity measures the total CO2 equivalent emissions (tonnes) for each 1 million Euros of turnover.

Source: Trucost proprietary database and company financial reports.

Table 2. Country level characteristics

Country	CR4	CR4 description (concentration)	HHI	HHI description (concentration)	Market Structure
Austria	0.44	Moderate	0.1849	Moderate	Oligopoly
Finland	0.28	Low	0.0730	Low	Competitive
France	0.88	High	0.7800	High	Monopolistic
Germany	0.68	Moderate	0.1320	Moderate	Oligopoly
Greece	1.00	High	0.9604	High	Monopolistic
Italy	0.70	Moderate	0.2668	High	Oligopoly
Portugal	0.68	Moderate	0.3664	High	Oligopoly
Spain	0.6	Moderate	0.1405	Moderate	Oligopoly
UK	0.45	Low	0.0597	Low	Competitive

Source: Own calculations based on Sijm et al (2008) and Domanico (2007).

Table 3. First stage regression on the effect of carbon returns on stock prices

	EVN	Ver-bund	Fortum	EDF	ENBW	EON	RWE	Vatten-fall	PPC	Edison	Eni Power	EDP	Endesa	ENEL	Iber-drola	Union Fenosa	British Energy	Centrica	Scottish & Southern
EU	AT	AT	FIN	FR	GER	GER	GER	GER	GR	IT	IT	POR	SPN	SPN	SPN	SPN	UK	UK	UK
22 April 2005- 24 April 2006																			
Spot	-0.010	0.069*	0.079***		-0.017	0.005	0.037***	0.002	0.003	0.002	0.013**	0.009	0.000	0.008	-0.01	-0.008	0.051***	0.043***	0.021**
	[0.028]	[0.036]	[0.029]		[0.016]	[0.017]	[0.010]	[0.017]	[0.019]	[0.007]	[0.007]	[0.010]	[0.007]	[0.006]	[0.007]	[0.010]	[0.017]	[0.015]	[0.009]
Future	-0.009	0.040	0.072**		-0.017	0.012	0.062***	-0.004	0.016	0.010	0.013	0.017	0.023**	-0.004	-0.012	0.028*	0.09**	0.047*	0.03
	[0.035]	[0.028]	[0.031]		[0.025]	[0.020]	[0.019]	[0.023]	[0.025]	[0.016]	[0.012]	[0.014]	[0.011]	[0.014]	[0.010]	[0.015]	[0.037]	[0.028]	[0.018]
28 April 2006- 31 Dec 2007																			
Spot	-0.014*	0.011	0.005	-0.001	0.005	-0.005	0.002	-0.003	-0.01	0.007	0.006	0.000	-0.002	0.003	-0.001	0.005	-0.006	0.002	0.002
	[0.007]	[0.009]	[0.007]	[0.008]	[0.006]	[0.007]	[0.008]	[0.009]	[0.011]	[0.009]	[0.005]	[0.006]	[0.005]	[0.004]	[0.006]	[0.005]	[0.009]	[0.009]	[0.006]
Future	-0.004	0.032	0.056***	0.021	0.012	0.01	0.008	-0.024	-0.023	-0.018	0.000	-0.006	0.009	0.006	0.024	-0.032	0.067	0.002	0.009
	[0.030]	[0.039]	[0.021]	[0.039]	[0.021]	[0.033]	[0.032]	[0.037]	[0.045]	[0.032]	[0.019]	[0.024]	[0.033]	[0.019]	[0.028]	[0.026]	[0.049]	[0.039]	[0.025]
22 April 2005- 31 Dec 2007																			
Spot	-0.011	0.018	0.013		0.004	-0.002	0.004	-0.002	-0.013	0.003	0.008*	0.002	-0.001	0.003	-0.003	0.004	0.002	0.003	0.003
	[0.007]	[0.011]	[0.010]		[0.005]	[0.006]	[0.008]	[0.008]	[0.011]	[0.008]	[0.005]	[0.005]	[0.005]	[0.004]	[0.005]	[0.005]	[0.009]	[0.009]	[0.006]
Future	-0.010	0.037*	0.065***		-0.008	0.011	0.043**	-0.010	0.005	0.002	0.009	0.009	0.016	0.001	0.000	0.028**	0.082***	0.031	0.025*
	[0.026]	[0.023]	[0.021]		[0.018]	[0.018]	[0.018]	[0.020]	[0.022]	[0.016]	[0.010]	[0.012]	[0.013]	[0.012]	[0.012]	[0.013]	[0.029]	[0.023]	[0.015]

Note: This table shows the effect of carbon returns (spot and future respectively) on company stock returns, controlling for the following independent variables: the respective national indices returns where sample companies are located, returns of (one month) forward price of gas, and returns of (one month) forward price for oil. Logarithmic returns in all cases. White standard errors are used to correct for heteroskedasticity and are reported in parentheses. Significance at 1% (***), 5% (**), 10% (*).

Table 4. GLS regression results on the effect of carbon returns on stock returns in the EU ETS spot market

22 April 2005- 24 April 2006	(1)	(2)	(3)	(4)
Market Structure	-0.032**	-0.033***	-0.033**	-0.029**
	[0.011]	[0.011]	[0.014]	[0.012]
Free allocation		0.036		
		[0.035]		
Carbon Turnover Intensity			0.001	
			[0.010]	
Carbon Intensity				0.000
				[0.000]
Constant	0.074	0.045	0.066	0.077
	[0.021]***	[0.035]	[0.067]	[0.022]***
Observations	18	18	18	18
R-squared	0.34	0.38	0.34	0.36
Adj R-squared	0.3	0.3	0.25	0.28

28 April 2006- 31 Dec 2007	(1)	(2)	(3)	(4)
Market Structure	-0.001	-0.002	0.001	-0.001
	[0.003]	[0.003]	[0.003]	[0.003]
Free allocation		0.012		
		[0.008]		
Carbon Turnover Intensity			-0.004	
			[0.002]	
Carbon Intensity				0.000
				[0.000]
Constant	0.004	-0.006	0.029	0.005
	[0.007]	[0.009]	[0.016]*	[0.007]
Observations	18	18	18	18
R-squared	0.01	0.14	0.17	0.03
Adj R-squared	-0.05	0.02	0.06	-0.1

22 April 2005- 31 Dec 2007	(1)	(2)	(3)	(4)
Market Structure	-0.004	-0.005	-0.002	-0.004
	[0.003]	[0.003]	[0.003]	[0.003]
Free allocation		0.014		
		[0.008]		
Carbon Turnover Intensity			-0.004	
			[0.002]	
Carbon Intensity				0.000
				[0.000]
Constant	0.01	-0.001	0.035	0.013
	[0.006]	[0.009]	[0.016]**	[0.007]*
Observations	18	18	18	18
R-squared	0.1	0.25	0.25	0.17
Adj R-squared	0.04	0.14	0.15	0.06

Note: This table examines the factors which drive the effect of carbon spot returns on the stock performance of companies. Column (1) shows the effect of market structure. Column (2) shows the effect of market structure when controlling for the free allocation of emission allowances. Column (3) shows the effect of market structure when controlling for the carbon turnover intensity for each company. Column (4) shows the effect of carbon structure when controlling for the carbon intensity of the electricity generation process. Significance at 1% (***), 5% (**), 10% (*).

Table 5. GLS regression results on the effect of carbon returns on stock returns in the EU ETS futures market

22 April 2005- 24 April 2006	(1)	(2)	(3)	(4)
Market Structure	-0.037**	-0.038**	-0.045**	-0.038
	[0.013]	[0.013]	[0.016]	[0.014]
Free allocation		0.023		
		[0.042]		
Carbon Turnover Intensity			0.01	
			[0.012]	
Carbon Intensity				0.000
				[0.000]
Constant	0.087	0.068	0.022	0.086
	[0.024]***	[0.042]	[0.076]	[0.026]***
Observations	18	18	18	18
R-squared	0.34	0.35	0.37	0.34
Adj R-squared	0.3	0.27	0.29	0.25

28 April 2006- 31 Dec 2007	(1)	(2)	(3)	(4)
Market Structure	-0.030***	-0.029**	-0.028**	-0.022
	[0.010]	[0.010]	[0.013]	[0.010]
Free allocation		-0.027		
		[0.033]		
Carbon Turnover Intensity			-0.002	
			[0.009]	
Carbon Intensity				0.000**
				[0.000]
Constant	0.061	0.083	0.077	0.069
	[0.019]***	[0.033]**	[0.062]	[0.017]***
Observations	18	18	18	18
R-squared	0.35	0.38	0.35	0.52
Adj R-squared	0.31	0.29	0.26	0.46

22 April 2005- 31 Dec 2007	(1)	(2)	(3)	(4)
Market Structure	-0.034	-0.034***	-0.039***	-0.032**
	[0.011]	[0.011]	[0.013]	[0.012]
Free allocation		0.007		
		[0.035]		
Carbon Turnover Intensity			0.006	
			[0.010]	
Carbon Intensity				0.000
				[0.000]
Constant	0.077	0.071	0.038	0.079
	[0.020]***	[0.035]*	[0.064]	[0.021]***
Observations	18	18	18	18
R-squared	0.39	0.39	0.41	0.4
Adj R-squared	0.35	0.31	0.33	0.32

Note: This table examines the factors which drive the effect of carbon future returns on the stock performance of companies. Column (1) shows the effect of market structure. Column (2) shows the effect of market structure when controlling for the free allocation of emission allowances. Column (3) shows the effect of market structure when controlling for the carbon turnover intensity for each company. Column (4) shows the effect of carbon structure when controlling for the carbon intensity of the electricity generation process. Significance at 1% (***), 5% (**), 10% (*).

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Appendix A

Description of the Electricity price regulations in the European Union

Country	Market Structure	Electricity pricing regulation
Austria	Oligopoly	No intervention in electricity price setting.
Finland	Competitive	There are no controls on electricity price although the Energy Market Authority reserves the right to intervene and adjust prices. There is currently no regulation restricting carbon cost pass through in the formation of prices.
France	Monopolistic	Price is controlled by the Government with periodic review. However, the cost of carbon is included at present in the tariff price.
Germany	Oligopoly	No intervention in electricity price setting.
Greece	Monopolistic	Greek Ministry of Development sets the electricity price with advice from the independent Regulatory Authority for Energy. A 'total cost plus' basis is used although the cost of carbon is explicitly excluded from the tariff price.
Italy	Oligopoly	A bifurcated market in which parts of the market are free and parts are regulated depending on whether the customer is described as "eligible". There is currently no restriction on carbon cost pass through in the formation of prices.
Portugal	Oligopoly	Prices are heavily regulated by the Portuguese regulator, Entidade Reguladora dos Serviços Energéticos, which sets the tariff every three years with an option to revise annually. Current tariffs are set to include all marginal costs including the cost of carbon.
Spain	Oligopoly	Prices are set by the Spanish government. Where this tariff has fallen short of the cost of carbon, the government has subsidised the deficit directly. However, the Royal Decree Act 3/2006 stated that freely allocated emission allowances will not be included in the compensation as of 1 July 2007.
UK	Competitive	No intervention in electricity price setting.

Appendix B

Country	Index Name	Coverage
Austria	Austrian Traded Index	Composed by Wiener Börse to reflect the Vienna Stock Exchange
Finland	OMX Helsinki 25	Market weighted index to reflect the Helsinki Stock Exchange
France	SBF 250	Represents France's largest 250 companies by capitalisation on the Paris Euronext.
Germany	DAX	Composed by Deutsche Boerse to represent the Frankfurt Stock Exchange
Greece	Athens General Index	Broad-based index to reflect the Athens Stock Exchange.
Italy	S&P/MIB Index	Capitalisation weighted index composed by S&P and Borsa Italiana to reflect the Italian equities market
Portugal	PSI Geral	Composed to represent the Euronext Lisbon
Spain	Madrid Stock Exchange General Index (IGBM)	Broad-based index to reflect the Madrid Stock Exchange.
UK	FTSE All Share	Composed to reflect the London Stock Exchange (represents 98% of capitalisation)