Page Proof Instructions and Queries

Please respond to and approve your proof through the "Edit" tab, using this PDF to review figure and table formatting and placement. This PDF can also be downloaded for your records. We strongly encourage you to provide any edits through the "Edit" tab, should you wish to provide corrections via PDF, please see the instructions below and email this PDF to your Production Editor.

Journal Title: Organization & Environment
Article Number: 924820

Thank you for choosing to publish with us. This is your final opportunity to ensure your article will be accurate at publication. Please review your proof carefully and respond to the queries using the circled tools in the image below, which are available in Adobe Reader DC* by clicking **Tools** from the top menu, then clicking **Comment**.

Please use *only* the tools circled in the image, as edits via other tools/methods can be lost during file conversion. For comments, questions, or formatting requests, please use T. Please do *not* use comment bubbles/sticky notes.

*If you do not see these tools, please ensure you have opened this file with **Adobe Reader DC**, available for free at get.adobe.com/reader or by going to Help > Check for Updates within other versions of Reader. For more detailed instructions, please see us.sagepub.com/ReaderXProofs.

No.	Query
GQ1	Please confirm that all author information, including names, affiliations, sequence, and contact details, is correct.
GQ2	Please confirm that the Funding and Conflict of Interest statements are accurate.
GQ3	Please note that we cannot add/amend ORCID iDs for any article at the proof stage. Following ORCID's guidelines, the publisher can include only ORCID iDs that the authors have specifically validated for each manuscript prior to official acceptance for publication.
1	Please provide complete reference details for Lundgren et al., 2015, or delete the citation.
2	Please provide the page range for the chapter in Ellerman, 2008.
3	Jammazi, 2012 is not mentioned in the text. Please insert the appropriate citation in the text, or delete the reference.
4	Moreno et al., 2017 is not mentioned in the text. Please insert the appropriate citation in the text, or delete the reference.
5	Please provide a 2-3 sentence bio for each author.

Article

Organization & Environment
1–19

DOI: 10.1177/1086026620924820
journals.sagepub.com/home/oae
SAGE

The Impact of EU Allowance Prices on the Stock Market Indices of the European Power Industries: Evidence From the Ongoing EU ETS Phase III

Agustín García[1,2], María Teresa García-Álvarez[3], and Blanca Moreno[4] [GQ: 1]

Abstract

The European Union Emissions Trading Scheme (EU ETS) was created in 2005 to price every ton of carbon dioxide emissions. Within this framework, EU carbon dioxide emission allowances can affect electric power industry stock performance. This article uses a multifactor market model and a panel data econometric technique to investigate the long-run impact of EU carbon dioxide emission allowances on the European power sector. We also use panel cointegration to check whether there is a long-run relationship, and fully modified ordinary least square and dynamic ordinary least square to estimate any such relationship. The panel data include a daily sample for the ongoing EU ETS Phase III (from 1 January 2013 until 22 April 2017) and data from six European Union members (Austria, France, Germany, Italy, Netherlands, and Spain). The estimated coefficients suggest that EU allowance prices have a statistically significant and positive long-run effect on the European power sector stock market in EU ETS Phase III. This potentially supports EU efforts to toughen carbon reduction regime targets in order to remove the surplus from the system.

Keywords

EU ETS, electricity sector, carbon prices, multifactor market model, panel data

Introduction

Since its establishment in 2005, the European Union Emissions Trading System (EU ETS) has been identified as a cornerstone of European climate policy.[1] The EU ETS is a cap-and-trade system that has multiyear compliance periods, covering specified installations in specified

[1]Tufts University, Medford, MA, USA
[2]University of Extremadura, Badajoz, Spain
[3]University of A Coruna, A Coruna, Galicia, Spain
[4]University of Oviedo, Oviedo, Asturias, Spain

Corresponding Author:
Blanca Moreno, Regional Economics Laboratory, Faculty of Economics and Business, Department of Applied Economic, University of Oviedo, Campus del Cristo s/n, Oviedo, Asturias 33006, Spain.
Email: morenob@uniovi.es

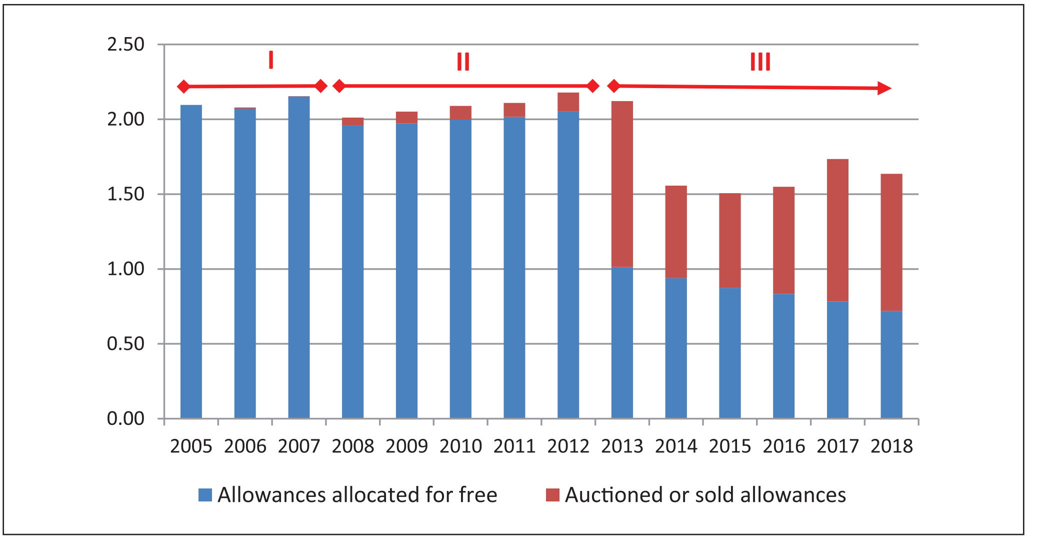

Figure 1. Total allocated allowances: Phases I, II, and III (1,000 million tCO2eq).
Source. Own elaboration from European Environment Agency (2019) data.

sectors of the European economy. It includes only large stationary sources of emissions (power generation and the most pollutant industrial sectors). Under this system, the covered firms can either use their rights to emit one ton of carbon, known as European Union Allowances (EUAs), to compensate their emissions or sell these rights to other companies that have need of their allowance (Reinaud, 2005). Therefore, the market establishes the price of carbon allowances.

The EUAs were asymmetrically distributed over both time and between industries. EU ETS Phase I (2005-2007) was a trial period during which allowances were allocated for free. The main achievement of this phase was the creation of a regulatory mechanism and supporting infrastructure to create a EUA market (Ellerman & Joskow, 2008). EU ETS Phase II (2008-2012) started up a double allocation method based mainly on free distribution, albeit with limited EUA auctioning for installations in specific sectors. The current EU ETS Phase III (2013-2020) provides for an increase in auctioning at the expense of free allocation (from 20% in 2013 up to 70% in 2020). By May 2017, more than three billion carbon allowances had been auctioned since auctioning started in October 2012 (European Union, 2017).

A number of issues have attracted the interest of scholars, including the allocation process, considering its unequal distribution across countries, the percentage of free allocation, and also its differential treatment by sector. In this respect, Ellerman et al. (2010) provided a detailed description and analysis of the EU ETS, focusing on the first phase. The initial allocation of EUAs was identified as advantageous for industrial sectors, but created a deficit in the power sector, based on the idea that this sector, without losses due to international competition, had a greater potential to reduce emissions than other sectors.[2]

Although upward, the growth in auctioning during the second phase was limited. The amount of EUAs auctioned increased substantially in the third phase, boosting the differential allocation across sectors. Figure 1 shows the total EUAs allocated according to the allocation system employed (free or auction). As Figure 1 shows the amount of auctioned EUAs increased substantially across the EU during the third phase.

Economic theory suggests that the EU ETS may have an impact on companies' stock market returns. EU carbon dioxide emission allowance prices can affect the cost structure of a company, irrespective of the sector, as it affects the input mix choice, the optimal amount of production or investment decisions, among others. The final effects on company profits are expected to depend on company capacity to pass on allowance costs to consumers and on abatement costs. Therefore, changes in allowance prices could be linked to changes in stock market returns, depending on how investors evaluate the impact of allowance prices on future company profits. In fact, capital market theory provides a framework for understanding the view taken by investors with regard to this possibility. If emitting companies are expected to bear most of the cost of EUAs, company investor expectations of future profits are revised downward, leading to lower stock market prices.

There can be expected to be differences between companies, as well as between sectors, countries or different periods of time due to the variety of market characteristics, technologies, or carbon intensities. Previous studies have investigated the effect of allowances prices on stock returns in several industries and countries during Phases I and II, when allowance allocation was predominantly for free, with mixed results for phases, sectors, and direction of the effects. For example, Oestreich and Tsiakas (2015) provided an empirical investigation of the effect of EUAs price on 80 firms trading on the Frankfurt Stock.

Exchange and found “that firms that received free carbon emission allowances significantly outperformed firms that did not” during EU ETS Phases I and II. Their results showed the presence of a high and significant carbon premium. This result confirmed empirically the same result showed by Goulder et al. (2010) through a simulation exercise.

The power sector plays a crucial role in the EU ETS system as the CO_2 emissions from electricity and heat production form the largest key category in the EU, accounting for 25% of total greenhouse gas emissions in 2015 (European Environment Agency, 2017). Thus, the study of the effect of EU carbon dioxide emission allowances on the stock market of power industry requires a special analysis.

Power companies should be able to reduce emissions by using new technologies with a relatively low emission abatement cost, as well as pass on allowance costs to consumers through prices. Thus, European Union (2017) maintains that “the experience of the first two trading periods shows that power generators have been able to pass on the notional cost of allowances to customers even though they received them for free.” As a result, companies in the electricity generation sector do not receive free allowances since 2013,[3] whereas free allocation is yet to be phased out in the other sectors.

Moreover, power companies are an interesting case in point because their output is a unique product that can be produced using several technologies with different carbon intensities. It is one of the most pollutant sectors and has a high potential for emission reductions. Moreover, sector allowances are more or less all auctioned in the ongoing phase. As Moreno and da Silva (2016) state, allowance price fluctuations can affect power company stock market value, but the final effect is ambiguous and depends on investor expectations about future profits. In sum, several factors can determine the final outcome on company profits: the sector’s ability to pass on the allowance cost to consumers, technologies, market characteristics (competition), demand elasticity, or abatement costs.[4]

Our article uses a capital asset pricing model (Lintner, 1965; Sharpe, 1964) to analyze the impact of EUA prices on the stock market of the European power sector during the ongoing EU ETS Phase III, estimated using a panel cointegration technique. Oberndorfer (2009), Veith et al. (2009), Mo et al. (2012), and da Silva et al. (2016) used the capital asset pricing model to test the effect of EUA on power company stock market prices. Moreover, the above studies used an econometric panel method as an estimation procedure: Veith et al. (2009) used data for 22 European power companies from 25 April, 2005, to 31 August, 2007; Oberndorfer (2009) used 12 European power companies with an estimation period spanning from 4 August, 2005, until 19 June, 2007; Mo et al. (2012) used 12 European power generating firms and annual data from

2006 to 2009; and da Silva et al. (2016) used 13 Spanish power companies using daily data from January 2008 to July 2014.

Unlike other studies, we estimate the long-run impact of EUA prices on power stock market returns in EU ETS Phase III using a multifactor market model and fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS) panel cointegration techniques. The panel data consist of a daily sample for the ongoing EU ETS Phase III (from 1 January, 2013. to 22 April, 2017) and data from six European countries (Austria, France, Germany, Italy, Netherlands, and Spain).

To the best of our knowledge, this is the first article to estimate the long-run relationship between EUA prices and power stock market returns using a panel data cointegration approach in an attempt to take advantage of the possibility of including specific factors from the different countries in the sample. Again, unlike others studies which refer to the impact of EUA prices on the power stock market of a single country (da Silva et al., 2016) or EU ETS Phases I and II, the novelty of our research is that it is based on the cross-sectional analysis of the European power sector stock market and on the expansion of the analysis to the latest EU ETS Phase III information. Section 2 presents a literature review addressing the link between carbon prices and stock returns. Section 3 shows a brief description of the applied methodology, including the multifactor model specification and the extension of the multifactor model with panel data. Section 4 describes the data and variables used in the study. Section 5 reports the empirical findings. Finally, Section 6 contains some concluding remarks and policy recommendations.

Literature Review

The effect of carbon prices on power company stock returns has been a matter of debate in empirical and theoretical literature. Both results (a positive and negative relationship between allowance prices and corporate value) can be explained from a theoretical point of view. It was Coase (1960), who came up with the idea of creating emissions markets, claiming that "pollutant agents need to be confronted with a price equal to the marginal external cost of their polluting activities to induce them to internalize the social costs." If this is the case, an increase in the allowance price is expected to lead to a fall in stock market returns due to higher output costs. In short, from this point of view, the relationship between EUA price and stock market returns can be expected to be negative, especially if, as is the case in EU ETS Phase III, companies have to buy EUAs.[5] However, Sijm et al. (2006) report a different finding based on the possibility of future windfall profits. The final effect of EUA prices on future company profits depends on the ability to pass allowance costs through to the market. Again, other market-specific and technology-specific factors have influenced the possible incorporation of allowance costs into electricity prices, such as market price structure and strategic producer behavior. For example, in a sector where the wholesale price is defined by a technology with relatively high carbon intensity, the inframarginal technologies with lower carbon intensity could benefit from a higher market price due to an allowance price increase. Thus, sector profits will rise because the marginal technology passes on allowance costs through prices. Therefore, profits will not fall.

The analysis of the impact of allowance prices on corporate stock returns in the power industry has been based on cross-country panel data or individual countries and main and they have focused mainly in EU ETS Phases I and II. Table 1 shows and overview of the impact of EUA prices on corporate stock returns in power sector.

As it is showed in Table 1, regarding the effect of EUA prices on stock returns, Oberndorfer (2009) used the GARCH model to study the case of the major European electricity companies. Oberndorfer (2009) found that EUA price increases (decreases) positively (negatively) affect stock returns. He highlighted that the specific effect of changes in EUA prices on stock returns may differ depending on the country. Veith et al. (2009) reported a positive correlation between

Table 1. Overview of the Impact of EUA Prices on Corporate Stock Returns in Power Sector.

Study	Method	Results	EU ETS phase	Countries/ companies
Sijm et al. (2006)	Trend analysis and simulation model	Electricity companies passed on part of opportunity costs of emission allowances to the electricity prices	I	Germany and the Netherlands
Zachmann and von Hirschhausen (2008)	Autoregressive distributed lag model	Emissions prices were passed through asymmetrically to electricity futures prices	I	Germany
Oberndorfer (2009)	GARCH model	EUA price variations on electricity corporations' stock can vary with country	I	12 European electricity corporations
Veith et al. (2009)	Multifactor model	Stock market returns are positively correlated with increases of emission rights prices	I	22 European electricity corporations
Keppler and Cruciani (2010)	Proposal of rent creation method	Positive impact of increases of EUA prices on stock market returns	I	European electricity companies
Mo et al. (2012)	Multifactor model	Corporate values were more sensitive to EUA price changes in Phase I	I-II	European electricity companies
Chan et al. (2013)	Difference-in differences and regression methods	Emission trading program has a positive impact on revenues of the European power sector	I-II	European power, cement and iron and steel sectors
Tian et al. (2016)	Ordinary least square, panel data and time-series methods	Stock market volatility is significantly driven (and in the same direction) by the volatility of the EUA prices	I-II	European electricity companies
da Silva et al. (2016)	Vector error cointegration model	EUA price changes did not have short-run effects on stock market returns in both phases. In the long run, different effects were obtained for every phase	II-III	Spanish power industry
Dutta (2017)	Realized volatility model	EUA prices did not have any influence on energy stock market	II-III	40 Companies included in the Wilder Hill Clean Energy Index
Ji et al. (2019)	Network approach	Strong information interdependence between carbon price returns and electricity stock returns	I-II-III	18 Top European electricity companies

Note. EUA = European Union Allowance; EU ETS = European Union Emissions Trading Scheme.

the EUA price changes and stock returns of 22 European electricity companies in the period 2005-2007 using a multifactor model. Keppler and Cruciani (2010) reported similar results when developing a revenue creation model in EUA ETS Phase I. Mo et al. (2012) studied the effects of EUA prices on the corporate value of European power companies in the period 2005-2009 using a multifactor market model. They found different results in EUA ETS Phase I and Phase II. EUA price increases tended to cause appreciation of company value in Phase I and depreciation in Phase II. Likewise, the company value was more sensitive to EUA price changes in Phase II. By means of the combination of different (ordinary least square [OLS], panel data, and time series) methods, Tian et al. (2016) concluded that the stock return volatility of European power companies was driven in the same direction by EUA market volatility in the EUA ETS Phase I and Phase II. da Silva et al. (2016) developed a vector error cointegration model to analyze the Spanish power industry in the period 2008-2014. Their results showed that EUA price changes did not have an impact on stock market return in either EU ETS Phase II or Phase III. However, they found that long-term relationships between EUA prices and stock market returns were positive in Phase II and not significant in Phase III. Dutta (2017) applied a realized volatility model to 40 companies of the Wilder Hill Clean Energy Index, whose results showed that emission allowance prices did not have any influence on stock market values. Recently, Ji et al. (2019) by using a network approach showed a strong interdependence between carbon price returns and electricity stock returns in 18 top European electricity companies from November 18, 2005, to May 10, 2018.

Therefore, we can conclude that different methods and results have been reported in the literature. Multifactor models have been one of the most used techniques in this research field (Mo et al., 2012; Veith et al., 2009). Using the above capital asset pricing model, multifactor models assess the impact of any factor on company value. Following Fama and French (1992), it is possible, based on the basic model where stock market return depends on market portfolio return, to include explanatory variables related to key price factors for company stock returns that shape the multifactor market model.

The empirical evidence about other pricing factors (e.g., fuel prices) being linked in stock markets in Europe, other countries or cross-country panels and their influence is unclear. A potential cause of this mixed evidence is aggregation, since the analysis includes a wide range of outputs and technologies with a diversity of carbon intensity, and a different electricity mix in cross-country panel studies. Apparently, oil price shock is the most significant pricing factor for the general stock index.

The above result is more evident at sectorial level. A sector-specific analysis shows significant evidence of oil price shock on some sector indices for some countries. For example, Arouri and Nguyen (2010) or Scholtens and Yurtsever (2012) found that oil price shocks had an asymmetric impact on company stock returns depending on the sector of activity. These results underscore the need for the specific sector to be included in the empirical analysis, and this is consistent with the uncertain link observed when aggregate data are used.

We attempt to overcome this problem by focusing in studies about the effect of fuel prices on energy industry. Table 2 shows the major studies that analyzed the impact of fuel prices on company stock returns in the energy industry.

Boyer and Filion (2007) used a multifactor model and found a positive correlation between increases of both crude oil and natural gas prices and the stock market values of 35 Canadian oil and gas companies in the period 1995-2002. Kilian and Park (2009) reported similar results using a variance decomposition method. Their results showed that increases of oil prices due to demand shocks played a major role in increases of U.S. stock prices in different industries (including the energy sector) in the period 1973 to 2006. Mohanty and Nandha (2011) applied four-factor asset pricing to the U.S. oil and gas sector over the period 1992 to 2008. Likewise, they concluded that there were significant positive relationships between oil price changes and the stock market in these industries. Similarly, Moya-Martínez et al. (2014) developed a multifactor market model and showed a strong correlation between oil price and stock market in the Spanish energy industry over the period 1993 to 2010.

Table 2. Overview of the Impact of Fuel Prices on Stock Returns in the Energy Industry.

Study	Method	Results	Countries/companies
Boyer and Filion (2007)	Multifactor model	The stock market was positively associated with increases of both crude oil and natural gas prices	35 Canadian oil and gas companies
Kilian and Park (2009)	Variance decomposition method	The strongest observed stock market response to oil demand shocks was for the energy industry	Four U.S. industries (including energy)
Mohanty and Nandha (2011)	Four-factor asset pricing model	Positive correlation between oil price changes and stock prices in oil and gas sector	40 U.S. oil and gas companies
Moya-Martínez et al. (2014)	Multifactor market model	Positive correlation between changes in oil and stock market prices	14 Spanish industries (including energy)
Ready (2017)	Simulation and regression models	Negative correlation between oil supply shocks and stock market	Ten industry portfolios (including energy)
Dutta (2017)	Realized volatility model	Significant impacts of oil price changes on clean energy stock returns	40 Companies included in the Wilder Hill Clean Energy Index
Ferrer et al. (2018)	An extension to the time-frequency space of the spillover index approach	Crude oil prices are not the key driver of renewable energy stocks	40 Companies included in the Wilder Hill Clean Energy Index

Ready (2017) developed both simulation and regression models to analyze the effects of oil price changes on the stock market in 10 industry portfolios constructed by Fama and French (1992). This study classified oil price changes by demand and supply shocks. Their results showed that there was a positive correlation between demand shocks and the stock market (particularly in industries that import large amounts of oil) and a negative correlation between supply shocks and the stock market (mainly in industries that produce consumer goods). By means of range-based realized volatility measures, Dutta (2017) found that oil price shocks had significant impacts on the stock returns of 40 companies included in the Wilder Hill Clean Energy Index. In contrast to this study, Ferrer et al. (2018) found that crude oil prices did not appear as a key driver of the stock market performance of renewable energy companies in the short-term or the long-term.

It can be concluded that empirical results are ambiguous for the power sector and other pollutant sectors of the European economy. Thus, some studies found a positive correlation between allowance prices and power stock returns (e.g., Chan et al., 2013; Keppler & Cruciani, 2010; Oberndorfer, 2009). Using daily data for Phase II and the first year of Phase III, Moreno and da Silva (2016) found, however, that EU ETS had a significant and sector-specific impact on Spanish stock market returns and a significant negative effect on the power sector. However, there is some agreement on increased oil prices having a positive impact on stock market in the energy industry.

Panel Data Model Specification

Multifactor market models are widely used in order to study the effect of any possible factor on company value change. Following Fama and French (1992), based on the basic model where the stock market return (R_t) depends on the market portfolio return (R_{mt}),

Table 3. European Union Energy Dependency in Terms of Consumed Energy Imported From Abroad (%): Average 2013-2016.

	All products	Solid fuels	Petroleum	Gas
Austria	62.5	94.0	92.5	82.5
France	46.7	96.0	98.4	99.8
Germany	62.5	46.1	96.3	88.8
Italy	76.8	98.1	90.0	90.0
Netherlands	39.2	106.0	96.2	−57.0
Spain	72.1	75.5	100.1	99.4
EU (28 countries)	53.6	43.2	87.6	68.1

Source. Own elaboration from European Commission (n.d.).

$$R_t = f\left(R_{mt}\right), \tag{1}$$

it is possible to incorporate explanatory variables to build the so-called multifactor market model as follows:

$$R_t = f\left(R_{mt}, x_{1t}, x_{2t}, \ldots, x_{nt}\right) \tag{2}$$

where $\left(x_{1t}, x_{2t}, \ldots, x_{nt}\right)$ are the relevant pricing factors for company stock returns.

Oberndorfer (2009), Veith et al. (2009), or Mo et al. (2013) used multifactor market models (Equation 2) to investigate the impact of EUA price changes on stock returns. The basic specification of the model is as follows:

$$R_t = \alpha + \beta_1 R_{mt} + \beta_2 P_t^{EUA} + u_t. \tag{3}$$

Apart from the stock market (R_t) return and the market portfolio return (R_{mt}), this basic model equation includes the price of allowances (P_t^{EUA}) and a disturbance term (u_t), with $E\left(u_t\right)$ and $var\left(u_t\right) = \sigma^2$ at any time *t*. Moreover, the basic model also includes other influencing factors, such as fuel prices (oil, gas, etc.), as some empirical results have shown that stock return is closely related to their price (see Lee et al., 2012; Moya-Martínez et al., 2014, for the Spanish case, and Acaravci et al., 2012, for gas).

Additionally, other authors like Lee et al. (2012) or Moya-Martínez et al. (2014) included the long-term interest rate as an influencing factor to account for market expectations.

Note also that EU countries have a high level of energy dependency, as Table 3 shows.

Therefore, the electricity industry is highly vulnerable to the international price of imported fuels like coal, oil, and gas. Imported fuels are invoiced in U.S. dollars, and it is therefore worth including the value of the U.S. dollar on the currency markets as an explanatory variable in the multifactor market model.

Thus, the initial multifactor market model can be specified as follows:

$$R_t = \alpha + \beta_1 R_{mt} + \beta_2 P_t^{EUA} + \beta_3 P_t^{oil} + \beta_4 P_t^{gas} + \beta_5 P_t^{coal} + \beta_6 r_t + \beta_7 ER_t + u_t, \tag{4}$$

where P_t^{oil}, P_t^{gas}, and P_t^{coal} are the coal, oil, and gas prices, respectively, and r_t and ER_t are the long-term interest rate and the exchange rate, respectively.

By taking into account disaggregated stock returns R of the power industry as a whole, the initial model (Equation 4) can also be specified in terms of a panel data model (see, e.g., Baltagi, 2013, for a detailed description of the technique). The above Equation (4) can thus be reformulated as follows:

$$R_{it} = \alpha_{it} + \beta_0 + \beta_1 R_{mt} + \beta_2 P_t^{EUA} + \beta_3 P_t^{oil} + \beta_4 P_t^{gas} + \beta_5 P_t^{coal} + \beta_6 r_t + \beta_7 ER_t + +u_{it}, \quad (5)$$

where i stands for the power sector of the analyzed EU member i (i = Austria, France, Germany, Italy, Netherlands, and Spain), α_i parameters denote the country effects and u_{it} represents the disturbances of this model, which are assumed to be independently and identically distributed random variables with mean zero and variance σ_u^2.

The proposed model (Equation 5) has been estimated considering both random and fixed effects to identify the most suitable panel model specification. According to the random effects model, α_i is considered as a component of the random disturbance, while the fixed effects model treats α_i as a regression parameter. A Hausman (1978) test is performed to establish whether the random or the fixed effects estimator is better. Furthermore, the Breuch–Pagan test (for random effects) or the F test (for fixed effects) is used to check whether there is a country-specific effect. The null hypothesis in both cases is that α_i is equal for all countries. If the individual country effect α_i is assumed to be equal across all countries, then the pooled OLS estimation is consistent and efficient.

Data and Variables

We used data from six countries (Austria, France, Germany, Italy, Netherlands, and Spain) in this research. The daily sampling period employed in our analysis is from 1 January, 2013, to 22 April, 2017. Information on the electricity sector daily stock price for each EU member was extracted from the DataStream Database. The proxies used for the market portfolio return (R_m) are Vienna Stock Exchange (Austrian Traded Index), Euronext Paris (CAC 40 Index), Deutsche Boerse (DAX, 30 Index), FTSE Italia (MIB Index), Euronext Amsterdam (AEX-Index) and Madrid Stock Exchange (IBEX 35 Index) for the cases of Austria, France, Germany, Italy, Netherlands, and Spain, respectively.

The 10-year Treasury yield is used to assess the interest rate r for each country. The natural gas price P^{Gas} (€/MMBTU) is the Henry Hub spot price, the coal price P^{Coal} (€/ton) is the API#2 spot index (CIF ARA, that is, cost of insurance and freight delivered to the Amsterdam/Rotterdam/Antwerp region) and the crude oil price P^{Oil} (€/bbl) is the Dated Brent. The EUA price series P^{EUA} (€/EUA) is the spot price of a ton of CO_2 quoted on the European Energy Exchange (EEX) based in Leipzig, Germany. The exchange rate is the local currency to U.S. dollar (€/\$). All the data and information was extracted from the Thomson Reuters Datastream and Bloomberg databases.

Table 4 summarizes the main descriptive statistics of the variables.

Price variables were transformed into their natural logarithms in order to reduce variability.

Results and Discussion of the Results

We used a unit root and cointegration analysis within a panel framework. In order to evaluate a possible long-term relationship between electricity sector stock prices and explanatory variables, the estimation method proceeds as follows: (a) panel unit root tests are conducted to assess the order of integration of the variables; (b) if these tests conclude that all series have the same order of integration, the long-term relationships between the variables are explored using a cointegration

Table 4. Descriptive Statistic Measures From 01/01/2012 to 22/03/2017.

Variable	Units	*M*	Max.	Min.	*SD*
R	Index	898.35	1148.44	530.55	187.97
R_m	Index	9630.86	11866.40	7553.20	1040.71
P^{EUA}	€/T	5.83	8.65	2.68	1.33
P^{Coal}	$/MT	68.99	90.60	43.40	13.59
P^{Gasl}	$/MMBTU	3.28	7.92	1.49	0.92
P^{Oil}	$/bbl	74.89	120.10	25.76	29.90
R	%	2.64	5.44	0.93	1.30
Exchange rate	€/$	1.21	1.39	1.04	0.12

test; and (c) the model could be estimated using two methods—DOLS and FMOLS—to examine the parameters of the long-term relationship between stock market price and energy prices.

Panel Unit Root Test and Panel Cointegration Test

To check the order of integration of the variables, we performed panel unit root tests. The panel unit root tests are estimated without individual trends, as Breitung (2000) found that some tests suffer from a dramatic loss of power when individual trends are included. Four different tests were estimated. One test assumes common unit root processes in the data (Levin et al., 2002). The remaining three assume individual unit root processes. They are the tests reported by Im et al. (2003) and the ADF-Fisher and PP-Fisher (Augmented Dickey-Fuller and Phillips-Perron, respectively) tests developed by Maddala and Wu (1999) and Choi (2001).

Table 5 reports results from the panel unit root tests, showing that all variables included in the model are at a 1% confidence level, whereas the Phillips-Perron Fisher's chi-square indicates that the unit root null hypothesis is rejected for the EUA price series (P^{EUA}) only. Generally, individual series could have a unit root if time series approaches were used. When moving away from time-series approaches and adopting more powerful panel unit root tests, however, the unit root null hypothesis could be rejected (as is the case here). Culver and Papell (1997), for example, found that if national inflation rates are pooled the unit root null hypothesis is rejected. All variables become stationary after first differencing.

The first condition for exploring long-term relationships (cointegration) among variables is fulfilled (all series have the same order of integration). Thus, we continue with the cointegration analysis within a panel framework.

The panel cointegration test was used to test the panel variables. The panel cointegration test was actually based on Kao residual cointegration tests and Johansen Fisher panel cointegration tests. Table 6 reports the results of the panel cointegration test of power stock price modeling.

All tests indicate that for all the variables used in this model, the null hypothesis (no cointegration) is rejected to any significance level. The empirical results suggest that all the variables used in the model are cointegrated.

Thus, both DOLS and FMOLS estimators are used to find the long-run relationship.

DOLS and FMOLS Estimation

The cointegration vector is estimated using a FMOLS procedure. This procedure provides consistent and efficient estimators of the long-run relationship, deals with heterogeneity across individual panel items, corrects serially correlated errors, removes endogeneity issues, and takes into account the integration and cointegration data order.

Table 5. Panel Unit Root Test Results (Only Intercept): Null Hypothesis: There is Unit Root.

	Variables							
Tests	R_{elect}	R_m	P^{EUA}	P^{Coal}	P^{Gas}	P^{Oil}	r	ER
Levels								
Levin, Lin, and Chu t*	−0.41282	−0.79103	0.75533	−1.28444*	−0.59183	−0.63569	−1.55165*	0.23925
Im, Pesaran, and Shin W-stat	−0.28412	−2.00476**	−2.24111**	0.41255	−1.51809*	1.40103	0.74677	1.98068
ADF—Fisher's chi-square	13.0671	20.2230*	21.3012**	6.33839	15.9557	3.61265	6.08192	2.57063
PP—Fisher's chi-square	11.7598	18.6930*	29.1730***	6.83941	15.3318	3.76212	6.23172	2.41638
First differences								
Levin, Lin, and Chu t*	−101.089***	−104.240***	−86.3528***	−103.197***	−91.4830***	−105.528***	−106.341***	−83.4516***
Im, Pesaran, and Shin W-stat	−867.131***	−89.6162***	−72.4872***	−83.5362***	−75.4755***	−86.1713***	−90.9308***	−94.2536***
ADF—Fisher's chi-square	831.842***	796.383***	1141.64***	953.377***	1099.27***	891.077***	759.998***	674.164***
PP—Fisher's chi-square	645.411***	793.743***	842.142***	950.840***	1016.99***	891.639***	750.548***	673.776***

Note. Probabilities for Fisher tests are computed using an asymptotic chi-square distribution. All other tests assume asymptotic normality; automatic lag length selection based on SIC. ER = exchange rate.
*Null rejected at 10% significance level. **Null rejected at 5% significance level. ***Null rejected at 1% significance level.

Table 6. Panel Cointegration Tests: Null Hypothesis: No Cointegration.

Test name	Test statistic	*p*
Kao residual cointegration tests (Engle-Granger based)[a]		
• ADF-statistic	−4.977359	0.0000
Johansen Fisher panel cointegration test[b]		
• Fisher statistics from trace test	85.11	0.0000
• Fisher statistics from maximum eigenvalue test	72.80	0.0000

[a]Automatic lag length selection based on SIC with a maximum lag of 21. [b]Probabilities are computed using an asymptotic chi-square distribution.

Table 7. Long-Term Estimation.

Independent variable	FMOLS[a]	DOLS[a]
R_m	0.544345***	0.515593***
P^{EUA}	0.075665*	0.078149***
P^{Coal}	−0.012693	−0.012133
P^{Gas}	0.033108	0.036088**
P^{Oil}	0.078527	0.072388***
ER	0.882353***	0.757728***
R	−0.086465***	−0.073691***

Note. Estimates refer to (fixed-effects) long-run elasticity of output with respect to the relevant regression. FMOLS = fully modified ordinary least square; DOLS = dynamic ordinary least square; ER = exchange rate.
[a]Rend specification (constant), long-run covariance methods (lags specification-AIC).
*Null rejected at 10% significance level. **Null rejected at 5% significance level. *** Null rejected at 1% significance level.

Pedroni (2000, 2001) proposes two methods to apply this fully modified method to panel cointegration regression: the pooled (or within-group) panel FMOLS estimator and the group-mean (between-group) FMOLS estimator. We use the between-group FMOLS estimator, as it provides for a more flexible alternative hypothesis and is much less affected by small sample size distortion than the within-group estimator (Kim et al., 2005).

Next, we then consider the DOLS panel cointegration estimator (Kao & Chiang, 2000). Table 7 reports the FMOLS and DOLS results.

In FMOLS estimations, the market portfolio (R_m), the exchange rate and interest rate (r) are statistically significant at the 1% significance level, and the EUA price (P^{EUA}) is statistically significant at the 10% significance level. In fact, as the variables are expressed in natural logarithms, the coefficients can be interpreted as elasticities. Thus, the results indicate that a 1% increase in market portfolio return increases the electricity sector stock price by 0.54%; a 1% increase in the exchange rate increases the electricity sector stock price by 0.88%; and a 1% increase in the interest rate decreases the electricity sector stock price by 0.086%. When the EUA price increases by 1%, the electricity sector stock price increases by 0.075%.

In terms of magnitude and sign, the coefficients estimated using FMOLS and DOLS are similar, but the variables related to the gas and oil price (P^{Gas} and P^{Oil}, respectively) are positive and statistically significant at the 5% and 1% significance levels, respectively, in DOLS. In fact, a 1% increase in gas and oil prices increases the electricity sector stock price by 0.36% and 0.07%, respectively. The price of coal (P^{Coal}) is not significant in either of the estimations of the panel model.

As shown above, our results suggest that EUA prices have a significant positive long-run effect on electricity industry stock returns. The empirical evidence is at odds with regard to the impact of EUA price variations on power stock markets. This is because many studies are based on a specific country (or region). Besides, the results reported in the literature also appear to depend on the method used and the EU ETS phase examined.

Generally, the literature appears to show that EU ETS had a positive impact on power companies (e.g., Chan et al., 2013; Ji et al., 2019; Keppler & Cruciani, 2010; Oberndorfer, 2009). This is consistent with our results. However, the specific impact of EUA price changes on electricity company stock returns may vary depending on the analyzed country, the power generation technology, the EU ETS phase and allowance allocation over time, as shown by Oberndorfer (2009), Bode (2006), and Mo et al. (2012), respectively.

Our results suggest that EU ETS Phase III has an influence on financial markets. This should be taken into account by investors, as the EUA price could lead to an appreciation of corporate value in the long run. Related to this finding, Oberndorfer (2009) showed, albeit for EU ETS Phase I, that the EU power sector has been thought to be able to pass on costs to consumers, thus generating windfall profits. Therefore, the development of EUA market prices may have important implications from the point of view of both economic and financial markets, possibly leading investors to hedge against EUA price fluctuations. Similar results were reported by Veith et al. (2009) and Keppler and Cruciani (2010) using different methods in EU ETS Phase I. They highlighted that the implementation of ETS not only led to an alteration of the cost structure of European electricity companies but also had the potential to increase prices that more than offset the imposed costs. Likewise, Mo et al. (2012) and Tian et al. (2016) found that stock returns were positively correlated with EUA price changes in EU ETS Phase I, although this did not apply to EUA ETS Phase II, where there was an inverse relationship between stock returns and EUA price changes for carbon-intensive producers.

Nevertheless, there has been hardly any research on EUA ETS Phase III, where EUAs for the power sector are allocated by auction. Exceptions are Dutta (2017) and da Silva et al. (2016), who analyzed the Spanish power industry and 40 companies included in the Wilder Hill Clean Energy Index, respectively. They showed that there were no significant relationships between EUA prices and stock returns.

On the other hand, our results suggest that European power sector stock returns reacted positively to an increase of both oil and gas prices. These results are consistent with findings by Veith et al. (2009), Mo et al. (2012), and Dutta (2017) for the EU energy sector. The results highlight the importance of enacting effective policies to mitigate the negative effect of both oil and gas price uncertainty in order to increase the use of renewable energy and improve energy consumption efficiency. Thus, the adoption of suitable actions to reduce stock returns volatility appears to be a key concept.

Conclusion

This article analyses the long-run impact of EUA prices, as well as other variables, such as fuel prices and exchange rate, on European electricity sector stock prices. A multifactor market model was specified and estimated using econometric analysis of panel data. Daily data from 1 January, 2013 to 22 April, 2017, were collected for six European Union members: Austria, France, Germany, Italy, Netherlands, and Spain.

The Johansen Fisher panel cointegration test and Kao residual cointegration test were used to check that there is a long-run relationship. FMOLS and DOLS were used to estimate the cointegrating parameters. Results reveal that there is strong evidence in favor of a positive long-run relationship between EUA prices and the power sector stock market for the panel of selected countries during the current EU ETS Phase III.

Table 8. Market Share of the Largest Electricity Generator in the Market, Percentage of Total Generation.

GEO/TIME	2013	2014	2015	2016	2017
Austria	55.5	—	—	—	—
France	83.8	86.8	85.7	82.5	79.90
Germany	32.0	32.0	32.0	33.5	32.20
Italy	27.0	29.0	27.0	24.0	19.00
Netherlands	—	—	—	—	—
Spain	22.0	23.8	24.5	25.4	22.50

Source. European Commission, Eurostat supply, transformation, and consumption of electricity statistics.

Table 9. Electricity Generation by Fuel (Percentage of the Total Gross Electricity Generation).

Fuel	Austria	France	Germany	Italy	Netherlands	Spain
Solid fossil fuels	2.5	2.3	37.1	11.1	26.7	16.4
Oil and petroleum products	1.1	1.3	0.9	3.9	1.0	5.7
Natural gas and manufactured gas	18.4	7.6	15.1	48.4	53.1	23.7
Nuclear	0.0	71.0	11.7	0.0	2.9	21.1
Renewables and biofuels	76.8	17.4	34.1	35.8	14.9	32.9
Wastes non-RES	1.2	0.4	1.1	0.8	1.4	0.3

Source. Own elaboration from European Commission (2018). RES = renewable sources.

An interesting point that arises from this positive long-run relationship is that it suggests the possibility of future windfall profits, attention should be paid to price formation mechanisms because electricity producer profits may place a heavy burden on electricity consumers. In that sense, the market structure, the demand elasticity to price variations or the number of substitutes of the principal source that the electricity firm uses to generate electricity, among others, influence the grade of the pass-through of environmental costs on prices.

Although the EU electricity market liberalization compels to introduce competition into electricity market, when comparing results of the impact of EU allowances price on sectors' stock market returns from different countries they might differ as countries could have different market conditions. For example, the European country with the highest market share of the largest generator in the electricity market (as a percentage of the total generation) is France with a percentage around 80% as it is shown in Table 8. In this context, it is possible to exercise market power and increase the pass-through of EUA costs to consumers.

In addition, the demand elasticity to electricity price variations could be low not only of the special characteristics of electricity output (such as no storability or the existence of capacity constraints in the short term offer) but also for the number of substitutes limited to gas in those countries where the electricity generation is based on this fuel as Italy or Netherlands, as it is shown in Table 9.

Note that the link between stock market value and CO_2 price increases might depend on the ability to transmit the allowance cost to the wholesale electricity market, as well as the relative carbon intensity of the inframarginal technologies. For example, in a sector where the wholesale price is defined by a technology with relatively high carbon intensity, the inframarginal technologies with lower carbon intensity could benefit from a higher market price due to an allowance price increase. In fact, under the capital market theory, the work of da Silva et al. (2016) showed a long-run positive effect of EU allowances on the stock price changes of Spanish power companies based on renewable sources (RES-E). The study was carried out by using daily data of Phase III from January 2013 to July 2014. In such case, EUA price rise of 1%, would, in equilibrium, be associated with a stock price for the RES sector increase of approximately 0.002%. However, the growing penetration of RES-E into the wholesale electricity market will reduce the wholesale electricity price as a result of the so-called merit order effect (see Dillig et al., 2016; Würzburg et al., 2013, for a review of this effect in EU electricity markets). It could reduce the RES-E firms' investors' expectations of future profits, leading to lower stock market share prices of the company.

A possible explanation for this result is the rational market behavior during EU ETS Phase I if price increases can be passed on (Oberndorfer, 2009), because the system can generate windfall profits for the analyzed companies (Sijm et al., 2006). Our results are interesting because they are related to EU ETS Phase III, without grandfathering allocation, and they support the positive long-run relationship between allowance prices and stock market values. This can shed light on the debate regarding the effect of environmental regulation on financial performance.

There have been widespread concerns that emissions were not sufficiently capped and changes should be introduced to generate decarbonization incentives compatible with business competitiveness. Climate policy based on carbon price has a modest impact on technological development if prices are too low and the pressure on technological development is not strong enough (Lundgren et al., 2015[AQ: 1]). As Ellerman et al. (2016, p. 105) states, " . . . under all likely scenarios [a continually declining cap] will create continuing scarcity, thus virtually guaranteeing that a carbon price will be a permanent feature of the European economic landscape."

Thus, a more stringent emission trading system has the potential to stimulate company innovation, which is considered to be positively connected with stock market value (Hall et al., 2005). In that sense, Joltreau and Sommerfeld (2019) found that grandfathering, main feature of EU ETS in Phases I and II, has been a main factor that limited the stimulation of low-carbon innovation in these periods; while the growing importance of auctions -in Phase III can increase climate-related innovation.

Table 10 shows that energy technology RD&D spending increased significantly in the countries of our sample during the Phase II, in which allowance auctioning begun and CO_2 prices were, at the beginning, in the upper range (close to 30€). These circumstances seem that have boosted investment in innovation in the energy sector. RD&D spending almost tripled in Phase II compared with the previous one, in which the allocations were allocated for free.

In Phase III, despite the fall in the CO_2 price, energy technology RD&D spending remained steady, with a small increase in the sample countries as a whole. During this period, when companies in the electricity generation sector did not receive free allowances in our sample, only in Spain there was a significant decrease in R&D spending in the sector, probably due to the vulnerability of its economy to the financial crisis. Nevertheless, Spanish R&D spending remained significantly higher than the initial phase of the market (more than double), as in the other countries considered. Germany remained a significant growth in investment.

Likewise, the Porter hypothesis (Porter & van der Linde, 1995) asserts that environmental policies that stimulate green innovation may lead to positive innovation-related outcomes and affect firm competitiveness (Lundgren & Zhou, 2017). Thus, if EU ETS works properly, it could motivate firms to innovate, improving financial performance by lowering costs and/or raising revenues (Marin et al., 2018). Gupta and Goldar (2005) have pointed out that firms with environmentally friendly behavior could increase the value of their stock market prices. Thus, a further step in this research could be to analyze the effects of environmental regulation on electricity sector investment and how this circumstance could indirectly increase its stock market value.

Table 10. Total Energy Technology RD&D Spending in Million (Currency: Euro 2018 prices).

EU country	Energy sector	Phase I (2005-2007)	Phase II (2008-2012)	Ongoing Phase III (2013-2017)
Austria	Fossil fuels	2.481	7.502	14.747
	Renewables	50.106	173.651	142.763
	Total budget	132.824	599.735	708.529
France	Fossil fuels	473.764	707.966	415.116
	Renewables	187.131	701.044	844.187
	Total Budget	3034.068	6177.627	6067.599
Germany	Fossil fuels	53.041	174.591	188.954
	Renewables	323.181	1103.771	1373.756
	Total budget	1431.503	3532.433	4596.849
Italy	Fossil fuels	112.51	345.207	473.339
	Renewables	162.009	530.269	462.308
	Total budget	1135.391	2480.916	2496.936
Netherlands	Fossil fuels	77.905	94.405	50.294
	Renewables	173.604	422.178	398.815
	Total budget	525.569	1137.983	861.302
Spain	Fossil fuels	12.446	18.681	17.929
	Renewables	90.227	429.946	220.933
	Total budget	199.753	837.167	448.527

Source. International Energy Agency (2019).

Another potentially interesting issue is to analyze the coexistence of several policy instruments affecting European power stock market prices. Combining an ETS with a renewable energy subsidy has a greater potential to improve welfare than the ETS alone (Lecuyer & Quirion, 2012).

Declaration of Conflicting Interests[GQ: 2]

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD[GQ: 3]

Agustín García https://orcid.org/0000-0002-3680-5850

Notes

1. Directive 2003/87/EC of the European Parliament and of the Council of 13 October, 2003, establishes a scheme for greenhouse gas emission allowance trading.
2. Electricity production was the only sector that was short on balance during the first phase. It accounts for 77% of the short positions in the EU ETS, receiving 49% of EUAs for 54% of emissions (Ellerman, 2008).
3. Power generators must buy all their allowances since 2013, with the exception of some countries (Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Poland, and Romania) for a transitional period until 2019. See Climate Action (European Union, 2017).
4. Sijm et al. (2006) revise several factors and their influence on the power sector during EU ETS Phase I.

5. As Burtraw et al. (2002) pointed out, companies are expected to add the allowance price to their costs in the short-term in both cases (whether they have to pay or they are grandfathering).

References

Acaravci, A., Ozturk, I., & Kandir, S. Y. (2012). Natural gas prices and stock prices: Evidence from EU-15 countries. *Economic Modelling*, *29*(5), 1646-1654. https://doi.org/10.1016/j.econmod.2012.05.006

Arouri, M. E. H., & Nguyen, D. K. (2010). Oil prices, stock markets and portfolio investment: Evidence from sector analysis in Europe over the last decade. *Energy Policy*, *38*(8), 4528-4539. https://doi.org/10.1016/j.enpol.2010.04.007

Baltagi, B. H. (2013). *Econometric analysis of panel data* (5th ed.). John Wiley.

Bode, S. (2006). Multi-period emissions trading in the electricity sector e winners and losers. *Energy Policy*, *34*(6), 680-691. https://doi.org/10.2139/ssrn.897438

Boyer, M. M., & Filion, D. (2007). Common and fundamental factors in stock returns of Canadian oil and gas companies. *Energy Economics*, *29*(3), 428-453. https://doi.org/10.1016/j.eneco.2005.12.003

Breitung, J. (2000). The local power of some unit root tests for panel data. In B. Baltagi (Ed.), *Advances in econometrics, nonstationary panels, panel pointegration, and dynamic panels* (Vol. 15, pp. 161-178). JAI Press.

Burtraw, D., Palmer, K., Bharvirkar, R., & Paul, A. (2002). The effect on asset values of the allocation of carbon dioxide emission allowances. *Electricity Journal*, *15*(1), 51-62. https://doi.org/10.1016/S1040-6190(02)00316-0

Chan, H. S. R., Li, S., & Zhang, F. (2013). Firm competitiveness and the European Union emissions trading scheme. *Energy Policy, 63*(December), 1056-1064. https://doi.org/10.1596/1813-9450-6662

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance*, *20*(2), 249-272. https://doi.org/10.1016/S0261-5606(00)00048-6

Coase, R. H. (1960). The problem of social cost. *Journal of Law and Economic*, *3*, 1-44. https://www.law.uchicago.edu/files/file/coase-problem.pdf

Culver, S. E., & Papell, D. H. (1997). Is there a unit root in the inflation rate? Evidence from sequential break and panel data models. *Journal of Applied Econometrics*, *12*(4), 435-444. https://doi.org/10.1002/(SICI)1099-1255(199707)12:4<435::AID-JAE430>3.0.CO;2-1

da Silva, P. P., Moreno, B., & Figueiredo, N. C. (2016). Firm specific impacts of CO_2 prices on the stock market value of the Spanish power industry. *Energy Policy, 94*(July), 492-501. https://doi.org/10.1016/j.enpol.2016.01.005

Dillig, M., Jung, M., & Karl, J. (2016). The impact of renewables on electricity prices in Germany: An estimation based on historic spot prices in the years 2011-2013. *Renewable and Sustainable Energy Reviews, 57*(May), 7-15. https://doi.org/10.1016/j.rser.2015.12.003

Dutta, A. (2017). Oil price uncertainty and clean energy stock returns: New evidence from crude oil volatility index. *Journal of Cleaner Production, 164*(October), 1157-1166. https://doi.org/10.1016/j.jclepro.2017.07.050

Ellerman, A. D. (2008). Lessons for the U.S. from the European Union's CO_2 emissions trading scheme. In A. D. Ellerman, M. D. Webster, J. Parsons, H. D. Jacoby, & M. McGuinness (Eds.), *Cap-and-trade: Contribution to the design of a U.S. greenhouse gas program*. MIT Center for Energy and Environmental Policy Research.[AQ: 2]

Ellerman, A. D., Convery, F. J., & de Perthuis, C. (2010). *Pricing carbon: The European Union emissions trading scheme*. Cambridge University Press.

Ellerman, A. D., & Joskow, P. L. (2008). *The European Union`s emissions trading system in perspective*. Pew Center of Global Climate Change.

Ellerman, A. D., Marcantonini, C., & Zaklan, A. (2016). The European Union emissions trading system: Ten years and counting. *Review of Environmental Economics and Policy*, *10*(1), 89-107. https://doi.org/10.1093/reep/rev014

European Commission. (n.d.). *Statistical Office of the European Union (Eurostat) database*. http://www.ec.europa.eu/eurostat/data/database

European Commission. (2018). *Data and analysis*. https://ec.europa.eu/energy/en/data-analysis/country

European Environment Agency. (2017). *Annual European Union greenhouse gas inventory 1990–2015 and inventory report 2017*. European Commission, DG Climate Action.

European Environment Agency. (2019). *EU Emissions Trading System (ETS) data viewer*. https://www.eea.europa.eu/data-and-maps

European Union. (2017). *Climate action*. https://ec.europa.eu/clima/

Fama, E., & French, K. (1992). Cross-section of expected stock returns. *Journal of Finance*, *47*(2), 427-465. https://doi.org/10.1111/j.1540-6261.1992.tb04398.x

Ferrer, R., Shahzad, S. J. H., López, R., & Jareño, F. (2018). Time and frequency dynamics of connectedness between renewable energy stocks and crude oil prices. *Energy Economics*, *76*(October), 1-20. https://doi.org/10.1016/j.eneco.2018.09.022

Goulder, L., Hafstead, M., & Dworsky, M. (2010). Impacts of alternative emissions allowance allocation methods under a Federal Cap-and-Trade Program. *Journal of Environmental Economics and Management*, *60*(3), 161-181. https://doi.org/10.1016/j.jeem.2010.06.002

Gupta, S., & Goldar, B. (2005). Do stock markets penalize environment-unfriendly behaviour? Evidence from India. *Ecological Economics*, *52*(1), 81-95. https://doi.org/10.1016/j.ecolecon.2004.06.011

Hall, B. H., Jaffe, A., & Trajtenberg, M. (2005). Market value and patent citations. *RAND Journal of Economics*, *36*(1), 16-38. https://www.jstor.org/stable/1593752

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica*, *46*(6), 1251-1271. https://doi.org/10.2307/1913827

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panel. *Journal of Econometrics*, *115*(1), 53-74. https://doi.org/10.1016/S0304-4076(03)00092-7

International Energy Agency. (2019). *Energy technology RD&D budgets*. https://iea.blob.core.windows.net/assets/0d6e358c-276c-4e2a-90b1-0823fca9c6dc/Energy_Technology_RDD_2019_Overview.pdf

Jammazi, R. (2012). Oil shock transmission to stock market returns: Wavelet-multivariate Markov switching GARCH approach. *Energy*, *37*(1), 430-454. https://doi.org/10.1016/j.energy.2011.11.011 **[AQ: 3]**

Ji, Q., Xia, T., Liu, F., & Xu, J. H. (2019). The information spillover between carbon price and power sector returns: Evidence from the major European electricity companies. *Journal of Cleaner Production, 208*(January), 1178-1187. https://doi.org/10.1016/j.jclepro.2018.10.167

Joltreau, E., & Sommerfeld, K. (2019). Why does emissions trading under the EU Emissions Trading System (ETS) not affect firms' competitiveness? Empirical findings from the literature. *Climate Policy*, *19*(4), 453-471. https://doi.org/10.1080/14693062.2018.1502145

Kao, C., & Chiang, M. H. (2000). On the estimation and inference of a cointegrated regression in panel data. *Advances in Econometrics*, *15*, 179-222. https://doi.org/10.2139/ssrn.1807931

Keppler, J. H., & Cruciani, M. (2010). Rents in the European power sector due to carbon trading. *Energy Policy*, *38*(8), 4280-4290. https://doi.org/10.1016/j.enpol.2010.03.057

Kilian, L., & Park, C. (2009). The impact of oil price shocks on the U.S. stock market. *International Economic Review*, *50*(4), 1267-1287. https://doi.org/10.1111/j.1468-2354.2009.00568.x

Kim, H., Oh, K. Y., & Jeong, C. W. (2005). Panel cointegration results on international capital mobility in Asian economies. *Journal of International Money and Finance*, *24*(1), 71-82. https://doi.org/10.1016/j.jimonfin.2004.10.006

Lecuyer, O., & Quirion, P. (2012). Can uncertainty justify overlapping policy instruments to mitigate emissions? *Ecological Economics, 93*(September), 177-191. https://doi.org/10.1016/j.ecolecon.2013.05.009

Lee, B.-J., Yang, C. W., & Huang, B.-N. (2012). Oil price movements and stock markets revisited: A case of sector stock price indexes in the G-7 countries. *Energy Economics*, *34*(5), 1284-1300. https://doi.org/10.1016/j.eneco.2012.06.004

Levin, A., Lin, C. F., & Chu, C. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, *108*(1), 1-24. https://doi.org/10.1016/S0304-4076(01)00098-7

Lintner, J. (1965). The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets. *Review of Economics and Statistics*, *47*(1), 13-37. https://doi.org/10.2307/1924119

Lundgren, T., & Zhou, W. (2017). Firm performance and the role of environmental management. *Journal of Environmental Management*, *203*(Pt. 1), 330-341. https://doi.org/10.1016/j.jenvman.2017.07.053

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, *61*(S1), 631-652. https://doi.org/10.1111/1468-0084.0610s1631

Marin, G., Marino, M., & Pellegrin, C. (2018). The impact of the European Emission Trading Scheme on multiple measures of economic performance. *Environmental and Resource Economics*, *71*(2), 551-582. https://doi.org/10.1007/s10640-017-0173-0

Mo, J. L., Zhu, L., & Fan, Y. (2012). The impact of the EU ETS on the corporate value of European electricity corporations. *Energy*, *45*(1), 3-11. https://doi.org/10.1016/j.energy.2012.02.037

Mohanty, S. K., & Nandha, M. (2011). Oil risk exposure: The case of the U.S. oil and gas sector. *Financial Review*, *46*(1), 165-191. https://doi.org/10.1111/j.1540-6288.2010.00295.x

Moreno, B., & da Silva, P. P. (2016). How do Spanish polluting sectors' stock market returns react to European Union allowances prices? A panel data approach. *Energy*, *103*(May), 240-250. https://doi.org/10.1016/j.energy.2016.02.094

Moreno, B., García-Álvarez, M. T., & Fonseca, A. R. (2017). Fuel prices impacts on stock market of metallurgical industry under the EU emissions trading system. *Energy*, *125*(15), 223-233. https://doi.org/10.1016/j.energy.2017.02.067[AQ: 4]

Moya-Martínez, P., Ferrer-Lapeña, R., & Escribano-Sotos, F. (2014). Oil price risk in the Spanish stock market: An industry perspective. *Economic Modelling, 37*(February), 280-290. https://doi.org/10.1016/j.econmod.2013.11.014

Oberndorfer, U. (2009). EU emission allowances and the stock market: Evidence from the electricity industry. *Ecological Economics*, *68*(4), 1116-1126. https://doi.org/10.1016/j.ecolecon.2008.07.026

Oestreich, A. M., & Tsiakas, I. (2015). Carbon emissions and stock returns: Evidence from the EU Emissions Trading Scheme. *Journal of Banking & Finance, 58*(September), 294-308. https://doi.org/10.1016/j.jbankfin.2015.05.005

Pedroni, P. (2000). Fully modified OLS for heterogeneous cointegrated panels. *Advances in Econometrics*, *15*, 93-130. https://doi.org/10.1016/S0731-9053(00)15004-2

Pedroni, P. (2001). Purchasing power parity tests in cointegrated panels. *Review of Economics and Statistics*, *83*(4), 723-741. https://doi.org/10.1162/003465301753237803

Porter, M. E., & van der Linde, C. (1995). Toward a new conception of environment-competitiveness relationship. *Journal of Economic Perspectives*, *9*(4), 97-118. https://doi.org/10.1257/jep.9.4.97

Ready, R. C. (2017). Oil prices and the stock market. *Review of Finance*, *22*(1), 155-176. https://doi.org/10.1093/rof/rfw071

Reinaud, J. (2005). Industrial competitiveness under the EU ETS. *Oil, Gas & Energy Law*, *3*(1), Article 1796. https://www.ogel.org/article.asp?key=1796

Scholtens, B., & Yurtsever, C. (2012). Oil price shocks and European industries. *Energy Economics*, *34*(4), 1187-1195. https://doi.org/10.1016/j.eneco.2011.10.012

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *Journal of Finance*, *19*(3), 425-442. https://doi.org/10.2307/2977928

Sijm, J., Neuhoff, K., & Chen, Y. (2006). CO_2 cost pass through and windfall profits in the power sector. *Climate Policy*, *6*(1), 49-72. https://doi.org/10.3763/cpol.2006.0604

Tian, Y., Akimov, A., Roca, E., & Wong, V. (2016). Does the carbon market help or hurt the stock price of electricity companies? Further evidence from the European context. *Journal of Cleaner Production*, *112*(Pt. 2), 1619-1626. https://doi.org/10.1016/j.jclepro.2015.07.028

Veith, S., Werner, J., & Zimmermann, J. (2009). Capital market response to emission rights returns: Evidence from the European power sector. *Energy Economics*, *31*(4), 605-613. https://doi.org/10.1016/j.eneco.2009.01.004

Würzburg, K., Labandeira, X., & Linares, P. (2013). Renewable generation and electricity prices: Taking stock and new evidence for Germany and Austria. *Energy Economics, 40*(Suppl. 1), S159-S171. https://doi.org/10.1016/j.eneco.2013.09.011

Zachmann, G., & von Hirschhausen, C. (2008). First evidence of asymmetric cost pass-through of EU emissions allowances: Examining wholesale electricity prices in Germany. *Economics Letters*, *99*(3), 465-469. https://doi.org/10.1016/j.econlet.2007.09.024

Author Biographies

[AQ: 5]