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Does the Carbon Market Help or Hurt the Stock Price of Electricity Companies? Further Evidence from the European Context

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Abstract

The electricity sector is one of the most important participants in the European Union Emissions Trading Scheme (EU-ETS). This study provides further evidence on the effect of the carbon pricing on the stock returns of electricity companies in the EU-ETS. The investigation is undertaken in both phases I and II of the EU-ETS using multivariate Generalised AutoRegressive Conditional Heteroskedasticity (M-GARCH) approaches which include a multivariate Constant Conditional Correlation Generalised AutoRegressive Conditional Heteroskedasticity (CCC-GARCH) and a Dynamic Conditional Correlation Multivariate Generalised AutoRegressive Conditional Heteroskedasticity (DCC-M-GARCH) methods. The results show that the carbon market significantly affected the returns of electricity companies in Phase 1, but not in phase II of the EU-ETS. The relationship between carbon prices and electricity prices was found to be positive and symmetric. However, no volatility spillover effect between the carbon market and electricity returns was found in Phase I, whereas such effect existed in Phase II and one which was positive. These results imply that in the short run, electricity companies are significantly affected by the carbon market but this effect diminishes over the long run. These also imply that the risk-return relationship does not seem to be in full operation in relation to the link between the carbon market and capital markets.

Key words: electricity stocks, carbon market; CO_2; emissions trading; EU-ETS, GARCH

JEL classification: C32, G12, L94, O52, Q43, Q48

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1. Introduction

The member states of the European Union (EU), as “regional integration organization” parties to the Kyoto Protocol, have collectively committed themselves to reducing CO_2 emissions by eight percent of the 1990 amount over the period 2008 to 2012. In 2005, the European Commission (EC) launched an emission trading scheme (ETS) based on the ‘cap-and-trade’ principle designed to achieve the Kyoto targets. This scheme is the largest international greenhouse gas (GHG) emission allowance market so far, which represents 84 % of the global carbon market value (World Bank, 2011).

The electricity sector is one of the most important participants of the EU ETS. Of the 12,727 installations involved in this scheme, about 65% of them are electricity producing plants. As a result, the allowances allocated to this sector have been greater than 64% of the overall allocation on the EU Members since 2005. While the overall allocation of allowances in the EU has been generous, the electricity sector has been in a net short position in the market since the introduction of the ETS except the initial year of 2005 (European Commission, 2006). As reported by the World Bank (2010), the power generators have been led to integrate carbon costs into their production processes, introducing low-carbon technologies, as well as switching to low-carbon energies.

Given the significance of the power generators’ involvement, and as an essential producer of a commodity – energy, required by the EU economy, the public is commonly concerned about whether the power supply could be secured, and whether the competiveness of the electricity producers would be diminished by the new environmental regulations. The World Bank (2010) points out that issues relating to the impacts of the high price volatility of carbon asset and windfall profits gained due to the 'grandfathering' allocation approach[2](Weishaar, 2009), still exist. These issues have direct implications for the involved electricity generators' performance in the capital market, as well as their investments in low-carbon technologies and energies.

The research on the European Union Allowance (EUA) market becomes increasingly significant with the steady rise in the number of participants. As of 2011, there are approximately 356 participants involved in EUA trading including governments, regulated companies and private investors, of which around 57 participants are financial institutions (BlueNext, 2011; EEX, 2011; ICE, 2011; NASDAQ OMX Commodities, 2011). However, the academic literature remains rather thin. Notable exceptions are studies of Oberndorfer (2009b), and Veith, Werner, and Zimmermann (2009), which investigated the EUA market from a finance perspective. Both studies found some evidence of a positive relationship between stock market returns and EUA prices. The authors explained their findings by arguing that the conventional electricity generating companies benefited from the ETS as they had the ability to pass on the price of EUA, which had been allocated for free, to the electricity wholesale market.

The findings of the above studies are somewhat counter-intuitive. On the one hand, the expected cash flows might improve due to the pass-through effect of the EUA price on the electricity wholesale price. On the other hand, the risk to cash flows is also increased due to the increased business risk for the non-compliance to the Kyoto reduction commitment by the electricity sector (Busch & Hoffmann, 2007; Kolk & Pinkse, 2004), which results in higher expected returns by the investors in electricity

[2] The grandfathering allowance approach is defined in Weishaar (2009) as a free allocation approach which is based on historical input, output or emission data. This approach is argued to give rise to strategic firm behavior. That is, a firm can increase their grandfathered amount by choosing higher production or emission levels before the benchmark year.

sector. This may lead to a lower stock price level, or even negative stock returns. This means, the carbon constraints should have a negative effect on the electricity stock performance. This inconsistency between the existing evidence and the theory served as an original motivation for this paper.

In general, this paper examines the effect of the EU-ETS on the stock price of electricity companies. The examination is conducted from four perspectives. Firstly, the paper empirically investigates the relationship between the EUA price dynamics and electricity stock performance. Secondly, it studies whether the electricity stock investors react differently to the EU carbon market during the EUA market shock period compared to the pre- and post-shock periods. Thirdly, the study analyses the symmetry of investors' reaction to a rising EUA price and to a falling EUA price. Finally, it explores whether there was a volatility spillover effect between the EUA market and electricity stocks. These analyses provide new knowledge which is highly useful to fund managers and electricity producers in terms of asset allocation and risk hedging. Also, the EU-ETS as a multi-national emission trading scheme, the study have implications to developing the environmental certificate trading practice worldwide.

The paper is structured as follows. Section 2 introduces the theory, a review of empirical evidence on EU carbon market, and the hypotheses for each of the four research objectives. Section 3 outlines the methods and M-GARCH estimation techniques proposed for the analyses. In Section 4, a description of data is presented. The estimation results are presented and discussed in Section 5. The study concludes in Section 6.

2. Theory, Empirical Evidence, and Hypotheses

The EU, to fulfill its emission reduction commitments under the Kyoto Protocol, introduced the ETS. Under this scheme, the electricity generators have to incorporate

EUA price into their production cost mix. This puts constraints on the way the generators conduct their business and reduces their profitability. In effect, the additional carbon constraints introduce an additional risk of non-compliance of the Kyoto Protocol (Busch & Hoffmann, 2007; Kolk & Pinkse, 2004). As the fundamental business risk is increased, in theory, the investors should require higher returns from electricity stocks to compensate for this additional risk. This, in turn, impacts negatively on the electricity stock performance.

In practice, the data show that the stated goal of the EU ETS to achieve emissions reduction has been so far successful[3] (World Bank, 2010). That is, the ETS has effectively motivated regulated companies to reduce emissions. Therefore, investors should have required more returns from regulated companies because of the additionally imposed risk from the Kyoto regulation. As argued by Schwert (1981), one of the main purposes of regulations is to distribute wealth from the regulated firms to consumers. This means, a new regulation should reduce the profitability of the regulated companies in the long-term.

A company's risk level in fulfilling its emission reduction commitment is represented by its exposure to the risk of the EUA market. As the allowances that were allocated to electricity generating companies were free-of-charge, the risk exposure to the EUA market may be argued to depend on whether it has a long position or a short position in this market. If a company has a long position in the EUA market, the company does not bear additional risks from the EU ETS. This is because no matter how the EUA price fluctuated, the companies could sell those unused EUAs for additional cash. In this case, the company's profitability is, in fact, enhanced. A positive relationship between EUA price return and electricity stock return is expected.

[3] The World Bank (2010) shows a 2 to 5 % annual decline during Phase I. The decline is continuing and even greater since 2008 when Phase II started.

However, if the company is short in the EUAs, then it has to buy EUAs from the market. In this case, the company is exposed to the EUA price risk. Thus, a negative relationship between EUA price return and electricity stock return is expected.

The counter-intuitive findings by (Oberndorfer, 2009b; Veith, et al., 2009) of positive relationship between EUA prices and electricity stock prices may result from the relative short time span of their datasets, and may be linked to temporary over allocation of free EUAs by European governments. It is hard to make longer term conclusions from the dataset which only extends for three year of the pilot Phase I.

The downward EUA price shocks that occurred in both phases were caused by the news that suggested that regulated companies were in aggregate long position in the EUAs. For example, in Phase I, after the first government announcement in the Netherlands and the Czech Republic on 25 April 2006 which disclosed that their actual emissions were 7 % and 15 % below the respective allocations, the EUA price fell by 10 %. This followed by the announcements of Belgian and French regulators about over-allocation of the EUAs, which imposed further downward pressure on the EUA prices. In Phase II, the GFC has had some negative impact on energy production and sales, which subsequently resulted in some unused EUAs. The rush of liquidation of EUAs over the period from June 2, 2008 to April 30, 2009 supports this argument (World Bank, 2010).

There are also some studies suggesting that the capital market might asymmetrically respond to rising and falling EUA prices. For example, Chen, Sijm, Hobbs, and Lise (2008) found electricity generators had the ability to pass the EUA constraint onto consumers. Zachmann and von Hirschhausen (2008) found that electricity price timely increased in response to rising EUA prices whereas they responded less to falling EUA prices. As electricity price development affects electricity generators' cash flows, it should also affect the firm's value of electricity generators which should be reflected in the stock price. Therefore, it is expected that there will be an asymmetric reaction of stock returns to the EUA price development.

The efficient market hypotheses suggest that stock prices timely reflect news coming to the market. When significant news arrives in the EUA carbon market, the EUA price tends to be more volatile. As a cost component of the electricity producers (Busch & Hoffmann, 2007; Kolk & Pinkse, 2004), the volatility of the EUA price should be directly transmitted into the volatility of the producers' future cash flows. As the current stock price is theoretically a function of discounted future cash flows, the volatility of the electricity stock should be raised.

Park and Ratti (2008), Pindyck (2004) and Bernanke (1983) similarly argued that the increased volatility in energy price could affect the present value of the discounted dividend stream, through increasing uncertainty about product demand or the future return on investments. Furthermore, Cuñado and Gracia (2003) and Park and Ratti (2008) confirmed this hypothesis by applying oil price volatility to common stocks. Therefore, it is also expected that EUA price volatility could affect the present value of discounted electricity stock's cash flows, by increasing the volatility of their discounted electricity stock's cash flows. That is, it is expected that an increased volatility in EUA market should subsequently increase the volatility of the electricity stocks.

3. Methodology

This study applies an extended Capital Asset Pricing Model (CAPM) with incorporation of the variables constructed to address the impact of EU ETS and a set of control variables. The use of the extended CAPM is based on the existing rich evidence supporting the market factor explaining energy stocks (Boyer & Filion, 2007; Oberndorfer, 2009a; Sadorsky, 2001).

3.1. CCC-GARCH (1,1) Specification Approach[4]

This approach produces results for all the research questions. This approach involves a mean equation and a variance equation which are discussed in details in the following subsections.

For the purpose of model specification, we apply Oberndorfer's (2009b) method to incorporate a set of control variables, which covers oil, gas and electricity price factors. These risk factors are developed based on the hypothesis by Chen, Roll, and Ross (1986) that any variable affecting a stock's expected future cash flows and/or discounted rate should be a risk factor of that stock. For energy stocks, the energy commodity price fluctuations which tend to affect the real cash flows of energy-producing companies were strongly recommended and confirmed by many energy stock valuation studies (Boyer & Filion, 2007; R. Faff & Chan, 1998; Regnier, 2007; Sadorsky, 2001, 2002; Weron, 2000). Also, the inclusion of gas and electricity price factors is important as they matter EUA pricing (Kirat & Ahamada, 2011; Mansanet-Bataller, Pardo, & Valor, 2007; Zachmann & von Hirschhausen, 2008).

The mean equation is shown below:

$$r_{\text{electricity stock},t} = \alpha + \beta_1 r_{\text{eua},t} + \beta_2 r_{\text{market},t} + \beta_3 r_{\text{oil},t} + \beta_4 r_{\text{gas},t} + \beta_5 r_{\text{electricity},t} + \gamma_1 IT_{\text{eua market shock}} + \gamma_2 IT_{\text{eua pre-market shock}} + \gamma_3 IT_{\text{asymmetric eua}} + \varepsilon_t \qquad (1)$$

In equation (1), α is a constant term; $r_{\text{electricity stock},t}$ is the dependent variable representing the electricity stock return in time t. $r_{\text{eua},t}$ is the independent variable representing the EUA price return in time t. $r_{\text{market},t}$, $r_{\text{oil},t}$, $r_{\text{gas},t}$, and $r_{\text{electricity},t}$ are

[4] CCC-GARCH (1,1) has the lowest Schwarz Info Criterion (SIC) values for both Phase I and Phase II datasets compared to other lag order combinations from 1 to 4.

control variables representing market return, oil price return, gas price return, and electricity price return in time *t*. All price return series are calculated following a continuous return formula which is argued to provide a more accurate measure of return compared to the discrete formula (Brailsford, Heaney, & Bilson, 2004): r_t = exp($Price_t$ / $Price_{t\text{-}1}$) ×100. ε_t is the error term which has a Student t-distribution and a zero mean., β_1, β_2, β_3, β_4, β_5, γ_1, γ_2, and γ_3 are parameters that need to be estimated by maximum likelihood.

$IT_{\text{eua market shock}}$ and $IT_{\text{eua pre-market shock}}$ are the interaction terms constructed to recognize the EUA effect on the electricity stock return during market shock period. This follows the methods used in Oberndorfer (2009b), where a dummy (i.e., 1 or 0) is utilized. Specifically, the post-shock period is selected as the reference group. $IT_{\text{eua market shock}}$, which represents EUA price dynamics during the market shock period, is created between EUA price return and a dummy by taking the value of one for the EUA price returns during this period and taking zero for the EUA price dynamics during periods before and after the market shock. Meanwhile, following the same approach, the other interaction term, $IT_{\text{eua pre-market shock}}$, representing EUA price returns during the pre-shock period is created. Similarly, it multiplies the EUA price returns with a dummy taking one for the shock period and zero for the period otherwise.

According to Ellerman and Buchner (2008), the EUA market shock in Phase I was caused by government announcements disclosing that the overall allowance allocation were more than the regulated companies’ actual emissions. As a result, the EUA price has fallen from about 30 euros in late April 2006 to around 10 euros during the first half of May 2006. The starting date of the EUA market shock is assumed 26 April 2006, and the ending date is 10 May 2006.

In Phase II, the EUA market shock was arguably caused by the GFC effect. As shown by World Bank (2010), the EUA market experienced a shock over the period from the beginning of June in 2008 to the mid of February in 2009. During this around 9-month period, the EUA price had a big fall from nearly 29 euros to about 8 euros. The period of shock is defined from 2 June 2008 (June 1 is a public holiday and was thus excluded) to 12 February 2009.

Additionally, $IT_{\text{asymmetric eua}}$ is another interaction term in equation (1) used to address the EUA asymmetric effect on the electricity stock return. Similarly, a dummy variable is utilized by taking the value of one when EUA price rises, and zero when EUA price decreases or does not change. $IT_{\text{asymmetric eua}}$ represents the positive EUA price return effect which is to investigate whether a rising EUA price will lead to a greater electricity stock return than a falling EUA price.

In equation (1), results on parameters β_1, γ_1, and γ_3 will respectively address the effect of the EUA market returns on electricity stock returns, such effect during the EUA market shock periods, and the EUA asymmetric effect on electricity stock returns.

Provided the ability to address time-varying co-variances between variables, a multivariate CCC-GARCH method is applied to the variance equation specification to address the volatility spillover effect among variables. This approach is introduced by Bollerslev (1990) with the assumption that the conditional correlations are constant over time.

The conditional co-variance matrix is produced following the equations below (Bauwens, Laurent, & Rombouts, 2006):

$$H_t = D_t R D_t = \rho_{\text{ij}}(h_{\text{ii}t} h_{\text{jj}t})^{1/2}$$

$$D_t = \text{diag}((h_{11t})^{1/2} \ldots (h_{\text{NN}t})^{1/2})$$

h_{iit} can be defined as any univariate GARCH model, and $R = (\rho_{ij})$ is a symmetric positive definite matrix with $\rho_{ii} = 1$.

The specific variance equation is produced as below:

$$h_t = a + bh_{t-1} + c(\varepsilon_{t-1})^2 + d_1 v_{\mathrm{eua},t} + d_2 v_{\mathrm{oil},t} + d_3 v_{\mathrm{gas},t} + d_4 v_{\mathrm{electricity},t} \qquad (2)$$

a is constant; h_t is the conditional variance of the error term, ε_t, in equation (1) with Student-t distribution and zero mean, which represent electricity stock volatility ($v_{\mathrm{electricity\ stock}}$) in time t; $v_{\mathrm{eua},t}$, $v_{\mathrm{oil},t}$, $v_{\mathrm{gas},t}$, and $v_{\mathrm{electricity},t}$ represent the volatilities of EUA, oil, gas and electricity prices respectively[5]; b, c, d_1, d_2, d_3, d_4 and h_t are parameters that are estimated by maximum likelihood.

In equation (2), results on parameter d_1 will address the volatility spillover effect between EUA market and the conventional electricity generation sector.

3.2. DCC-M-GARCH (1,2)[6]

The application of dynamic conditional correlation (DCC) specification is considered significant as some studies have already evidenced that conditional correlations between different financial variables are not constant (Ewing, Malik, & Ozfidan, 2002; Fleming, Kirby, & Ostdiek, 1998; Hassan & Malik, 2007; Kodres & Pritsker, 2002).

The DCC model of Engle (2002) is defined as follows:

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[5] The volatilities, which are primarily used in CCC-GARCH process, are the squared returns obtained by the formulea: $r_t = \exp(Price_t / Price_{t-1}) \times 100$.

[6] DCC-M-GARCH (1,2) has the lowest SIC values for both Phase I and Phase II datasets compared to other lag order combinations from 1 to 4.

R_t = diag($(q_{11,t})^{-1/2} \ldots (q_{NN,t})^{-1/2}$)$Q_t$diag($(q_{11,t})^{-1/2} \ldots (q_{NN,t})^{-1/2}$)

where the N ×N symmetric positive define matrix $Q_t = (q_{ij,t})$ is given by:

$Q_t = (1 - \alpha - \beta)\text{average}(Q) + \alpha\mu_{t-1}\mu'_{t-1} + \beta Q_{t-1}$

$\mu_t = (\mu_{1t}\mu_{2t} \ldots \mu_{Nt})'$

Average(Q) is the N ×N unconditional variance matrix of μ_t, and α and β are non-negative scalar parameters satisfying $\alpha + \beta < 1$.

The correlation coefficient between any two variables is estimated following the expression below:

$\rho_{ij,t} = ((1 - \alpha - \beta)\text{average}(q_{ij}) + \alpha\mu_{i,t-1}\mu_{j,t-1} + \beta q_{ij,t-1}) / ((1 - \alpha - \beta)\text{average}(q_{ii}) + \alpha(\mu_{i,t-1})^2 + \beta q_{ii,t-1})^{1/2}((1 - \alpha - \beta)\text{average}(q_{jj}) + \alpha(\mu_{j,t-1})^2 + \beta q_{jj,t-1})$ (3)

$\rho_{ij,t}$ are the conditional correlations between variables i and j in time t; α and β are non-negative scalar parameters satisfying $\alpha + \beta < 1$; $q_{ij,t}$ and $q_{ij,t-1}$ are conditional co-variances between variables i and j in time t and t-1 respectively; $(\mu_{i,t-1})^2$ and $(\mu_{j,t-1})^2$ are unconditional variances of variables i and j in time t-1; $\mu_{i,t-1}\mu_{j,t-1}$ are unconditional co-variances between variables i and j in time t-1.

As it is shown in equation (3), the results on the conditional correlation between $r_{\text{electricity stock}}$ and r_{eua}, which can be represented by $\rho_{\text{electricity stock,eua}}$, will address the relationship between EUA market volatility and the volatility of conventional electricity generation sector.

4. Data

The sample period extends from 21 November 2005 to 30 June 2011 when the data for all the variables are available[7].

Phase I of the ETS was a pilot period organized by the EU, whereas Phase II is the official phase for the Kyoto targets. The banking of EUAs was prohibited between the phases. That is, the unused EUAs could not be carried forward from phase I to Phase II, meaning keeping unused EUAs was useless. Therefore, this cut-off point may have some implications for the effect of EUA market on electricity stock performance. To address the possible differences in the effects between the two phases, analyses are respectively applied to two subsamples: one includes data from Phase I, which ranges from 2005 to 2007; the other subsample includes data from Phase II, which ranges from 2007 to 2011.

The analysis follows an aggregated approach where an equally-weighted electricity stock portfolio is constructed to represent the financial performance of the EU conventional electricity generation sector. The electricity companies are selected based on the components of the Dow Jones Euro Stoxx Utilities Index as at 30 June 2011, which covers the largest utility companies in the Eurozone. For the purpose of homogeneity of the sample, only conventional electricity companies are selected for the study.

The EUA spot prices are used in this study. Given the EU ETS has just operated for less than 7 years, the trading in the futures market was very thin with large number of zero trading days. In contrast, the spot market provides a continuous series of price change values necessary for robust econometric testing (BlueNext, 2008).

[7] EUA price data is available from 4 August 2005, and stock price data for Électricité De France is available from 21 November 2005.

5. Empirical Results

5.1. Descriptive Statistics and Diagnostic Tests

Table 1 provides descriptive statistics for each of these return series in Phase I and Phase II.

A graph of the developments of the EUA price return and electricity portfolio return in the two phases are generated and presented in Fig. 1. The EUA market shock can be observed in the second quarter of 2006, and during the second half of the year 2008 to the first half of the year 2009. As is evident from the graph, volatility of the EUA prices has risen towards the end of Phase I.

Investors are most concerned about risk associated with the stock returns. Thus it is important to get an insight into risk in relation to the electricity stock return. As is shown in Fig. 2, the conditional volatility of the electricity portfolio return is dynamic and changing throughout the whole sample period. This is why GARCH approaches, which are able to address these characteristics, are proposed and applied in this study.

Table 1

Descriptive Statistics of Data.

	Electricity Portfolio Return	Market Return	EUA Price Return	Oil Price Return	Gas Price Return	Electricity Price Return
Phase I						
Mean	0.1098	0.0519	-1.2536	0.0588	-0.0722	0.0356
Median	0.1273	0.1155	0.0000	0.1505	-0.4274	0.5697
Maximum	3.5656	3.0109	51.0826	5.1580	47.5962	49.3529
Minimum	-2.6574	-3.4062	-51.0826	-5.3006	-26.2015	-75.0392
Std. Dev.	0.7633	0.9286	8.7142	1.6451	5.8774	8.9025
Skewness	0.0747	-0.4437	-0.2258	-0.2285	2.0924	-2.5089
Kurtosis	4.4562	4.4818	10.0251	3.1581	15.5132	26.2962
Jarque-Bera	46.87453***	65.2595***	1084.0490***	5.1168*	3808.283***	12422.6100***
Augmented Dickey Fuller	-22.5024***	-24.9177***	-24.8285***	-24.0211***	-21.8377***	-26.7966***
Observations	525	525	525	525	525	525
Phase II						

Mean	-0.0523	-0.0329	-0.0518	0.0184	-0.0097	-0.0150
Median	-0.0341	0.0000	0.0000	0.0533	-0.1528	0.2746
Maximum	13.6575	9.9621	10.5479	14.8062	35.7641	37.2534
Minimum	-8.4962	-8.2498	-10.2852	-10.5271	-11.2918	-61.3401
Std. Dev.	1.4844	1.7312	2.3751	2.2409	3.6965	5.9915
Skewness	0.3431	0.1189	-0.2747	0.1550	2.3766	-2.7575
Kurtosis	14.6893	7.9088	5.4717	6.7838	23.6369	37.1587
Jarque-Bera	4815.9990***	848.2738***	225.1942***	506.2587***	15752.6500***	42052.6800***
Augmented Dickey Fuller	-28.0125***	-29.3627***	-16.1113***	-27.6283***	-28.0074***	-34.5527***
Observations	843	843	843	843	843	843

Jarque-Bera refers to Jarque-Bera test statistic for normality: H_0: data are normally distributed, H_1: data are not normally distributed; Augmented Dickey Fuller refers to Augmented Dickey Fuller unit root test statistic: H_0: unit root (non-stationary), H_1: no unit root (stationary); t-Statistic values are presented for Jarque-Bera test and Augmented Dickey Fuller unit root test; *, **, ***, indicate levels of significance at 10 %, 5 %, and 1 % respectively.

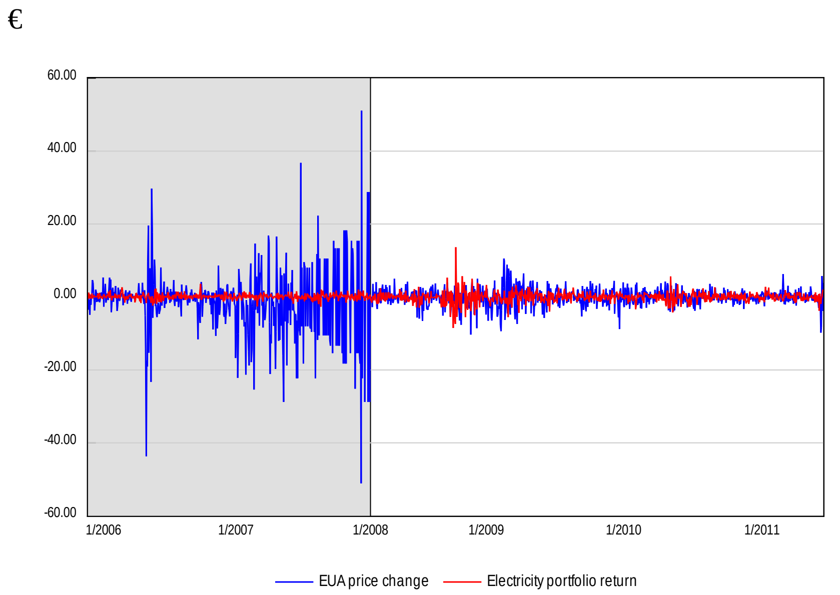

Figure 1: Developments of EUA Price Return and Electricity Stock Portfolio Return throughout Phase I and Phase II

Note: The shaded areas represent Phase I period; the remainder areas represent Phase II period.

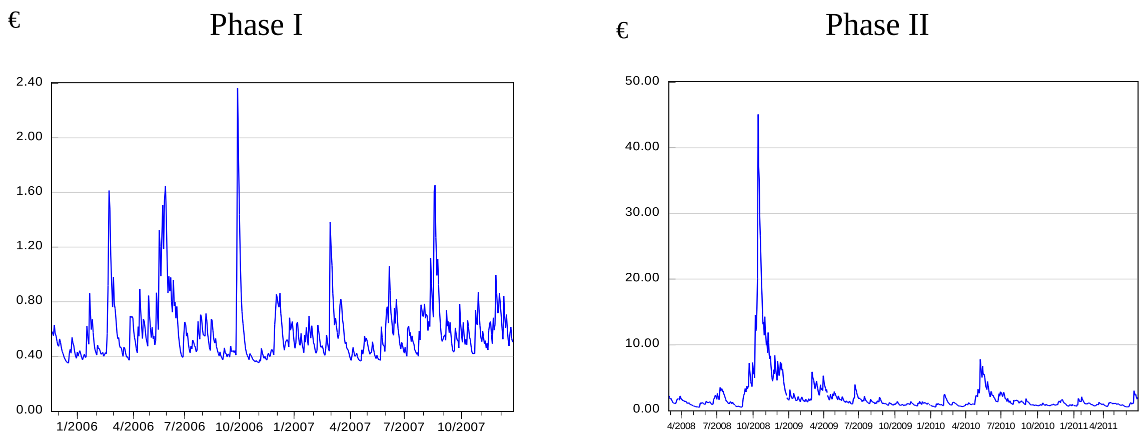

Figure 2: Conditional Variance of Electricity Stock Portfolio Return

5.2. Estimation Results

The results for each phase applying CCC-GARCH (1, 1) are presented in Table 2. As shown at the bottom of Table 2, the R-squared values, 51.97 % in Phase I and 69.77 % in Phase II of the variations in the electricity stock returns are explained by the model. In addition, the Durbin-Watson statistics, which are 1.6964 in Phase I and 1.9400 in Phase II, show that there is a minor positive autocorrelation effect for each of the dataset as they are close to 2 at which no autocorrelation effect exists. Moreover, neither of the constant terms (α) in the mean equation is significant, indicating the models are well specified for both phases. These results indicate that the model fits the data well and the electricity portfolio return is sufficiently explained by the hypothesized independent variables.

Table 2

Results of CCC-GARCH (1,1) Approach.

		Phase I	Phase II
		Mean Equation	
EUA variable			
β_1	(eua)	-0.0062^{**}	0.0029
γ_1	(eua market shock)	0.0304^{***}	0.0458^{**}
γ_2	(eua pre-market shock)	-0.0037	0.0442
γ_3	(asymmetric eua)	0.0061	-0.0361
Constant and control variables			
α	(constant)	0.03880	0.0138
β_2	(market return)	0.5727^{***}	0.6673^{***}
β_3	(oil)	0.01419	0.0018
β_4	(gas)	-0.0014	0.0072
β_5	(electricity)	0.0037^{*}	0.0085^{**}
		Variance Equation	
EUA variable			
d_1	(eua volatility)	-0.0000	0.0051^{**}
Constant, GARCH term, ARCH term and control variables			
α	(constant)	0.2933^{***}	0.0365^{***}
b	(GARCH (1) term)	-0.2689^{***}	0.724119^{***}
c	(ARCH (1) term)	0.2654^{***}	0.1499^{***}
d_2	(oil volatility)	-0.0075^{***}	0.0027

d_3	(gas volatility)	0.0002	0.0003
d_4	(electricity volatility)	-0.0000	-0.0001***
Observations		525	843
R-squared		0.5197	0.6977
Durbin-Watson stat		1.6964	1.9400

The estimated coefficients are presented in the table. All the values are given to four decimal places. *, **, ***, indicate levels of significance at 10 %, 5 %, and 1 % respectively.

Results for EUA return effect, β_1, are different between Phase I and Phase II. In Phase I, the EUA price return is found to have a negative impact on the electricity stock return at a 5 % level of significance, though the estimated coefficient is small, i.e., -0.0062, indicating a relatively small explanatory power. In contrast, the EUA price return is found to have no impact on the electricity stock return in Phase II at any conventional level of significance (i.e., 1 %, 5 %, or 10 %).

Results on γ_1 show the EUA return effect during the EUA market shock periods. For both phases, a significant positive relationship between the EUA price returns and the electricity stock returns during market shock periods is found. Moreover, both results are significant but at 1 % level in Phase I and 5 % level in Phase II.

In relation to the potential asymmetric effect of the EUA on electricity stock returns ($\gamma_3{}_3$), no evidence was found that the EUA variable has asymmetric effects on electricity stock returns in both phases.

The volatility spillover effect between EUA and electricity stock variables is indicated by the results on d_1 in the variance equation. Under the assumption of a constant conditional correlation, the volatility of the EUA price is found to have a spillover effect on electricity stock at 5 % level in Phase II, whereas there is no evidence of this effect in Phase I. The estimated coefficient of the EUA volatility in Phase II (i.e., 0.0051) is positive, indicating a slightly positive effect on electricity stock volatility. In Phase I, the coefficient is estimated to be 0.0000, which further indicates that the volatility of EUA variable had no impact on the electricity stock volatility.

The DCC parameters are presented in Table 3. For both phases, p-values for the alpha and beta parameters respectively indicate volatility spillover effect from other markets and persistence of this effect is highly significant. The estimated coefficients for betas, which are 0.9262 in Phase I and 0.9490 in Phase II, indicate the persistence effects are strong. The estimated coefficients for alphas, which is 0.0086 in Phase I and 0.0193 in Phase II, indicate a relatively weak volatility spillover effects.

Table 3

Results for DCC-M-GARCH Parameters

	Phase I	Phase II
alpha	0.0086^{**}	0.0193^{***}
beta	0.9262^{***}	0.9490^{***}

The estimated coefficients are presented in this table. *, **, ***, indicate levels of significance at 10 %, 5 %, and 1 % respectively.

In Fig. 3, the graphs in terms of the dynamic conditional correlations between electricity stock return and EUA price return are shown. Apparently, the conditional correlation series present as dynamic and time-varying, which show the DCC-M-GARCH is considered a better approach for explaining volatility spillover effects over the CCC-GARCH.

Phase I Phase II

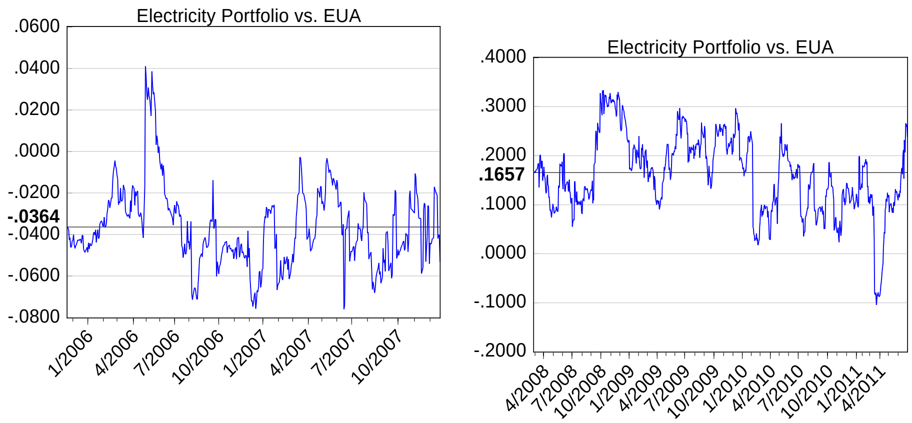

Figure 3. Dynamic Conditional Correlations between Electricity Stock Return and EUA Price Return for Phase I and Phase II

In Table 4, the results of estimated average conditional correlation coefficient between the electricity stock variable and each independent variable are presented. The results for the EUA variable, indicate the relationship between the EUA price returns and the electricity stock returns. The results are different between the two phases. In Phase I, the average conditional correlation for the EUA variable is estimated to be -0.0364, indicating on average there was a negative relationship between the EUA price returns and the electricity stock returns. In Phase II, the average conditional correlation turns out to be positive, estimated to be 0.1657, showing on average there is a positive relationship between the EUA price changes and the electricity stock returns in Phase II.

These results can also be seen in the graphs in Fig. 3. Clearly, the dynamic conditional correlations generally developed within the range between -0.08 to 0.00 in Phase I, suggesting an average negative relationship between the EUA price returns and the electricity stock returns. In the graph for Phase II, the conditional correlations are mostly lying within the range between 0.00 to around 0.30, which is above 0, showing that this relationship on average is likely to be positive.

Table 4

Results for Relationships between Electricity Stock Variable and Individual Hypothesized Variables

	Phase I	Phase II
EUA ($\rho_{\text{electricity stock,eua}}$)	-0.0364	0.1657***
Control variables		
Market	0.7114***	0.7880***
Oil	0.0792*	0.2905***
Gas	0.0077	0.0714
Electricity	0.1141***	-0.0410

The estimated average conditional correlations are presented in the table. All the values are given to four decimal places. *, **, ***, indicate levels of significance at 10 %, 5 %, and 1 % respectively.

In addition, although the average relationship is estimated to be negative in Phase I, we can find in the graphs in Fig. 3 that, during the market shock (26 April to 10 May 2006), the conditional correlations had a large increase beyond zero to around 0.04. In Phase II, shown in the second graph of Fig. 3, the conditional correlations during the market shock (2 June 2008 to 30 April 2009) by GFC developed mostly above the estimated average conditional correlation (i.e., 0.1657). In particular, the conditional correlations reached a peak at around 0.3300 in the months of November and December in 2008. These findings suggest that in Phase II there is a much stronger positive relationship between the EUA and the electricity stock variables.

Regarding the spillover effect between the EUA market and electricity stock volatilities, the results for Phase I and Phase II are also different. In Phase I, the effect is not significant at any conventional level at 10 %. In Phase II, this effect turns out to be highly significant at 1 % level.

5.3. Robustness Tests

To confirm the validity of the outcomes of the modeling, the number of robustness checked were performed.

Firstly, coal price factor was added to the model, i.e., both mean and variance equations. Results obtained by additionally incorporating coal price factor are similar to those produced from the multivariate GARCH processes.

Secondly, the market volatility is added into the variance equation. Again, the impact on the results is marginal with one notable exception. Market volatility turns out to be most important factor for variance equation in Phase II (i.e., 0.0225^{***}) and partially replaces the effects of EUA variables, some of the other variables on electricity stock in terms of both return and volatility.

Thirdly, we have tested the model on the performance of individual companies included in the electricity stock portfolio. The results generally confirm the earlier findings with minor variations in terms of significance of control variables.

All the analyses do not produce significant results on asymmetric EUA variable, showing the investors of electricity stock do not respond differently to a rising EUA price from a falling EUA price. Since the results in the robustness tests are similar to the main results, we therefore no longer present these in the paper. However, these results are available upon request from the authors.

5.4. Discussion about the EUA Effect

The negative relationship between EUA price returns and electricity stock returns obtained in Phase I confirms the theory but contradicts Oberndorfer (2009b) and Veith, Werner and Zimmermann (2009). Both studies have found that this impact was positive during Phase I. For Veith, et al. (2009), the inconsistency may be primarily due to the use of different econometric techniques. Veith, et al. (2009) based the analysis on an OLS approach. This approach is unable to capture volatility clustering and spillover effects in time series data. Furthermore, there is no assumption for the spillover effect between variables.

As for Oberndorfer (2009b), differences in the sample portfolio components may partly contribute to the inconsistent results between Oberndorfer (2009b) and this study. Oberndorfer (2009b) was based on the Dow Jones Euro Stoxx Utilities Index as at 1 August, 2007 whereas this study is based on the index as at 30 June 2011. The components of the Dow Jones Euro Stoxx Utilities Index have changed over time to keep consistent with the current market structure, such as new entrants, stock delistings, or changes of subsectors (e.g., from conventional generation to alternative generation) (STOXX, 2011). In addition, the EUA price data are sourced from a different Exchange. In this study, the EUA prices are derived from BlueNext Exchange whereas Oberndorfer (2009b) used data from the European Energy Exchange (EEX). BlueNext is considered as the largest EUA spot market. It has a high trading volume and is more liquid market. Moreover, with respect to the quality of the data, the EUA price data from the EEX remain almost unchanged and extremely low (at around 0.02 euro) throughout the year of 2008. The BlueNext, on the other hand, provide a consistent series of EUA prices regarding the whole sample period concerned in this study.

The sample period for Phase I in this study is different from Oberndorfer (2009b). In this study, the Phase I period starts from 21 November 2005 to the end of 2007. Oberndorfer (2009b) chose the sample starting from 4 August 2005 to 19 June 2007. The author excluded the data from late 2007 by arguing that the EUA prices did not vary too much during that time due to the high relative allocation within the scheme. The inclusion of this period provides opportunity to gain full picture of Phase I.

Oberndorfer (2009b) uses GARCH (1,1) approach in his study. The multivariate GARCH approaches proposed in this study are considered statistically superior in addressing time-varying volatilities and spillover effects between market volatilities than a univariate GARCH (1,1) method with multivariate extension. Therefore, the findings should provide a more reliable insight on the economic relationships between the electricity sector and the EUA market. Finally, this study has a larger sample set than Oberndofer's (2009b) paper and therefore provides more reliable results.

With respect to the results for Phase II, on the contrary, the relationship between EUA price returns and electricity stock returns is found to be insignificant albeit with small positive coefficient. We attribute the finding to the impact of GFC on the European markets and economies. As it was argued by World Bank (2010), the reduction in energy demand caused by the GFC led to energy production and sales to fall as well. The energy production companies, consequently, had a decrease in their actual CO_2 emissions during this period. This resulted in unused EUAs in hands of some electricity companies. Those companies could sell these unused EUAs to compensate for their loss in sales revenues.

Moreover, in electricity generators Europe has somewhat increased their production of energy using clean energy sources, therefore reducing their exposure to the EUA market. As it is shown in Fig. 4 below, the actual emissions by the combustion sector had a big fall from 2008 to 2009. Compared to the preceding years, the actual emissions in 2009 was the lowest. Accordingly, investors may see this rush of selling free-charge EUAs was an opportunity for generators to increase profitability.

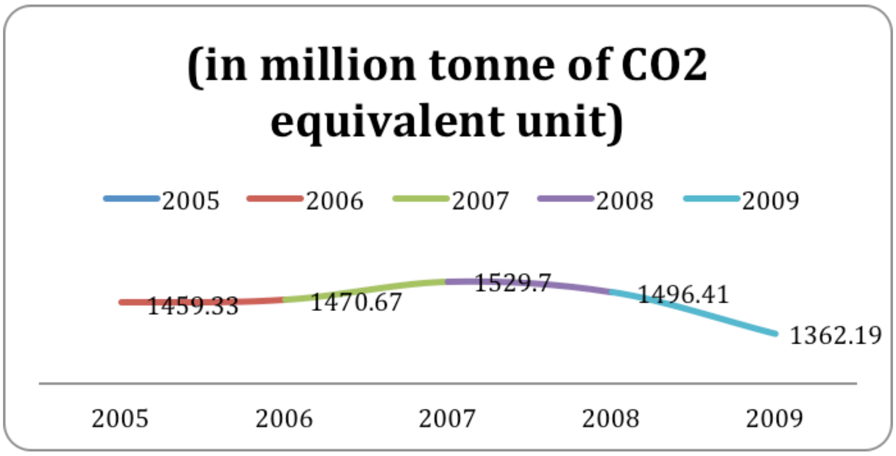

Figure 4: Verified Emission of the Combustion Sector of EU-27 from 2005 to 2009

Note: Source: Community Transaction Log (CITL) (http://ec.europa.eu/environment/ets/) as of March 2009 for the reporting years 2005 and 2006, 11 May 2009 for the reporting year 2007 and data as of 17 May 2010 for the reporting year 2008 and 2009; combustion sector covers the activities related to the generation of electrical power and heat (non-process related); verified Emissions is defined as the amount of the total emissions actually emitted by each installation; data are in million ton of CO_2 equivalent unit.

For the market shock period in each of the phases, it is found that the EUA price returns had a positive impact on electricity stock returns, and this impact is more significant in the market shock period than in the periods before and after the market shock. The findings confirm the results of Oberndorfer (2009b) for Phase I, who also found a significant positive impact of the EUA price returns on electricity stock returns during the market shock caused by the government's disclosure of the over-allocated allowances in Phase I. Similar results are found in Phase II, for the market shock caused by the GFC. As it was discussed before, the possibility of trading unused EUAs resulted from the reduced production caused by the GFC is high. Investors might consider this was an opportunity for electricity generators to improve profitability during the GFC and therefore, see EUA price was beneficial for electricity generators.

For both phases, there is no evidence supporting investors respond to a rising EUA price more than a falling EUA price. This is consistent with Oberndorfer (2009b). Therefore, it may be argued that the asymmetric responses of electricity prices to EUA price changes found by Zachmann & von Hirschhausen's (2008) do not necessarily indicate a corresponding asymmetric response in stock markets. This finding can be attributed to investors may be ignoring the asymmetric effect that has been found in the electricity wholesale market in response to the EUA price development.

The volatility spillover effect between the EUA market and electricity stocks is found to be significant in Phase II whereas there is no evidence from Phase I. There may be two explanations for this finding. First, Phase I was a test phase of a completely new market and thus likely to be little-integrated with other markets. As for Phase II, World Bank (2010) is convinced that existing evidence from the EU ETS suggests that market became much more matured. This means greater informational efficiency of the market when news entering this market are timely reflected in the electricity stock price. This also implies that the risk of the EUA market has been incorporated into the volatility of future cash flows of conventional electricity generators, which implies that this effect will be persistent in the long run.

The other explanation may be that, during a market crisis, when the market is highly volatile, the correlations between markets increase. Previous studies, such as Forbes and Rigobon (2002), Longin and Solnik (2001) documented this phenomenon for the stocks. More recently, Sandoval Junior and Franca (Sandoval Junior & Franca, 2012) found this increased correlations among world stock indices for the number of crises which included GFC. The findings in this study provide further evidence of augmented link between volatility of stock markets and stocks of individual sectors in the market downfalls. These results are also very robust at firm level. This finding is important for portfolio managers to select different asset classes for their investment portfolios. It is also particularly important to electricity generators in terms of hedging unexpected EUA price fluctuations (Benz & Truck, 2006).

Results from all the approaches indicate that the overall stock market and electricity market have a strong and direct implication for electricity stocks. This is consistent with existing findings supporting the extremely great explanatory power of the stock market (Boyer & Filion, 2007; Carhart, 1997; R. Faff & Chan, 1998; R. W. Faff & Brailsford, 1999; Fama & French, 1993; Khoo, 1994; Liu, 2006; Sadorsky, 2001). The importance of the electricity wholesale market recognised in relation to electricity stocks is remarkable. In contrast to some previous studies, such as Oberndorfer (2009b), Boyer and Filion (2007), Park and Ratti (2008), and Sadorsky (2001), oil price returns seem not important for electricity stocks. In contrast, the gas market is found to be the least important for electricity stocks in terms of both price changes and market volatility. This is especially surprising given that the EU electricity generators commonly use gas generation inputs other than oil (EIA, 2007). Siliverstovs, L'Hégaret,, Neumann, and von Hirschhausen (2005) provide a reason for this finding that the gas sold in Europe is generally based on long-term contracts with a price that is determined by a formula linking gas price to oil price. This is used to prevent incentives for fuel switching. Another reason could be that generators often hedge relatively strongly against the gas price risk than the oil price risk.

6. Conclusion

This study has investigated the impact of the EU ETS on the electricity generation sector from a finance perspective with the use of contemporary M-GARCH methods. Previous studies in this area examined Phase I data only and applied a traditional OLS or a univariate GARCH approach. In contrast, this study not only revisits Phase I data but also provides evidence for Phase II. The more sophisticated CCC-GARCH and DCC-M-GARCH methods are utilised for the purpose.

The relationship between the EUA market return and the electricity stock returns was found to be negative in Phase I. No evidence in support of an asymmetric reaction of investors to the EUA price rises and falls was found. Whether this impact is positive or negative depends on the view of investors on whether electricity generators are able to make a profit by trading the free emission allowances in the market rather than whether the allowances are allocated for free or not. The view of investors on the profitability of electricity generators in Phase I was that it was linked with the compliance effort of the electricity generation sector. However, in Phase II, it did not produce evidence of a significant relationship between stock performance and carbon price. These findings may indicate that in the short term, companies are heavily impacted by the carbon market but over the long-term, they become less and less affected by the carbon market as they are able to adjust their production techniques that become less dependent on carbon intensive inputs. This may imply that the electricity generators should consider the carbon price fluctuations which affect their finance costs by developing appropriate hedging strategies, particularly in the early stages of a company's involvement in the carbon market.

A positive impact of the EUA price returns on the electricity stock returns was found during the period of the EUA market shock in both phases. In addition, this impact was proved to be more pronounced compared to the EUA price impact during periods before and after the shock. Thus, it seems that economic shocks such as the GFC can even be beneficial to companies in terms of their trading in the carbon market. During economic downturns, as companies cut down on their production and therefore their carbon emissions, they may find themselves with surplus carbon credits which they can trade profitably.

A positive effect of the EUA market volatility on the electricity stock price volatility was found in Phase II but not in Phase I. This may have been caused by the GFC and correlations of volatilities in stock market and carbon market have increased. Since no test for direction of causality being performed, stock market may have in fact been a driver in this relationship. These findings indicate that there seems to be different forces that impacted returns and risks in the carbon market in the period of investigation. It should be noted that these findings and explanations are somewhat provisional since the EU ETS has operated for only seven years.

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