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## The impact of EU allowance prices on the stock market indices of the European power industries: Evidence from the ongoing EU ETS Phase III

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Abstract:	<p>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 (EUA) can affect electric power industry stock performance.</p> <p>This paper 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 OLS (FMOLS) and dynamic OLS (DOLS) to estimate any such relationship.</p> <p>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</p>

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## 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 (EUA) can affect electric power industry stock performance.

This paper 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 OLS (FMOLS) and dynamic OLS (DOLS) 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

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## 1. Introduction

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

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<sup>1</sup> 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.

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3 A number of issues have attracted the interest of scholars, including the allocation process,  
4 considering its unequal distribution across countries, the percentage of free allocation, and  
5 also its differential treatment by sector. In this respect, Ellerman *et al.* (2010) provided a  
6 detailed description and analysis of the EU ETS, focusing on the first phase. The initial  
7 allocation of EUAs was identified as advantageous for industrial sectors, but created a  
8 deficit in the power sector, based on the idea that this sector, without losses due to  
9 international competition, had a greater potential to reduce emissions than other sectors.<sup>2</sup>  
10 Although upward, the growth in auctioning during the second phase was limited. The  
11 amount of EUAs auctioned increased substantially in the third phase, boosting the  
12 differential allocation across sectors. Figure 1 shows the total EUAs allocated according  
13 to the allocation system employed (free or auction). As Figure 1 shows, the amount of  
14 auctioned EUAs increased substantially across the EU during the third phase.

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22 **Figure 1. Total allocated allowances. Phases I, II and III (1,000 million tCO<sub>2</sub>eq)**

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

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38 There can be expected to be differences between companies, as well as between sectors,  
39 countries or different periods of time due to the variety of market characteristics,  
40 technologies, or carbon intensities. Previous studies have investigated the effect of  
41 allowances prices on stock returns in several industries and countries during Phase I and  
42 II, when allowance allocation was predominantly for free, with mixed results for phases,  
43 sectors, and direction of the effects. For example, Oestreich and Tsiakas (2015) provided an  
44 empirical investigation of the effect of EUAs price on 80 firms trading on the Frankfurt Stock  
45 Exchange and found "that firms that received free carbon emission allowances significantly  
46 outperformed firms that did not" during EU ETS Phase I and II. Their results showed the

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59 <sup>2</sup> Electricity production was the only sector that was short on balance during the first phase. It accounts for 77%  
60 of the short positions in the EU ETS, receiving 49% of EUAs for 54% of emissions (Ellerman, 2008).

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3 presence of a high and significant carbon premium. This result confirmed empirically the  
4 same result showed by Goulder et al. (2010) through a simulation exercise.  
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8 The power sector plays a crucial role in the EU ETS system as the CO<sub>2</sub> emissions from  
9 electricity and heat production form the largest key category in the EU, accounting for 25% of  
10 total greenhouse gas (GHG) emissions in 2015 (European Environment Agency, 2017). Thus,  
11 the study of the effect of EU carbon dioxide emission allowances on the stock market of  
12 power industry requires a special analysis.  
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15 Power companies should be able to reduce emissions by using new technologies with a  
16 relatively low emission abatement cost, as well as pass on allowance costs to consumers  
17 through prices. Thus, European Union (2017) maintains that “the experience of the first  
18 two trading periods shows that power generators have been able to pass on the notional  
19 cost of allowances to customers even though they received them for free”. As a result,  
20 companies in the electricity generation sector do not receive free allowances since 2013<sup>3</sup>,  
21 whereas free allocation is yet to be phased out in the other sectors.  
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24 Moreover, power companies are an interesting case in point because their output is a  
25 unique product that can be produced using several technologies with different carbon  
26 intensities. It is one of the most pollutant sectors and has a high potential for emission  
27 reductions. Moreover, sector allowances are more or less all auctioned in the ongoing  
28 phase. As Moreno and da Silva (2016) state, allowance price fluctuations can affect power  
29 company stock market value, but the final effect is ambiguous and depends on investor  
30 expectations about future profits. In sum, several factors can determine the final outcome  
31 on company profits: the sector’s ability to pass on the allowance cost to consumers,  
32 technologies, market characteristics (competition), demand elasticity or abatement costs<sup>4</sup>.  
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41 Our paper uses a capital asset pricing model (Sharpe, 1964; Litner, 1965) to analyze the  
42 impact of EUA prices on the stock market of the European power sector during the  
43 ongoing EU ETS Phase III, estimated using a panel cointegration technique. Oberndorfer  
44 (2009), Veith *et al.* (2009), Mo *et al.* (2012), and da Silva *et al.* (2016) used the capital asset  
45 pricing model to test the effect of EUA on power company stock market prices. Moreover,  
46 the above studies used an econometric panel method as an estimation procedure: Veith *et al.*  
47 (2009) used data for 22 European power companies from 25 April 2005 to 31 August 2007;  
48 Oberndorfer (2009) used 12 European power companies with an estimation period spanning  
49 from 4 August 2005 until 19 June 2007; Mo *et al.* (2012) used 12 European power generating  
50 firms and annual data from 2006 to 2009; and da Silva *et al.* (2016) used 13 Spanish power  
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58 <sup>3</sup> Power generators must buy all their allowances since 2013, with the exception of some countries (Bulgaria,  
59 Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Poland and Romania) for a transitional period until 2019.  
60 See Climate Action (European Union, 2017).

<sup>4</sup> Sijm *et al.* (2006) revise several factors and their influence on the power sector during EU ETS Phase I.

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3 companies using daily data from January 2008 to July 2014.  
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6 Unlike other studies, we estimate the long-run impact of EUA prices on power stock  
7 market returns in EU ETS Phase III using a multifactor market model and fully modified  
8 OLS (FMOLS) and dynamic OLS (DOLS) panel cointegration techniques. The panel data  
9 consist of a daily sample for the ongoing EU ETS Phase III (from 1 January 2013 to 22  
10 April 2017) and data from six European countries (Austria, France, Germany, Italy,  
11 Netherlands and Spain).  
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16 To the best of our knowledge, this is the first paper to estimate the long-run relationship  
17 between EUA prices and power stock market returns using a panel data cointegration  
18 approach in an attempt to take advantage of the possibility of including specific factors  
19 from the different countries in the sample. Again, unlike others studies which refer to the  
20 impact of EUA prices on the power stock market of a single country (da Silva *et al.* 2016) or  
21 EU ETS Phases I and II, the novelty of our research is that it is based on the cross-sectional  
22 analysis of the European power sector stock market and on the expansion of the analysis to  
23 the latest EU ETS Phase III information. Section 2 presents a literature review addressing the  
24 link between carbon prices and stock returns. Section 3 shows a brief description of the  
25 applied methodology, including the multifactor model specification and the extension of the  
26 multifactor model with panel data. Section 4 describes the data and variables used in the  
27 study. Section 5 reports the empirical findings. Finally, Section 6 contains some concluding  
28 remarks and policy recommendations.  
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## 37 **2. Literature review**

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39 The effect of carbon prices on power company stock returns has been a matter of debate in  
40 empirical and theoretical literature. Both results (a positive and negative relationship  
41 between allowance prices and corporate value) can be explained from a theoretical point  
42 of view. It was Coase (1960) who came up with the idea of creating emissions markets,  
43 claiming that “*pollutant agents need to be confronted with a price equal to the marginal*  
44 *external cost of their polluting activities to induce them to internalize the social costs*”. If  
45 this is the case, an increase in the allowance price is expected to lead to a fall in stock  
46 market returns due to higher output costs. In short, from this point of view, the relationship  
47 between EUA price and stock market returns can be expected to be negative, especially if,  
48 as is the case in EU ETS Phase III, companies have to buy EUAs.<sup>5</sup> However, Sijm *et al.*  
49 (2006) report a different finding based on the possibility of future windfall profits. The  
50 final effect of EUA prices on future company profits depends on the ability to pass  
51 allowance costs through to the market. Again, other market-specific and technology-  
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59 <sup>5</sup> As Burtraw *et al.* (2002) pointed out, companies are expected to add the allowance price to their costs in the  
60 short-term in both cases (whether they have to pay or they are grandfathering).

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3 specific factors have influenced the possible incorporation of allowance costs into  
4 electricity prices, such as market price structure and strategic producer behavior. For  
5 example, in a sector where the wholesale price is defined by a technology with relatively  
6 high carbon intensity, the infra-marginal technologies with lower carbon intensity could  
7 benefit from a higher market price due to an allowance price increase. Thus, sector profits  
8 will rise because the marginal technology passes on allowance costs through prices.  
9 Therefore, profits will not fall.  
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16 The analysis of the impact of allowance prices on corporate stock returns in the power  
17 industry has been based on cross-country panel data or individual countries and main and  
18 they have focused mainly in EU ETS Phases I and II. Table 1 shows and overview of the  
19 impact of EUA prices on corporate stock returns in power sector.  
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25 **Table 1. Overview of the impact of EUA prices on corporate stock returns in power**  
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31 As it is showed in Table 1, regarding the effect of EUA prices on stock returns, Oberndorfer  
32 (2009) used the GARCH model to study the case of the major European electricity  
33 companies. Oberndorfer (2009) found that EUA price increases (decreases) positively  
34 (negatively) affect stock returns. He highlighted that the specific effect of changes in EUA  
35 prices on stock returns may differ depending on the country. Veith *et al.* (2009) reported a  
36 positive correlation between the EUA price changes and stock returns of 22 European  
37 electricity companies in the period 2005-2007 using a multifactor model. Keppler and  
38 Cruciani (2010) reported similar results when developing a revenue creation model in EUA  
39 ETS Phase I. Mo *et al.* (2012) studied the effects of EUA prices on the corporate value of  
40 European power companies in the period 2005-2009 using a multifactor market model. They  
41 found different results in EUA ETS Phase I and Phase II. EUA price increases tended to cause  
42 appreciation of company value in Phase I and depreciation in Phase II. Likewise, the company  
43 value was more sensitive to EUA price changes in Phase II. By means of the combination of  
44 different (ordinary least square, panel data and time series) methods, Tian *et al.* (2016)  
45 concluded that the stock return volatility of European power companies was driven in the  
46 same direction by EUA market volatility in the EUA ETS Phase I and Phase II. Da Silva *et al.*  
47 (2016) developed a vector error cointegration model to analyze the Spanish power industry in  
48 the period 2008-2014. Their results showed that EUA price changes did not have an impact  
49 on stock market return in either EU ETS Phase II or Phase III. However, they found that long-  
50 term relationships between EUA prices and stock market returns were positive in Phase II and  
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3 not significant in Phase III. Dutta (2017) applied a realized volatility model to 40 companies  
4 of the Wilder Hill Clean Energy Index whose results showed that emission allowance prices  
5 did not have any influence on stock market values. Recently, Ji *et al.* (2019) by using a  
6 network approach showed a strong interdependence between carbon price returns and  
7 electricity stock returns in 18 top European electricity companies from November 18, 2005, to  
8 May 10, 2018.  
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14 Therefore, we can conclude that different methods and results have been reported in the  
15 literature. Multifactor models have been one of the most used techniques in this research  
16 field (Veith *et al.*, 2009; Mo *et al.*; 2012). Using the above capital asset pricing model,  
17 multifactor models assess the impact of any factor on company value. Following Fama  
18 and French (1992), it is possible, based on the basic model where stock market return  
19 depends on market portfolio return, to include explanatory variables related to key price  
20 factors for company stock returns that shape the multifactor market model.  
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26 The empirical evidence about other pricing factors (for example, fuel prices) being linked  
27 in stock markets in Europe, other countries or cross-country panels and their influence is  
28 unclear. A potential cause of this mixed evidence is aggregation, since the analysis  
29 includes a wide range of outputs and technologies with a diversity of carbon intensity, and  
30 a different electricity mix in cross-country panel studies. Apparently, oil price shock is the  
31 most significant pricing factor for the general stock index.  
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37 The above result is more evident at sectorial level. A sector-specific analysis shows  
38 significant evidence of oil price shock on some sector indices for some countries. For  
39 example, Arouri and Nguyen (2010) or Scholtens and Yurtsever (2012) found that oil  
40 price shocks had an asymmetric impact on company stock returns depending on the sector  
41 of activity. These results underscore the need for the specific sector to be included in the  
42 empirical analysis, and this is consistent with the uncertain link observed when aggregate  
43 data are used.  
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47 We attempt to overcome this problem by focusing in studies about the effect of fuel prices  
48 on energy industry. Table 2 shows the major studies that analyzed the impact of fuel prices  
49 on company stock returns in the energy industry.  
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### 53 **Table 2. Overview of the impact of fuel prices on stock returns in the energy industry**

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57 Boyer and Filion (2006) used a multifactor model and found a positive correlation between  
58 increases of both crude oil and natural gas prices and the stock market values of 35 Canadian  
59 oil and gas companies in the period 1995-2002. Kilian and Park (2009) reported similar  
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3 results using a variance decomposition method. Their results showed that increases of oil  
4 prices due to demand shocks played a major role in increases of US stock prices in different  
5 industries (including the energy sector) in the period 1973 to 2006. Mohanty and Nandha  
6 (2011) applied four-factor asset pricing to the US oil and gas sector over the period 1992 to  
7 2008. Likewise, they concluded that there were significant positive relationships between oil  
8 price changes and the stock market in these industries. Similarly, Moya-Martínez *et al.* (2014)  
9 developed a multifactor market model and showed a strong correlation between oil price and  
10 stock market in the Spanish energy industry over the period 1993 to 2010.

11 Ready (2016) developed both simulation and regression models to analyze the effects of oil  
12 price changes on the stock market in ten industry portfolios constructed by Fama and French  
13 (1997). This study classified oil price changes by demand and supply shocks. Their results  
14 showed that there was a positive correlation between demand shocks and the stock market  
15 (particularly in industries that import large amounts of oil) and a negative correlation between  
16 supply shocks and the stock market (mainly in industries that produce consumer goods). By  
17 means of range-based realized volatility measures, Dutta (2017) found that oil price shocks  
18 had significant impacts on the stock returns of 40 companies included in the Wilder Hill  
19 Clean Energy Index. In contrast to this study, Ferrer *et al.* (2018) found that crude oil prices  
20 did not appear as a key driver of the stock market performance of renewable energy  
21 companies in the short-term or the long-term.  
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32 It can be concluded that empirical results are ambiguous for the power sector and other  
33 pollutant sectors of the European economy. Thus, some studies found a positive  
34 correlation between allowance prices and power stock returns (for example, Oberndorfer,  
35 2009; Keppler and Cruciani, 2010 or Chan *et al.*, 2013). Using daily data for Phase II and  
36 the first year of Phase III, Moreno and da Silva (2016) found, however, that EU ETS had a  
37 significant and sector-specific impact on Spanish stock market returns and a significant  
38 negative effect on the power sector. However, there is some agreement on increased oil  
39 prices having a positive impact on stock market in the energy industry.  
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### 46 3. Panel data model specification

47 Multifactor market models are widely used in order to study the effect of any possible  
48 factor on company value change. Following Fama and French (1992), based on the basic  
49 model where the stock market return ( $R_t$ ) depends on the market portfolio return ( $R_{mt}$ ),  
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$$51 R_t = f(R_{mt}), \quad (1)$$

52 it is possible to incorporate explanatory variables to build the so-called multifactor market  
53 model as follows:  
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$$57 R_t = f(R_{mt}, x_{1t}, x_{2t}, \dots, x_{nt}) \quad (2)$$

58 where  $(x_{1t}, x_{2t}, \dots, x_{nt})$  are the relevant pricing factors for company stock returns.  
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Oberndorfer (2009), Veith *et al.* (2009) or Mo *et al.* (2013) used multifactor market models (Eq.2) to investigate the impact of EUA price changes on stock returns. The basic specification of the model is as follows:

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

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  $E(u_t)$  and  $var(u_t) = \sigma^2$  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 or 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.

**Table 3. European Union energy dependency in terms of consumed energy imported from abroad (%).**

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

Thus, the initial multifactor market model can be specified as

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

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 (Eq. 4) can also be specified in terms of a panel data model (see for example Baltagi (2013) for a detailed description of the technique). The above equation (4) can thus be reformulated as:

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

where  $i$  stands for the power sector of the analyzed EU member  $i$  ( $i =$  Austria, France, Germany, Italy, Netherlands and Spain),  $\alpha_i$  parameters denote the country effects and  $u_{it}$

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3 represents the disturbances of this model, which are assumed to be independently and  
4 identically distributed random variables with mean zero and variance  $\sigma_u^2$ .  
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8 The proposed model (Eq. 5) has been estimated considering both random and fixed effects  
9 to identify the most suitable panel model specification. According to the random effects  
10 model,  $\alpha_i$  is considered as a component of the random disturbance, while the fixed effects  
11 model treats  $\alpha_i$  as a regression parameter. A Hausman test is performed (Hausman, 1978)  
12 to establish whether the random or the fixed effects estimator is better. Furthermore, the  
13 Breuch-Pagan test (for random effects) or the F test (for fixed effects) is used to check  
14 whether there is a country-specific effect. The null hypothesis in both cases is that  $\alpha_i$  is  
15 equal for all countries. If the individual country effect  $\alpha_i$  is assumed to be equal across all  
16 countries, then the pooled ordinary least square (OLS) estimation is consistent and  
17 efficient.  
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#### 23 24 **4. Data and variables**

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26 We used data from six countries (Austria, France, Germany, Italy, Netherlands and Spain)  
27 in this research. The daily sampling period employed in our analysis is from 1 January  
28 2013 to 22 April 2017. Information on the electricity sector daily stock price for each EU  
29 member was extracted from the DataStream Database. The proxies used for the market  
30 portfolio return ( $R_m$ ) are Vienna Stock Exchange (Austrian Traded Index), Euronext Paris  
31 (CAC 40 Index), Deutsche Boerse (DAX, 30 Index), FTSE Italia (MIB Index), Euronext  
32 Amsterdam (AEX-Index) and Madrid Stock Exchange (IBEX 35 Index) for the cases of  
33 Austria, France, Germany, Italy, Netherlands, and Spain, respectively.  
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40 The 10-year Treasury yield is used to assess the interest rate  $r$  for each country. The natural  
41 gas price  $P^{Gas}$  (€/MMBTU) is the Henry Hub spot price, the coal price  $P^{Coal}$  (€/ton) is the  
42 API#2 spot index (CIF ARA, that is, cost of insurance and freight delivered to the  
43 Amsterdam/Rotterdam/Antwerp region) and the crude oil price  $P^{Oil}$  (€/bbl) is the Dated Brent.  
44 The EUA price series  $P^{EUA}$  (€/EUA) is the spot price of a ton of CO<sub>2</sub> quoted on the European  
45 Energy Exchange (EEX) based in Leipzig, Germany. The exchange rate ( $ER$ ) is the local  
46 currency to US dollar (€/€). All the data and information was extracted from the Thomson  
47 Reuters Datastream and Bloomberg databases.  
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53 Table 4 summarizes the main descriptive statistics of the variables.  
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#### 56 **Table 4. Descriptive statistic measures**

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

## 4 5 6 **5. Results and discussion of the results**

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8 We used a unit root and cointegration analysis within a panel framework. In order to  
9 evaluate a possible long-term relationship between electricity sector stock prices and  
10 explanatory variables, the estimation method proceeds as follows: i) panel unit root tests  
11 are conducted to assess the order of integration of the variables, ii) if these tests conclude  
12 that all series have the same order of integration, the long-term relationships between the  
13 variables are explored using a cointegration test; and iii) the model could be estimated  
14 using two methods —dynamic OLS, and fully modified OLS— to examine the parameters  
15 of the long-term relationship between stock market price and energy prices.  
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### 20 21 **5.1. Panel unit root test and panel cointegration test**

22 To check the order of integration of the variables, we performed panel unit root tests. The  
23 panel unit root tests are estimated without individual trends, as Breitung (2000) found that  
24 some tests suffer from a dramatic loss of power when individual trends are included. Four  
25 different tests were estimated. One test assumes common unit root processes in the data  
26 (Levin *et al.*, 2002). The remaining three assume individual unit root processes. They are  
27 the tests reported by Im *et al.* (2003) and the ADF-Fisher and PP-Fisher (Augmented  
28 Dickey-Fuller and Phillips-Perron, respectively) tests developed by Maddala and Wu  
29 (1999) and Choi (2001).  
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36 Table 5 reports results from the panel unit root tests, showing that all variables included in  
37 the model are I(1) at a 1% confidence level, whereas the Phillips-Perron Fisher's chi-  
38 square indicates that the unit root null hypothesis is rejected for the EUA price series ( $P^{EUA}$   
39 ) only. Generally, individual series could have a unit root if time series approaches were  
40 used. When moving away from time-series approaches and adopting more powerful panel  
41 unit root tests, however, the unit root null hypothesis could be rejected (as is the case  
42 here). Culver and Papell (1997), for example, found that if national inflation rates are  
43 pooled the unit root null hypothesis is rejected. All variables become stationary after first  
44 differencing.  
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#### 50 51 **Table 5. Panel unit root test results.**

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

**Table 6. Panel cointegration tests. Null hypothesis: no cointegration.**

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.

## 5.2. Dynamic OLS and fully modified OLS estimation

The cointegration vector is estimated using a fully modified OLS (FMOL) 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.

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 dynamic OLS (DOLS) panel cointegration estimator (Kao and Chiang, 2000). Table 7 reports the FMOLS and DOLS results.

**Table 7. Long-term estimation**

In FMOLS estimations, the market portfolio ( $R_m$ ), the exchange rate ( $ER$ ) 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

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3 similar, but the variables related to the gas and oil price ( $P^{Gas}$  and  $P^{Oil}$ , respectively) are  
4 positive and statistically significant at the 5% and 1% significance levels, respectively, in  
5 DOLS. In fact, a 1% increase in gas and oil prices increases the electricity sector stock price  
6 by 0.36% and 0.07%, respectively. The price of coal ( $P^{Coal}$ ) is not significant in either of the  
7 estimations of the panel model.  
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11  
12 As shown above, our results suggest that EUA prices have a significant positive long-run  
13 effect on electricity industry stock returns. The empirical evidence is at odds with regard to  
14 the impact of EUA price variations on power stock markets. This is because many studies are  
15 based on a specific country (or region). Besides, the results reported in the literature also  
16 appear to depend on the method used and the EU ETS phase examined.  
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21 Generally, the literature appears to show that EU ETS had a positive impact on power  
22 companies (for example, Oberndorfer, 2009; Keppler and Cruciani, 2010; Chan *et al.*, 2013;  
23 Ji *et al.*, 2019). This is consistent with our results. However, the specific impact of EUA price  
24 changes on electricity company stock returns may vary depending on the analyzed country,  
25 the power generation technology, the EU ETS phase and allowance allocation over time, as  
26 shown by Oberndorfer (2009), Bode (2006), and Mo *et al.* (2010), respectively.  
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32 Our results suggest that EU ETS Phase III has an influence on financial markets. This should  
33 be taken into account by investors, as the EUA price could lead to an appreciation of  
34 corporate value in the long run. Related to this finding, Oberndorfer (2009) showed, albeit  
35 for EU ETS Phase I, that the EU power sector has been thought to be able to pass on costs to  
36 consumers, thus generating windfall profits. Therefore, the development of EUA market  
37 prices may have important implications from the point of view of both economic and  
38 financial markets, possibly leading investors to hedge against EUA price fluctuations.  
39 Similar results were reported by Veith *et al.* (2009) and Keppler and Cruciani (2010) using  
40 different methods in EU ETS Phase I. They highlighted that the implementation of ETS not  
41 only led to an alteration of the cost structure of European electricity companies but also had  
42 the potential to increase prices that more than offset the imposed costs. Likewise, Mo *et al.*  
43 (2012) and Tian *et al.* (2016) found that stock returns were positively correlated with EUA  
44 price changes in EU ETS Phase I, although this did not apply to EUA ETS Phase II, where  
45 there was an inverse relationship between stock returns and EUA price changes for carbon-  
46 intensive producers.  
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56 Nevertheless, there has been hardly any research on EUA ETS Phase III, where EUAs for  
57 the power sector are allocated by auction. Exceptions are Dutta (2017) and da Silva *et al.*  
58 (2016), who analyzed the Spanish power industry and 40 companies included in the Wilder  
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3 Hill Clean Energy index, respectively. They showed that there were no significant  
4 relationships between EUA prices and stock returns.  
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8 On the other hand, our results suggest that European power sector stock returns reacted  
9 positively to an increase of both oil and gas prices. These results are consistent with findings  
10 by Veith *et al.* (2009), Mo *et al.* (2012), and Dutta (2017) for the EU energy sector. The  
11 results highlight the importance of enacting effective policies to mitigate the negative effect  
12 of both oil and gas price uncertainty in order to increase the use of renewable energy and  
13 improve energy consumption efficiency. Thus, the adoption of suitable actions to reduce  
14 stock returns volatility appears to be a key concept.  
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## 19 **6. Conclusion**

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21 This paper analyses the long-run impact of EUA prices, as well as other variables, such as  
22 fuel prices and exchange rate, on European electricity sector stock prices. A multifactor  
23 market model was specified and estimated using econometric analysis of panel data. Daily  
24 data from 1 January 2013 to 22 April 2017 were collected for six European Union members:  
25 Austria, France, Germany, Italy, Netherlands and Spain.  
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30 The Johansen Fisher panel cointegration test and Kao residual cointegration test were used to  
31 check that there is a long-run relationship. Fully modified OLS (FMOLS) and dynamic OLS  
32 (DOLS) were used to estimate the cointegrating parameters. Results reveal that there is  
33 strong evidence in favor of a positive long-run relationship between EUA prices and the  
34 power sector stock market for the panel of selected countries during the current EU ETS  
35 Phase III.  
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39 An interesting point that arises from this positive long-run relationship is that it suggests the  
40 possibility of future windfall profits, attention should be paid to price formation mechanisms  
41 because electricity producer profits may place a heavy burden on electricity consumers. In that  
42 sense, the market structure, the demand elasticity to price variations or the number of  
43 substitutes of the principal source that the electricity firm uses to generate electricity, among  
44 others, influence the grade of the pass-through of environmental costs on prices.  
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48 Although the EU electricity market liberalization compels to introduce competition into  
49 electricity market, when comparing results of the impact of EU allowances price on sectors'  
50 stock market returns from different countries they might differ as countries could have  
51 different market conditions. For example, the European country with the highest market share  
52 of the largest generator in the electricity market (as a percentage of the total generation) is  
53 France with a percentage around 80% as it is shown in Table 8. In this context, it is possible  
54 to exercise market power and increase the pass-through of EUA costs to consumers.  
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3 **Table 8. Market share of the largest electricity generator in the market, % of total**  
4 **generation**  
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10 In addition, the demand elasticity to electricity price variations could be low not only of the  
11 special characteristics of electricity output (such as no storability or the existence of capacity  
12 constraints in the short term offer) but also for the number of substitutes limited to gas in  
13 those countries where the electricity generation is based on this fuel as Italy or Netherlands, as  
14 it is shown in Table 9.  
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19 **Table 9. Electricity Generation by Fuel [% of the Total Gross Electricity generation]**  
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24 Note that the link between stock market value and CO<sub>2</sub> price increases might depend on the  
25 ability to transmit the allowance cost to the wholesale electricity market, as well as the relative  
26 carbon intensity of the infra-marginal technologies. For example, in a sector where the  
27 wholesale price is defined by a technology with relatively high carbon intensity, the infra-  
28 marginal technologies with lower carbon intensity could benefit from a higher market  
29 price due to an allowance price increase. In fact, under the Capital Market Theory, the work  
30 of da Silva *et al.* (2016) showed a long-run positive effect of EU allowances on the stock  
31 price changes of Spanish power companies based on renewable sources (RES-E). The study  
32 was carried out by using daily data of Phase III from January 2013 to July 2014. In such case,  
33 EUA price rise of 1%, would, in equilibrium, be associated with a stock price for the RES  
34 sector increase of approximately 0.002%. However, the growing penetration of RES-E into  
35 the wholesale electricity market will reduce the wholesale electricity price as a result of the  
36 so-called merit order effect (see Dillig *et al.* 2016 and Würzburg *et al.* 2013 for a review of  
37 this effect in EU electricity markets). It could reduce the RES-E firms' investors' expectations  
38 of future profits, leading to lower stock market share prices of the company.  
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48 A possible explanation for this result is the rational market behavior during EU ETS Phase I if  
49 price increases can be passed on (Oberndorfer, 2009), because the system can generate  
50 windfall profits for the analyzed companies (Sijm *et al.*, 2006). Our results are interesting  
51 because they are related to EU ETS Phase III, without grandfathering allocation, and they  
52 support the positive long-run relationship between allowance prices and stock market values.  
53 This can shed light on the debate regarding the effect of environmental regulation on financial  
54 performance.  
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60 There have been widespread concerns that emissions were not sufficiently capped and

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3 changes should be introduced to generate decarbonization incentives compatible with  
4 business competitiveness. Climate policy based on carbon price has a modest impact on  
5 technological development if prices are too low and the pressure on technological  
6 development is not strong enough (Lundgren *et al.*, 2015). As Ellerman *et al.* (2016) states,  
7 "...under all likely scenarios, (a continually declining cap) will create continuing scarcity, thus  
8 virtually guaranteeing that a carbon price will be a permanent feature of the European  
9 economic landscape".  
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14 Thus, a more stringent emission trading system has the potential to stimulate company  
15 innovation, which is considered to be positively connected with stock market value (Hall *et al.*,  
16 2005). In that sense, Joltreau and Sommerfeld (2019) found that grandfathering, main feature  
17 of EU ETS in Phases I and II, has been a main factor that limited the stimulation of low-  
18 carbon innovation in these periods; whilst the growing importance of auctions -in Phase III-  
19 can increase climate-related innovation.  
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24 Table 10 shows that energy technology RD&D spending increased significantly in the  
25 countries of our sample during the Phase II, in which allowance auctioning begun and CO<sub>2</sub>  
26 prices were, at the beginning, in the upper range (close to 30€). These circumstances seem  
27 that have boosted investment in innovation in the energy sector. RD&D spending almost  
28 tripled in Phase II compared to the previous one, in which the allocations were allocated for  
29 free.  
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34 In Phase III, despite the fall in the CO<sub>2</sub> price, energy technology RD&D spending remained  
35 steady, with a small increase in the sample countries as a whole. During this period, when  
36 companies in the electricity generation sector did not receive free allowances in our sample,  
37 only in Spain there was a significant decrease in R&D spending in the sector, probably due to  
38 the vulnerability of its economy to the financial crisis. Nevertheless, Spanish R&D spending  
39 remained significantly higher than the initial phase of the market (more than double), as in the  
40 other countries considered. Germany remained a significant growth in investment.  
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48 **Table 10. Total Energy Technology RD&D spending in Million (currency: Euro 2018**  
49 **prices).**  
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54 Likewise, the Porter hypothesis (Porter and van der Linde, 1995) asserts that environmental  
55 policies that stimulate green innovation may lead to positive innovation-related outcomes and  
56 affect firm competitiveness (Lundgren and Zhou, 2017). Thus, if EU ETS works properly, it  
57 could motivate firms to innovate, improving financial performance by lowering costs and/or  
58 raising revenues (Marin *et al.*, 2015). Gupta and Goldar (2009) have pointed out that firms  
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3 with environmentally friendly behavior could increase the value of their stock market prices.  
4 Thus, a further step in this research could be to analyze the effects of environmental  
5 regulation on electricity sector investment and how this circumstance could indirectly  
6 increase its stock market value  
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10 Another potentially interesting issue is to analyze the coexistence of several policy instruments  
11 affecting European power stock market prices. Combining an ETS with a renewable energy  
12 subsidy has a greater potential to improve welfare than the ETS alone (Lecuyer and Quirion,  
13 2012).  
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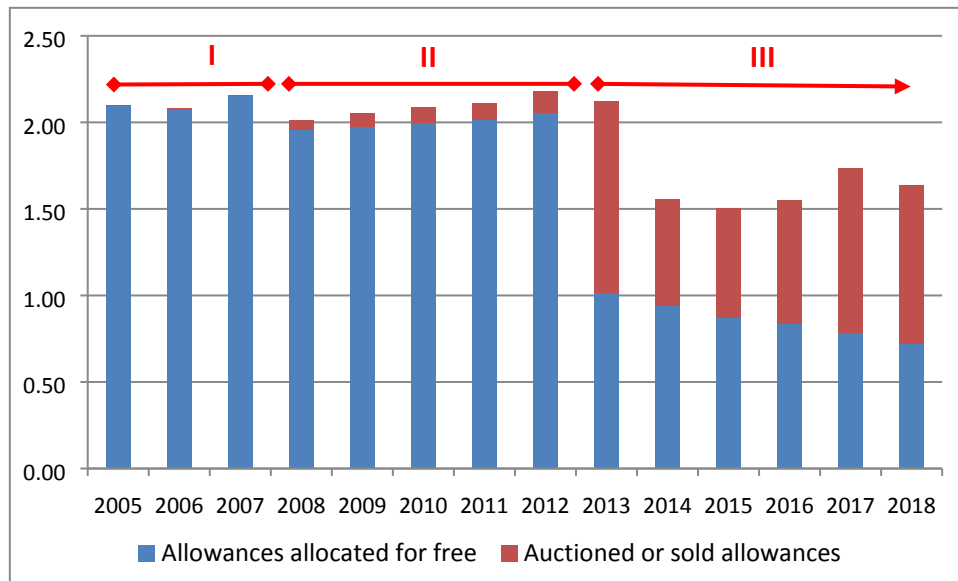
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Figure 1. Total allocated allowances. Phases I, II and III (1,000 million tCO<sub>2</sub>eq)



Source: Own elaboration from European Environment Agency (2019) data

Table 1. Overview of the impact of EUA prices on corporate stock returns in power sector

Study	Method	Results	EU ETS Phase	Countries/ Companies
Sjim <i>et al.</i> (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 <i>et al.</i> (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 <i>et al.</i> (2012)	Multifactor model	Corporate values were more sensitive to EUA price changes in Phase I	I -II	European electricity companies
Chan <i>et al.</i> (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 <i>et al.</i> (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 <i>et al.</i> (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 <i>et al.</i> (2019)	Network approach	Strong information interdependence between carbon price returns and electricity stock returns	I-II-III	18 top European electricity companies

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 US 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 US oil and gas companies
Moya-Martínez <i>et al.</i> (2014)	Multifactor market model	Positive correlation between changes in oil and stock market prices	14 Spanish industries (including energy )
Ready (2016)	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 <i>et al.</i> (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

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.) Statistical Office of the European Union (Eurostat) database. Retrieved: February 12, 2018 from [www.http://ec.europa.eu/eurostat/data/database](http://ec.europa.eu/eurostat/data/database).

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Table 4. Descriptive statistic measures (01/01/2012-22/03/2017)

Variable	Units	Mean	Max.	Min.	Std. Dev.
$R$	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
ER	€/S	1.21	1.39	1.04	0.12

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Table 5. Panel unit root test results (only intercept). Null hypothesis: There is unit root

Tests	Variables							
	$R_{elect}$	$R_m$	$P^{EUA}$	$P^{Coal}$	$P^{Gas}$	$P^{Oil}$	$r$	$ER$
<b>Levels</b>								
Levin, Lin & 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
<b>First differences</b>								
Levin, Lin & 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***

\*\*\* null rejected at 1% significance level, \*\* null rejected at 5% significance level and \* null rejected at 10% significance level; 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.

Table 6. Panel cointegration tests. Null hypothesis: no cointegration.

Test name	Test statistic	p-value
Kao residual cointegration tests (Engle-Granger based) <sup>a</sup>		
• ADF-statistic	-4.977359	0.0000
Johansen Fisher panel cointegration test <sup>b</sup>		
• Fisher statistics from trace test	85.11	0.0000
• Fisher statistics from maximum eigenvalue test	72.80	0.0000

<sup>a</sup> Automatic lag length selection based on SIC with a maximum lag of 21.

<sup>b</sup> Probabilities are computed using an asymptotic chi-square distribution

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Table 7. Long-term estimation

Independent Variable	FMOLS <sup>a</sup>	DOLS <sup>a</sup>
$R_m$	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.

<sup>a</sup>Trend specification (constant), long-run covariance methods (lags specification-AIC), \*\*\* null rejected at 1% significance level, \*\* null rejected at 5% significance level and \* null rejected at 10% significance level

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Table 8. Market share of the largest electricity generator in the market, % 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.

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Table 9. Electricity Generation by Fuel [% of the Total Gross Electricity generation]

<b>Fuel</b>	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), "Data and Analysis," <https://ec.europa.eu/energy/en/data-analysis/country>

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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 (20013-2017)
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).