Discussion Paper No. 08-059

EU Emission Allowances and the Stock Market: Evidence from the Electricity Industry

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Non-Technical Summary

This paper constitutes – to our knowledge – the first econometric analysis on stock market effects of the EU Emission Trading Scheme. We analyse electricity stock return reactions to changes in EU Emission Allowance (EUA) prices, taking into account possible asymmetries in the relationship between EUA price changes and electricity stock returns, as well as country- and time-specific effects. Moreover, we test whether EUA return volatility and European electricity stock volatility are related. Our results suggest that EUA price increases (decreases) positively (negatively) affect stock returns from the most important electricity corporations covered by the EU ETS. In this respect, the electricity corporations considered are upvalued in case of an EUA appreciation, and downvalued in situations where the price of EU Emission Allowances falls. The effect differs from country to country: Amongst the electricity corporations considered, Spanish corporations are shown to exhibit a negative EUA-to-stock market relationship. In contrast, the effect is positive for corporations from other countries such as Germany and the UK. Stock markets do not seem to react differently to EUA appreciations in comparison to depreciations. Moreover, electricity stock return and EUA price change volatility are not shown to be positively related.

Given these results, it becomes apparent that EU ETS effectively has an impact on financial markets and has economic consequences, affecting the value of the corporations covered. The first ETS phase seems to be marked at least to some extent by uncertainty of financial market agents concerning the importance of the newly created EU carbon market for the stock market: The EUA effect on electricity stocks is shown to vary over time, being especially high during the EUA market shock in early 2006. Such a “premium” on the EUA effect could be based on the exceptionally high attention of the general public (and seemingly also of stock market agents) to the carbon market at that time. The fact that EUA price changes positively affect European electricity stocks (at least for most countries analysed) is the consequence of fully rational electricity pricing under a grandfathering allocation rule if pass-through for costs created by the ETS is possible. This result, however, calls into question free allowance allocation to these corporations, as free allocation is seen as an instrument to support firms suffering from production cost increases generated by EUA price rises. The “inverse” EUA effect for the Spanish corporations could stem from stringent price regulation at the Spanish electricity market, where cost pass-through, in contrast to the electricity markets in other European countries, is not possible.

Das Wichtigste in Kürze

Dieses Papier untersucht die Aktienmarkteffekte von Preisentwicklungen auf dem Markt für Emissionszertifikate im Rahmen des Europäischen Emissionshandelssystems (EU ETS). Die Analyse fokussiert dabei auf die Aktienmarktperformance des europäischen Elektrizitätssektors, der gemessen an CO2-Emissionen größten Branche im EU ETS. Nach unseren Ergebnissen spielt der Zertifikatmarkt eine wichtige Rolle für die Aktienentwicklungen der analysierten Elektrizitätsfirmen. Ein Anstieg des Zertifikatpreises sorgt für Kursgewinne bei den Aktien der Elektrizitätsfirmen aus fast allen europäischen Ländern. Hingegen scheint die Volatilität der Emissionsrechte entgegen anderslautender Erwartungen nicht auf die Aktienkursentwicklung der untersuchten Unternehmen zu wirken.

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Abstract: This paper constitutes – to our best knowledge – the first econometric analysis on stock market effects of the EU Emission Trading Scheme (EU ETS). Our results suggest that EU Emission Allowance (EUA) price developments matter to the stock performance of electricity firms: EUA price changes and stock returns of the most important European electricity corporations are shown to be positively related. This effect does not work asymmetrically, so that stock markets do not seem to react differently to EUA appreciations in comparison to depreciations. The carbon market effect is shown to be both time- and country-specific: It is particularly strong for the period of EUA market shock in early 2006, and differs with respect to the countries where the electricity corporations analysed are headquartered. Stock market reactions to EUA volatility could not be shown.

Keywords: EU ETS; electricity stocks; asset pricing

JEL classification: Q48; Q43; G12; C13

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I. Introduction

In 2005, the European Union Greenhouse Gas Emission Trading Scheme (EU ETS) was launched. Against the institutional background of the Kyoto Protocol that requires European countries to reduce their greenhouse gas emissions on average by 8% until 2012 compared with 1990 emissions levels (UNFCCC, 1997), the EU ETS represents a cornerstone of the EU member states' climate policy. Applying to four industrial sectors in its first phase (2005 to 2007)[1], the ETS covers approximately 46% of the total CO2 emissions of EU countries. The energy sector, and, at the sub-sectoral level, the electricity industry is the most dominant player within the scheme. Of some 10 000 installations covered, approximately 3600 are affiliated to the power and heating industry. These installations make up 1.2 billion tons of CO2 emissions within the scheme, while overall ETS emissions do not even reach 2 billion tons (Ellerman and Buchner, forthcoming).

Although overall allowance allocation in the first phase of the scheme has been qualified as relatively generous by many scholars (e.g. Ellerman and Buchner, forthcoming, Kettner et al., 2008), since its initiation the EU ETS has led to discussions on potential losses in competitiveness for the companies covered. According to Neuhoff et al. (2006), due to the sequential allocation process of EU ETS, decisions in the power sector are distorted. Moreover, the electricity sector seems to be rather an exception as far as generous allowance allocation is concerned. Buchner et al. (2006) show that this sector has been the only one that faced a net short position already in 2005. The authors attribute the relatively stringent allowance allocation for this sector to both the absence of international competition and the assumption of comparably low emission abatement costs in electricity generation.

Previous quantitative studies have assessed the economic implications of the EU ETS predominantly in numerical modelling frameworks. Böhringer et al. (2005) show that the exclusive coverage of energy-intensive installations by the ETS implies that – in the absence of the Kyoto Protocol's project-based mechanisms – the remaining industries outside the ETS have to be regulated by complementary abatement policies in order to meet the national Kyoto targets. This implies that under a generous ETS cap, negative economic effects may be much larger for sectors outside than inside the ETS. Assessing both the economy-wide and the sectoral competitiveness effects of the EU ETS, Alexeeva-Talebi and Anger (2007) argue that the burden on ETS sectors might be minimised even under ambitious caps of the scheme if the project-based mechanisms of the Kyoto Protocol are available and if the EU ETS is linked to other emerging trading systems outside Europe.

Empirical evidence on the economic consequences of EU ETS is, in contrast, rather scant. Demailly and Quirion (forthcoming) provide a case study on the iron and steel industry, suggesting that losses in competitiveness for this sector are small. From a case study for the German electricity industry, Hoffmann (2007) concludes that, while being an important driver for small-scale investments, EU ETS has only limited impact on large-scale investment. Zachmann and von Hirschhausen (forthcoming) analyse the impact of EU Emission Allowance (EUA) price developments on German wholesale electricity prices; they find evidence for an asymmetric cost pass-through in a sense that rising EUA prices affect electricity prices more strongly than falling EUA prices. They attribute this finding to either slowly developing knowledge about EUAs as a cost factor or to a possible exercise of market power by German electricity generators. Anger and Oberndorfer (2008) analyse the impact of relative allowance allocation on both economic performance and employment of German

[1] These sectors are energy (e.g. electric power, oil refinement), production and processing of ferrous metals, minerals (e.g. cement, glass), as well as pulp and paper.

companies using econometric techniques. They do not find evidence for revenue and employment effects of relative allowance allocation. The impact of EUA price developments on firm performance, in contrast, has not yet been analysed, yet. In this respect, this paper aims at starting to fill this gap. The focus is on financial market impacts of EU allowance price developments for European electricity corporations, i.e. for firms of the most important EU ETS sector (as measured by its emissions).

In this respect, this analysis represents an early approach of policy evaluation with regard to the scheme: Against the background of stock prices representing discounted cash flows of the respective corporations (Fama, 1970), we assess how the market for EU Emission Allowances (the so-called carbon market[2]) affects the value of corporations covered by the scheme. The EUA price effect is especially relevant for the future development of the EU ETS. Already in the second ETS phase (which started in 2008), regulation by allowance allocation via grandfathering has become more stringent (Schleich et al., 2007). Such development is expected to continue given the climate policy goals of the EU aiming at an emission reduction in greenhouse gases of 20% by 2020 (30% if there is an international agreement committing other developed countries to comparable emission reductions, European Commission, 2008). As shown by numerical simulations, the stricter the allowance allocation, the higher is the EUA price (cp. e.g. Anger, 2008). This result underlines the importance of knowledge concerning the stock market effects as an indicator of economic effects of EUA price developments. Particularly, if corporations covered by the scheme were upvalued by EUA price rises that indicate stringency of regulation within the ETS, free allowance allocation to these corporations could be questioned: Free allocation can act as a temporary subsidy to support firm balance sheets, which may be justified for sectors to which production cost increases as indicated by EUA price rises may not be passed on to the consumers particularly due to international competition (Hepburn et al., 2006). The values of corporations from such sectors, however, should not increase when the EUA price rises. Apart from policy evaluation with respect to possible EUA price effects on the value of corporations covered by the EU ETS, the question about how financial markets perceive carbon constraints that may emerge due to ETS regulation has been qualified as very important from a corporate management point of view (Busch and Hoffmann, 2007). This knowledge is particularly important for hedging against EUA price risks, enabling investors to take into account feedback from the stock market when the EUA price moves.

In this paper, we analyse electricity stock return reactions to changes in EU Emission Allowance prices. We take into account possible differences in such a relationship over time – with respect to the EUA market shock in early 2006 – as well as between corporations. This is particularly relevant to corporations operating in different countries that are marked by differences especially in allowance allocation (and therefore in possibly different initial EUA long / short positions) according to the different National Allocation Plans (NAPs) or in the structure of the respective electricity market, possibly affecting EUA cost pass-through behaviour. We investigate whether the relationship between EUA price changes and electricity stock returns is asymmetric, which would be consistent with the EUA effect on German wholesale electricity prices. Additionally, we apply a GARCH approach in order to test whether EUA return volatility and European electricity stock volatility are related. The remainder of this paper is structured as follows: The following chapter presents the three main hypotheses for our empirical investigation. In chapter three, we highlight our methodological

[2] The markets for certificates such as Certified Emission Reductions (CERs), Emission Reduction Units (ERUs) and Voluntary Emission Reductions (VERs) are also emerging carbon markets; because of the particular relevance of EUAs is the context of this study, these markets are neglected here and "carbon market" is used as a synonym for the market for EU Emission Allowances here.

approach; in section four we describe the dataset. Chapter five gives the results of the econometric examination. Chapter six concludes.

II. Hypotheses

Hypothesis 1: EU Emission Allowance price increases (decreases) positively (negatively) affect electricity stock returns.

Benz and Trück (2006) specify EU Emission Allowances as a factor of production held by the respective firm: EUAs are exhausted for CO2 emission and removed from the market after utilisation. In this respect, EUA price changes directly change the value of EUAs held and therefore the value of the respective firm (i.e. increase in case of EUA appreciations, and vice versa). Moreover, economic theory, modelling studies as well as the first empirical papers available suggest that the EU ETS and especially developments in the EU carbon market influence cash flows of the companies covered by the scheme. While generally high prices of CO2 emission could be interpreted as an indicator of stringency of regulation shrinking future cash flows, scholars have argued that under the EU ETS effects could work differently. Following Sijm et al. (2006), profits for the marginal production unit for electricity will rise by the respective CO2 costs for this unit if Emission Allowances are fully grandfathered. Profit increases for the infra-marginal unit (under full grandfathering) will depend on the carbon intensity of this unit relative to the intensity of the marginal unit, and will consequently be lower than the CO2 costs for the production unit only if the infra-marginal unit is more carbon-intensive than the marginal unit.[3] This suggests that, under full grandfathering[4], electricity generators can profit from EU ETS and that the profit increase itself is positively related to the EUA prices. Against this background, expected future cash flows of electricity generators covered by the ETS should rise (fall) with rising (falling) EUA prices, leading to rising (falling) stock returns under the hypothesis of efficient capital markets (if financial markets incorporate news into security prices without delay, e.g. Fama, 1970). It is possible, however, that the amplitude of this effect itself depends particularly on country-specific characteristics such as differences in EUA long / short positions due to country-specific NAPs (i.e. relative allowance allocation) and the structure of the national electricity market in which a corporation operates. Moreover, it is unclear whether such an effect would be stable over time, particularly with respect to the EUA market shock in early 2006 that caused a structural break in the EUA prices (Alberola et al., 2008a).

Hypothesis 2: The relationship between EU Emission Allowance price changes and electricity stock returns is asymmetric.

Zachmann and von Hirschhausen's (forthcoming) estimation results suggest that – at least in Germany – electricity generation businesses can increase their future cash flows in times of rising EU Emission Allowance prices, as these price rises are passed through to the wholesale electricity market. In contrast, cash flows would barely shrink in case of falling EUA prices, as electricity prices seem to respond less strongly to falling in comparison to rising EUA prices. Given this, expected future cash flows and therefore stock returns of European electricity corporations should respond asymmetrically to EUA price developments. However,

[3] This reasoning does only hold if emission trading does not lead to a change in the merit order and if the electricity demand response to the price increases induced is not large enough to stop the operation of a set of power generators (Sijm et al., 2006).

[4] Although auctioning of up to 5% of total EUAs was permitted during the first phase of the scheme (2005-2007), the member states made little use of this option. Almost all emission allowances were grandfathered by means of National Allocation Plans.

reasons for an asymmetric cost pass-through are largely unknown – Zachmann and von Hirschhausen (forthcoming) propose market power as well as little knowledge of the recently developed ETS market as explanations – as is the answer to the question whether such an asymmetric cost pass-through applies to the German wholesale electricity market only or to all European electricity markets, including long-term and consumer-specific electricity contracts that are widespread. Against this background, the relationship between EUA price changes and stock returns from electricity corporations could be asymmetric, and these asymmetric effects could be country-specific.

Hypothesis 3: EUA volatility is positively related to electricity stock return volatility.

Not only appreciations and depreciations in levels of the EU Emission Allowances may matter for the market development of electricity stocks. An increase (decline) in volatility in the market for EUAs should render the expectations for future cash flows of the corporations covered more (less) volatile. This issue is of special relevance given the high volatility of the EUA price since the establishment of the EU ETS; hedging against unexpected carbon price fluctuations is an important issue here (Benz and Trück, forthcoming). Moreover, price volatility of stocks is highly relevant for the attractiveness of the respective asset for potential investors. In the context of a simple (μ,σ)-rule (Markowitz, 1952), for instance, both the – desired – expected return and the – undesired – volatility matter to portfolio selection.

III. Empirical Approach

The main objective of this paper is to address the impacts of EU Emission Allowance price developments on stock performance of European electricity corporations. For this purpose, on the one hand, we make use of an equal-weighted portfolio of the most important electricity stocks from the Eurozone. On the other hand, we analyse stock returns of these corporations in disaggregated form within the framework of a panel approach, i.e. for a richer dataset and without loss of information due to portfolio aggregation. This allows for identifying firm-specific EUA effects (e.g. with respect to the countries where the corporations analysed are headquartered), while we have to refrain from analysing stock return volatility in this framework, as Panel GARCH models are a topic of current econometric research (Cermeno and Grier, 2003).

In order to avoid misspecification of the econometric approach, we include the market return as well as oil, gas, and electricity price changes as control variables into the estimated equations. The relationship between the market return and the returns of single stocks or stock portfolios has its theoretical foundations in the Capital Asset Pricing Model (CAPM; Sharpe, 1964, and Lintner, 1965), suggesting that the reward-to-risk ratio for any security (such as a stock) in relation to that of the overall market is the decisive factor for the pricing of the respective security. However, the existing literature has also stressed the importance of resource price change variables as determinants of energy stock prices. Manning (1991) for the UK oil industry, Hammoudeh et al. (2004) for its U.S. counterpart, Faff and Brailsford (1999) for the Australian oil and gas sector, and Sadorsky (2001) and Boyer and Filion (2007) for the Canadian energy industry show that besides the market return, the oil and, in some cases, the gas price change may be important drivers of stock returns of energy-related businesses. European energy stocks, according to Oberndorfer (2008), are sensitive to oil, but not to gas price changes. Moreover, Oberndorfer (2008) shows that energy stock volatility is not related to volatility in the resource market.

The inclusion of oil and gas price changes as explanatory variables for electricity stock returns is especially important given the possibility that resource price changes may not only be drivers of energy stock prices, but also of the EUA price itself (e.g. Mansanet-Bataller et al., 2007). In this respect, the exclusion of (statistically significant) resource price variables – as well as of electricity price variables that are affected by the EUA prices themselves (Zachmann and von Hirschhausen, forthcoming) – may cause severely biased estimates with respect to the effect of the EUA price change on electricity stock returns. This could result in a statistically significant EUA effect that is simply due to impacts of resource or electricity price developments. In this respect, our basic approach with regard to the analysis of the electricity stock portfolio is:

$$r_t = \alpha + \beta_1 r_{m,t} + \beta_2 r_{eua,t} + \beta_3 r_{o,t} + \beta_4 r_{g,t} + \beta_5 r_{e,t} + \varepsilon_t \tag{1}$$

Here, r_t and $r_{m,t}$ are the returns for the electricity stock portfolio and the market portfolio at the end of period *t* (i.e., between *t*–1 and *t*). Equation (1) additionally includes the change of the EUA price $r_{eua,t}$, the change of the oil price $r_{o,t}$, of the gas price $r_{g,t}$, and of the electricity price $r_{e,t}$. ε_t is the disturbance term with $E(\varepsilon_t) = 0$ and $\mathrm{var}(\varepsilon_t) = \sigma^2$. α and β_1, β_2, β_3, β_4, β_5 besides σ^2 are the unknown parameters that have to be estimated by OLS.

We additionally use a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) application. Models of the GARCH-class (Bollerslev, 1986) are very appealing approaches for the analysis of high-frequent time series in financial markets. The reason for this is the fact that they address the phenomenon of volatility clustering, i.e. of a positive correlation between current and past volatility of asset returns. Amongst those approaches, the use of the GARCH(1,1) model (i.e. an ARMA(1,1) model for the conditional variance of the mean equation error term that is jointly estimated with the mean equation itself, here as usual by maximum likelihood) is widespread as it generally sufficiently explains systematic variation of asset price volatility (cp. e.g. Andersen and Bollerslev, 1998). We augment such GARCH(1,1) framework by including EU Emission Allowance, oil, gas and electricity volatility variables into the variance equation. Doing this, we allow for the conditional variance of the ideosynchratic error term of the portfolio to be not only determined by its own dynamics, but also by "external" factors. In this respect, our approach relates to the literature of so-called volatility spillovers (cp. e.g. Hamao et al., 1990) – in our setting from the energy (including the carbon) market to the stock market segment of electricity corporations.

$$r_t = \alpha + \beta_1 r_{m,t} + \beta_2 r_{eua,t} + \beta_3 r_{o,t} + \beta_4 r_{g,t} + \beta_5 r_{e,t} + \varepsilon_t \tag{2}$$

$$h_t = a + b h_{t-1} + c\varepsilon_{t-1}^2 + d_1 v_{eua,t} + d_2 v_{o,t} + d_3 v_{g,t} + d_4 v_{e,t} \tag{3}$$

$v_{eua,t}$ represents EUA volatility, $v_{o,t}$ oil volatility, $v_{g,t}$ gas volatility, $v_{e,t}$ electricity volatility. We assume (Student) *t*-distribution for the zero mean error term ε_t. h_t is the conditional variance of the error term. α, β_1, β_2, β_3, β_4, β_5, a, b, c, d_1, d_2, d_3 and d_4 besides h_t are the unknown parameters that are estimated by maximum likelihood.

As indicated, we additionally apply a panel data approach taking into account disaggregate stock returns $r_{i,t}$ of all electricity corporations *i* forming the portfolio, allowing for the use of a much richer dataset in both observations and information compared to a portfolio approach (cp. e.g. Boyer and Filion, 2007). The respective approach can thus be formulated as

$$r_{i,t} = \alpha + \beta_1 r_{m,t} + \beta_2 r_{eua,t} + \beta_3 r_{o,t} + \beta_4 r_{g,t} + \beta_5 r_{e,t} + \varepsilon_{i,t} \, . \quad (4)$$

Variable definition and parameter estimation via OLS is analogous to equation (1). This basic panel framework is augmented by interaction terms between the EUA price change $r_{eua,t}$ and country-specific indicator variables in order to take into account country-specific stock market effects of EUA price developments.

Additionally, in all approaches interaction terms between the EUA price change and an indicator variable that takes the value of zero for EUA price decreases (as well as for price changes of zero) and the value of one for EUA price increases are incorporated in order to take into account possible asymmetries in the relationship between the EUA price change and the electricity stock and portfolio returns respectively. Moreover, in the panel approach this variable is also interacted with country indicator variables as described above in order to test for country-specific asymmetries. As a further model extension for all approaches, an interaction term between the EUA price change and an indicator variable for the EUA market shock period in early 2006 and for the period before this market shock respectively are incorporated into the empirical analysis.

IV. Data and Variables

Our analysis covers roughly the first period of the European Union Emission Trading Scheme, with a constraint for the very early ETS phase for which no EU Emission Allowance price data is available: We have a sufficient data basis for the EU Allowance settlement price (and for all other variables) from August, 4, 2005 until June 19, 2007. [5] Given this sample period of barely two years, daily data is the only realistic frequency for our econometric approach as weekly or monthly data would provide too few observations in order to conduct a serious time series analysis. In this respect, we are fully aware of the fact that low frequency data (i.e. weekly or monthly data) is often preferred in comparison to daily data in order to circumvent errors-in-variables problems in terms of irregularities, which is especially due to low – daily – trading (volumes) (cp. e.g. Scholes and Williams, 1977). As electricity corporations in general (and this also holds for the corporations considered here) are stocks with high trading volumes, such errors-in-variables problems should be negligible in our setting. EUA settlement price data stems directly from the European Energy Exchange (EEX), Leipzig. This is, together with Nord Pool, European Climate Exchange, and Powernext, the predominant EUA marketplace. EUA price data from EEX, Leipzig, is publicly available for scientific use and free of charge. Moreover, as reported by Mansanet-Bataller et al. (2007), EUA prices have developed very similarly in all marketplaces, so that the choice of marketplace should not be crucial for the analysis. All other series used in our analysis are taken from Datastream (Thomson Financial).

Stock returns of the most important electricity corporations whose business is affected by EU ETS form the dependent variable of our analysis. The return series are analysed individually (pooled) within a panel data framework, as well as aggregated within an equal-weighted portfolio. For the analysis, we choose electricity corporations included in the Dow Jones Euro Stoxx Utilities Index (as at August 1, 2007), for which financial market (return) data is

[5] This corresponds to the length of the EUA settlement price time series the European Energy Exchange (EEX), Leipzig, made available to the authors. Generally, it seems difficult to integrate data from late 2007, as EUA prices did barely vary at that period due to the high relative allocation within the scheme.

available for the whole sample period. Corporations whose main business activity is the generation (and distribution) of electricity from renewable resources have been excluded given their low exposure to the ETS regulation. All in all, the corporations forming our stock portfolio are Aem (Italy - IT), British Energy Group (United Kingdom - UK), Eon (Germany - GE), Endesa (Spain - ES), Enel (IT), Energias de Portugal (Portugal - PO), Fortum (Finland - FI), Iberdrola (ES), International Power (UK), RWE (GE), Scottish & Southern Energy (UK), and Union Fenosa (ES). The electricity portfolio return series (as well as all individual stock return series; results available on request) is stationary according to a Dickey-Fuller unit root test (Table 4).[6]

As explanatory variable of main interest we include the EUA settlement price change into our analysis. This series reflects the EUA price developments at the EEX, Leipzig. Although future or forward prices are less affected by very short run demand and supply fluctuations and therefore less noisy in comparison to spot prices (cp. Sadorsky, 2001), we opted for the settlement price instead of an EUA future from the EEX as there is little trade at the future in comparison to the spot market. The use of EUA futures would be very problematic for our analysis relying on daily data given the fact that for a multitude of days included in our sample period, price changes taking the value of zero due to trading volumes of zero would occur. Such a problem is avoided by using the EUA settlement price (change). The EUA price, together with price data of the electricity stock portfolio, is graphically shown in Figure 1. Besides the EUA price change variable as such, an interaction term with an indicator variable that takes the value of zero for EUA price decreases (as well as for price changes of zero) and the value of one for EUA price increases is also applied in order to take into account possible asymmetric stock market effects from the carbon market.

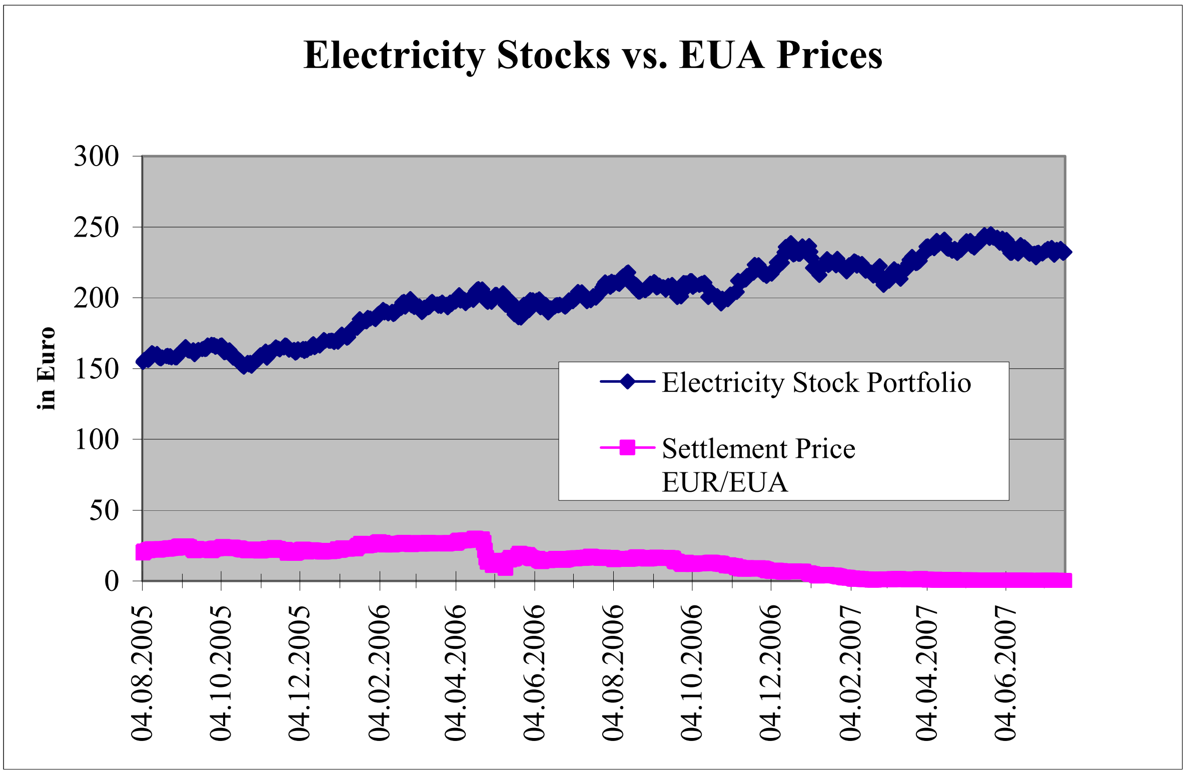

Figure 1 EUA and electricity stock portfolio price data for the sample period

[6] A unit root test without trend term was conducted for these as well as for all other variables used. According to visual inspection, none of the series exhibits trends.

As indicated in the previous section and shown in Figure 1, the release of emissions data revealing long EUA positions in nearly all countries covered by the EU ETS (Ellerman and Buchner, forthcoming) evidently led to a fall (without subsequent recovery) in EUA prices from nearly 30 euros in late April to approximately 10 euros in early / mid May. We created interaction terms between the EUA price change and an indicator variable taking the value of one for the EUA market shock period in early 2006 (26 April to 10 May, 2006; zero otherwise) as well as for the period previous to this market shock (until 25 April; zero respectively). Moreover, interaction terms between the EUA price change and the dummy variables taking the value of one (zero otherwise) for the country where the respective corporation is headquartered have been generated for the panel analysis. We have created such interaction terms for the corporations stemming from Germany, UK and Italy well as an aggregate indicator variable for the countries with only one corporation in the sample (Portugal and Finland; "others"). This means that in the panel analysis, corporations from Spain constitute the so-called reference category with respect to the EUA effect, to which the interaction terms refer. The choice of the reference category is technically inescapable and does not affect the overall regression results (e.g. Greene, 2003). In addition, the same procedure is followed in order to test for country-specific asymmetric effects.

The market return for our analysis is calculated from the Dow Jones Euro STOXX. It is the broadest market index of the Eurozone stock market, representing large, mid and small capitalisation companies of all Eurozone members. It has a varying number of components (September 2007: 317 corporations). In order to control for a possible impact of oil price changes on the electricity stock returns, we use the (Crude Oil) Brent time series (euros per barrel). Brent is the most relevant traded crude for European energy firms. In accordance with existing literature, we use a (one month) forward instead of spot return of this series. Consequently, we use the change of the one month forward natural gas time series from Intercontinentalexchange (ICE, London; euros per 100 000 British Thermal Units). We choose this time series for natural gas, since gas trading at the EEX, Leipzig, only started in 2007 and EEX gas data is therefore not available for our whole sample period. Besides ICE and EEX, only the APX, Zeebrugge, is another European gas marketplace. However, as gas trading is a very recent activity here as well (since 2005), we opted in favour of the ICE data. The disadvantage of using ICE data, however, is that UK gas prices may be driven by fundamentals of its domestic supply and demand if the UK interconnector to Belgium is full or shut down, so that prices may temporarily decouple from continental gas prices (Kjärstad and Johnsson, 2007). Generally, UK and continental gas prices are, however, closely related due to arbitrage possibilities. The choice of the electricity price series is even more difficult, as no common market for electricity in the EU exists. Although price differences have significantly diminished over the last years, convergence of European electricity prices has not been achieved (Zachmann, forthcoming). In order to stick most closely to the EUA price data, we opted for the Phelix Month Base from the EEX, Leipzig (euros per Mega Watt Hour). This series reflects German electricity prices. As Germany is the biggest electricity market in Europe (and the EEX is one of the most liquid European power exchanges, cp. e.g. Zachmann, forthcoming), German electricity prices may be the best available proxy for overall European electricity price developments.

In order to analyse whether EUA volatility and electricity stock return volatility are related, we incorporate different volatility variables in our framework. As explanatory volatility variables, we include the squared EUA, oil, gas, and electricity price changes into our empirical approach. These volatility variables are constructed in a very similar way compared to Hamao et al.'s (1990) "volatility surprises" from stock markets: The authors use the squared residuals from estimated augmented market models for the respective markets as volatility terms. However, given the fact that price changes from the energy market (which we consider instead of stock markets in Hamao et al., 1990) are generally not explained by an (augmented) market model, our approach seems more adequate for this special setting.

A look at the correlations between the variables considered in this analysis reveals that the dependent variable is strongly and positively related to the market excess return (Table 5). The correlation between EUA price change and electricity stock portfolio return is positive as well. Amongst the explanatory variables, the EUA price change correlates relatively strongly with resource price returns, underpinning the findings of Mansanet-Bataller et al. (2007). The absolute values of the correlation coefficients are modest, though, so that multicollinearity should not be too severe in our setting.[7]

V. Results

Basic Specification and Asymmetries

Estimating Equation (1) and (4), we mostly obtain the results we expected (Table 1). They suggest a highly significant positive impact of the market return on electricity stock returns (with an estimated beta factor smaller than one). For oil, gas, and electricity price changes, however, no clear evidence for the direction of the impact on electricity stock returns (or, respectively, for an impact at all) is indicated. The findings particularly of the panel analysis, indicating a negative effect of oil price changes, are consistent with the previous literature on energy stocks. According to different specification tests reported in Table 1, there is no indication of any misspecification of our empirical approach.

Results of all specifications reported in Table 1 are consistent with Hypothesis 1 formulated above and therefore provide empirical evidence for a positive impact of the EUA price change on electricity stock returns. Regressing the above described electricity stock portfolio return on the full set of explanatory variables (Equation (1)) yields a statistically even highly significant coefficient for the EUA price change variable. This result holds when making use of a Pooled OLS panel specification (Equation (4)). The value of the estimated EUA coefficient (0.01 to 0.02 for all settings) is modest. According to an F-Test, the null hypothesis of no Fixed (i.e. corporation specific) Effects cannot be rejected at any conventional level for this and all following specifications, indicating that Pooled OLS gives consistent and efficient results. We therefore refrain from reporting Fixed Effects estimation results.

[7] Some of the correlations between energy price variables are lower than expected, particularly between the gas price change and both the oil and electricity price change, respectively. One reason for this finding may be the fact that gas prices observed at European energy exchanges seem to be rather neglected by financial market agents, probably due to the widespread use of long-term gas contracts (e.g. Siliverstovs et al., 2004, Oberndorfer, 2008).

Table 1 Results Basic Specification and Asymmetries

	(1)	*(4) Pooled OLS*	*(1)Asymmetry*	*(4) Pooled OLS Asymmetry*
α	0.00 (0.00)	0.00*** (0.00)	0.00 (0.00)	0.00** (0.00)
β_1 (market)	0.74*** (0.04)	0.74*** (0.02)	0.73*** (0.05)	0.74*** (0.02)
β_2 (eua)	0.02*** (0.01)	0.01*** (0.00)	0.02** (0.01)	0.01** (0.00)
β_3 (oil)	0.04* (0.02)	-0.01* (0.01)	0.04* (0.02)	-0.01 (0.01)
β_4 (gas)	0.01* (0.01)	0.00 (0.00)	0.01* (0.01)	0.00 (0.00)
β_5 (electricity)	-0.00 (0.00)	0.00** (0.00)	-0.00 (0.00)	0.00** (0.00)
***δ* (asymmetric eua)**	-	-	-0.00 (0.01)	0.00 (0.00)
Obs.	481	5772	481	5772
R-squared	0.34	0.19	0.34	0.19
F-Test	61.72***	273.75	41.53***	228.14***
Wald-Test (Chi-sq.)	-	-	-	-
ARCH (Chi-sq.)	0.04	-	0.04	-
BG-Autoc. (Chi-sq.)	0.33	-	0.34	-
Durb. Autoc. (Chi-sq.)	0.33	-	0.33	-
RESET-Test	1.44	-	1.42	-

Note: Standard errors in brackets (OLS estimations: White heteroskedasticity-robust s.e.). *, ** and *** show significance at the 10%-, 5%-, and 1%-level, respectively. None of the specification tests indicates misspecification.

Whereas generally EUA price changes affect stock returns of European electricity corporations, we do not find evidence for an asymmetric reaction of electricity stock returns to EUA price changes. In contrast to the results provided by Zachmann and von Hirschhausen (forthcoming) suggesting asymmetric responses of wholesale electricity prices to EUA price changes, and in contrast to Hypothesis 2, such an asymmetric relationship cannot be observed in the stock market. An interaction term between a dummy variable taking the value of one when EUA price changes are positive (and zero otherwise) and the EUA price change itself added to Equation (1) does not yield any statistical significance. This result is unaffected by the elimination of insignificant explanatory variables.[8]

GARCH-Approach and Market Shock

The highly significant positive EUA effect on the electricity stock portfolio returns also holds when using a GARCH approach. The specification based on Equation (2)/(3) allows for identifying the structure of the Equation (1) error term's conditional variance by its own dynamics and "external" factors (spillovers from other markets). The results from Equation (2)/(3) suggest, however, that electricity stock return volatility is not related to EUA price (change) volatility (Table 2). Moreover, we get no evidence for a statistically significant effect of oil, gas, and electricity market volatility on electricity stock volatility. This result is not affected by excluding statistically insignificant control variables from the empirical framework. In this respect, Hypothesis 3 suggesting a positive relationship between EUA volatility and electricity stock return volatility is not supported by the empirical results. Moreover, the results of an ARCH LM test do not indicate that volatility clustering is present in the electricity stock portfolio, so that the formulation of a GARCH approach is not beneficial in comparison to OLS.

[8] The missing evidence for asymmetry in the relationship between EUA price changes and electricity stock returns has also proved robustness over different approaches in modelling such asymmetry. For brevity, only the specification lined out in chapters III and IV has been reported here. All other regression results, including specifications from which insignificant explanatory variables have been excluded, are available on request.

In contrast, independently of basing the analysis on Equation (1), (2)/(3), or (4), we find evidence for a particularly strong impact of EUA price changes on electricity stock returns during the period of market shock in April / May 2006, when EUA prices fell from nearly 30 euros to approximately 10 euros in a few days only. During these days, the EUA effect is shown to be highly significantly stronger than later on during the sample period. In contrast, no statistically significant difference in the EUA effect during the pre-market shock period compared to the period after the shock can be shown. Moreover, the volatility analysis has not shown to be sensitive to the EUA market shock. Corresponding results have not been included in the manuscript, but are available from the authors on request.

Table 2 Results GARCH Specification and Market Shock

	(2)/(3) GARCH (1,1)	*(2)/(3) GARCH (1,1) Market Shock*	*(1)Market Shock*	*(4) Pooled OLS Market Shock*
Mean Equation				
α	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00*** (0.00)
β_1 (market)	0.74*** (0.04)	0.74*** (0.04)	0.73*** (0.04)	0.74*** (0.02)
β_2 (eua)	0.02*** (0.01)	0.01* (0.01)	0.01** (0.01)	0.00* (0.00)
β_3 (oil)	0.04* (0.02)	0.04 (0.02)	0.04 (0.02)	-0.01 (0.01)
β_4 (gas)	0.01 (0.01)	0.01 (0.01)	0.01* (0.01)	0.00 (0.00)
β_5 (electricity)	-0.00 (0.01)	-0.00 (0.01)	-0.00 (0.00)	0.00* (0.00)
γ_1 (eua pre-market shock)	-	0.05 (0.03)	0.04 (0.03)	0.02 (0.01)
γ_2 (eua market shock)	-	0.04* (0.02)	0.03*** (0.01)	0.03*** (0.01)
Variance Equation				
a	-14.57*** (0.54)	-14.71*** (3.65)	-	-
***b* (GARCH (1) term)**	0.96*** (0.04)	0.96*** (0.04)	-	-
***c* (ARCH (1) term)**	0.03 (0.02)	0.03 (0.02)	-	-
d_1 (eua volatility)	10.15 (14.91)	11.99 (13.22)	-	-
d_2 (oil volatility)	1177.74 (1468.04)	1245.85 (1516.15)	-	-
d_3 (gas volatility)	14.21 (52.63)	12.87 (61.25)	-	-
d_4 (electricity volatility)	16.11 (15.08)	16.56 (15.93)	-	-
Obs.	481	481	481	5772
R-squared	-	-	0.35	0.19
F-Test	-	-	46.02***	196.01***
Wald-Test (Chi-sq.)	846.86***	305.43	-	-
ARCH (Chi-sq.)	-	-	0.05	-
BG-Autoc. (Chi-sq.)	-	-	0.55	-
Durb. Autoc. (Chi-sq.)	-	-	0.54	-
RESET-Test	-	-	1.30	-

Note: White heteroskedasticity-robust standard errors in brackets *, ** and *** show significance at the 10%-, 5%-, and 1%-level, respectively. None of the specification tests indicates misspecification.

Country-Specific EUA Effects

Analysing disaggregated electricity stock returns within a panel data framework suggests that the EUA effect on the stock market is country-specific. An F-Test on the joint significance of country interaction terms with the EUA price change (Table 3) leads to the rejection of the null hypothesis of no country-specific EUA effects at any conventional level. In this setting (column 1), Spanish electricity corporations as the baseline even exhibit a significantly (but small as far as the size of the estimated coefficient is concerned) negative relationship between EUA price changes and stock returns. The relationship for electricity corporations from all other countries covered significantly differs from this. All country-specific EUA interaction term coefficients are positive and significantly differ from zero at least at the 5%-level, and their absolute values suggest an overall positive EUA effect for nearly all countries considered. The coefficient is highest for the UK corporations covered. Also the market shock interaction term coefficient remains highly significant in this setting.

Table 3 Results Country-Specific EUA-Effect

	(4)Pooled OLS Country-Specific EUA Effect	*(4) Pooled OLS Country-Specific EUA Effect and Asymmetry*
α	0.00*** (0.00)	0.00* (0.00)
β_1 (market)	0.74*** (0.02)	0.74*** (0.02)
β_2 (eua)	-0.01** (0.00)	-0.02*** (0.01)
β_3 (oil)	-0.01 (0.01)	-0.01 (0.01)
β_4 (gas)	0.00 (0.00)	0.00 (0.00)
β_5 (electricity)	0.00* (0.00)	0.00* (0.00)
γ (eua market shock)	0.03*** (0.01)	0.03*** (0.01)
θ_1 (eua germany)	0.02*** (0.01)	0.03*** (0.01)
θ_2 (eua united kingdom)	0.03*** (0.01)	0.03*** (0.01)
θ_3 (eua italy)	0.01** (0.01)	0.02** (0.01)
θ_4 (eua other)	0.02** (0.01)	0.02** (0.01)
δ (asymmetric eua)	-	0.01 (0.01)
κ_1 (asymmetric eua germany)	-	-0.01 (0.02)
κ_2 (asymmetric eua united kingdom)	-	-0.01 (0.02)
κ_3 (asymmetric eua italy)	-	-0.01 (0.01)
κ_3 (asymmetric eua other)	-	-0.00 (0.02)
Obs.	5772	5772
R-squared	0.19	0.19
F-Test	139.70***	93.81***
F-Test on country-specific interaction terms	5.02***	-
F-Test on country-specific asymmetry interaction terms	-	0.56

Note: White heteroskedasticity-robust standard errors in brackets *, ** and *** show significance at the 10%-, 5%-, and 1%-level, respectively. None of the specification tests indicates misspecification.

In contrast, there is no evidence for an asymmetric effect of the EUA price change on electricity stock returns for any of the countries represented in our sample. None of the coefficients referring to such an asymmetric effect shows significance at any conventional level. Moreover, an F-Test on the joint significance of country interaction terms with the asymmetric EUA price change does not indicate the presence of such asymmetric effects.

VI. Conclusions

This paper constitutes – to our knowledge – the first econometric analysis on stock market effects of the EU Emission Trading Scheme. We analyse electricity stock return reactions to changes in EU Emission Allowance prices, taking into account possible asymmetries in the relationship between EUA price changes and electricity stock returns, as well as country- and time-specific effects. Moreover, within the framework of a GARCH approach we test whether

EUA return volatility and European electricity stock volatility are related. Our results suggest that EUA price increases (decreases) positively (negatively) affect stock returns from the most important electricity corporations covered by the EU ETS. In this respect, the electricity corporations considered are upvalued in case of an EUA appreciation, and downvalued in situations where the price of EU Emission Allowances falls. However, the effect differs from country to country: Amongst the electricity corporations considered, Spanish corporations are shown to exhibit a negative EUA-to-stock market relationship. In contrast, the effect is positive for corporations from other countries such as Germany and the UK. Stock markets do not seem to react differently to EUA appreciations in comparison to depreciations. Moreover, electricity stock return and EUA price change volatility are not shown to be positively related.

Given these results, it becomes apparent that EU ETS effectively has an impact on financial (stock) markets and therefore has economic consequences, affecting the value of the corporations covered. While Anger and Oberndorfer (2008) cannot show economic impacts of relative EU Emission Allowance allocation, price developments of the EUA market matter from an economic and financial market point of view, a finding that may be important for investors e.g. seeking to hedge against EUA price risks. The first ETS phase seems to be marked at least to some extent by uncertainty of financial market agents concerning the importance of the newly created EU carbon market for the stock market: The EUA effect on electricity stocks is shown to vary over time, being especially high during the EUA market shock in early 2006. Such a "premium" on the EUA effect could be based on the exceptionally high attention of the general public (and seemingly also of stock market agents) to the carbon market at that time. In this respect, the results shed new light on Zachmann and von Hirschhausen's (forthcoming) claim of slowly developing knowledge concerning the European Emission Allowances amongst financial market agents. The fact that EUA price changes positively affect European electricity stocks (at least for most countries analysed) is the consequence of fully rational electricity pricing under a grandfathering allocation rule if pass-through for costs created by the ETS is possible: Against the background of the European carbon market, opportunity costs of fossil power generation according to the EUA price exist. Due to the design of the scheme with almost 100% of Emission Allowances grandfathered instead of auctioned in the first phase and (initial) EUA long positions for most of the companies covered by the scheme, an increase in future cash flows of electricity firms in case of an EUA appreciation is straightforward, with positive stock market reactions as a logical consequence. This result, however, calls into question free allowance allocation to these corporations, as free allocation is seen as an instrument to support firms suffering from production cost increases generated by EUA price rises (Hepburn et al., 2006).

At least German electricity wholesale prices seem to react asymmetrically to EUA price changes in that rising EUA prices have a stronger impact on electricity prices than falling EUA prices (Zachmann and von Hirschhausen, forthcoming). However, stock markets do not seem to consequently react asymmetrically in the pricing of electricity stocks. One possible explanation of this result may be the stock market agents' ignorance of the asymmetric cost pass-through in the electricity market. Alternatively, it is unclear whether such asymmetry in the EUA price-to-electricity price relationship only relates to the German electricity exchange or to European electricity markets as a whole, where also customer-specific long-term contracts play an important role. This has not yet been shown. However, even for the German corporations considered, there is no indication of asymmetric stock market effects. Finally, we do not find a significant effect of EUA volatility on stock volatility for the corporations covered by the ETS, even against the background of a relatively volatile EU carbon market (Benz and Trück, forthcoming). This may weaken the widespread argument stating that volatility shocks from the EUA market may create economic damage to the corporations covered by the scheme and deteriorate the performance of the EU ETS in comparison with EU-wide taxes (Baldursson and von der Fehr, 2004). Future research, however, may provide additional insights into this relationship, e.g. by the application of multivariate GARCH models (Bauwens et al., 2006). The "inverse" EUA effect for the Spanish corporations could stem from stringent price regulation at the Spanish electricity market, where cost pass-through, in contrast to the electricity markets in other European countries, is not possible. Another factor driving this result could be the relative allocation with EU Emission Allowances, resulting from characteristics of the Spanish NAP: According to Kettner et al. (2008), the Spanish power and heat sector was, amongst its counterparts from other European countries, the one with the largest short position.

Generally, our results refer to the current design of the scheme with almost 100% of Emission Allowances grandfathered instead of auctioned, to an emissions cap that is in general assessed to be rather generous (e.g. Ellerman and Buchner, forthcoming, Kettner et al., 2008), and to the power sector that is suspected to be able to pass through costs very easily to the consumers. Because of those phenomena, the ETS has been suspected of generating windfall profits for many companies covered (Sijm et al., 2006). However, a much stronger emissions cap in the second compared to the first phase, as it is expected from early analysis of the National Allocation Plans of the ETS member states (Betz et al., 2006, Schleich et al., 2007), may also increase economic consequences of emission regulation under the EU ETS. While our results suggest that a long-term EUA price rise in the future could benefit electricity corporations to which the ETS applies, this should particularly come true if the EUA price rises were to be anchored in more stringent (free) allowance allocation for corporations outside the electricity sector. However, as the European Commission's (2008) recent plans suggest full auctioning for the power sector in 2013 – first evidence for such development is the rise of the auctioning limit to 10% in the second EU ETS phase (in comparison to 5% in the first phase) – possible benefits as suggested by the results of the empirical analysis seem to be at least temporally restricted. It will be interesting to see whether positive stock market reactions to EUA price rises will occur under such new climate policy regime. Again, however, benefits (or losses) for infra-marginal units will depend on the extent of EUA cost pass-through as well as their carbon intensity relative to the intensity of the marginal unit. The possibility of reduced benefits or even losses of electricity generators in case of EUA price rises is underlined by the evidence for Spanish electricity corporations, where cost pass-through is restricted and allowance allocation was least generous in the first phase.

This paper is among the first empirical contributions to the question of economic impacts of the European Union Emission Trading Scheme. Econometric analysis with respect to EU ETS is just evolving. Additional insights into EUA prices (cp. Alberola et al., 2008a and b, Mansanet-Bataller et al., 2007, or Benz and Trück, forthcoming) will be needed for the second EU ETS phase that started in 2008. Also the EUA impact on electricity and stock prices should be further examined; here it would be particularly interesting to assess whether or how electricity generators' portfolios of power plants affect their stock returns' relationship to the EU Emission Allowance market. Related issues that have to be tackled in order to complement the existing literature are widespread: Of particular interest will be the analysis of ETS impacts on industry relocation, trade flows, and (environmental) innovation against the background of the pollution haven (Cave and Blomquist, forthcoming) as well as the Porter hypothesis (Porter and van der Linde, 1995, and Frondel et al., forthcoming).

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Appendix

Table 4 Dickey-Fuller Unit Root Tests

Variable	Test Statistic
r	-21.187***
r_m	-21.827***
r_{EUA}	-18.287***
v_{EUA}	-15.932***
r_o	-24.876***
v_o	-23.852***
r_g	-21.276***
v_g	-21.891***
r_e	-30.318***
v_e	-16.158***

Note: *** shows significance (rejection of the null hypothesis of a unit root) at the 1%-level.

Table 5 Correlation Matrix

	r	r_m	r_{EUA}	v_{EUA}	r_o	v_o	r_g	v_g	r_e	v_e
r	1.0000									
r_m	0.5660	1.0000								
r_{EUA}	0.1162	-0.0108	1.0000							
v_{EUA}	-0.0820	-0.0953	-0.1635	1.0000						
r_o	0.1044	0.0522	0.0805	-0.0628	1.0000					
v_o	0.0316	0.0116	0.0098	0.0697	-0.1106	1.0000				
r_g	0.1290	0.0694	0.1611	-0.0117	0.0586	0.0328	1.0000			
v_g	0.0350	0.0149	0.0580	-0.0156	-0.0227	-0.0153	0.6169	1.0000		
r_e	-0.0031	0.0356	-0.0416	-0.0091	-0.0021	-0.0414	-0.0144	-0.0447	1.0000	
v_e	0.0276	0.0421	0.0004	-0.0325	0.0703	-0.0097	0.0140	-0.0089	-0.1329	1.0000

Note: 481 observations. Pearson's correlation coefficients for the respective variable pairs are given.