Energy Policy 94 (2016) 492–501

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Firm-specific impacts of CO_2 prices on the stock market value of the Spanish power industry

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HIGHLIGHTS

- EU ETS impacts on stock market returns of Spanish power sector.
- Long-run positive effect of EU ETS on market returns is found only in Phase II.
- No short-run effects were found.
- EUA price effect is company-specific.

ARTICLE INFO

Article history:
Received 1 July 2015
Received in revised form
2 December 2015
Accepted 8 January 2016
Available online 1 February 2016

Jel classification:
C22
G12
Q4

Keywords:
European Union Emission Trading System
Electricity sector
Energy prices
Vector error correction analysis

ABSTRACT

European Union carbon emissions allowances (EUA) price fluctuations can affect electricity companies' stock market values as these oscillations may change firms' profitability and thus investors' decisions. This outcome can differ not only contingent on the EU ETS Phase, but also on firms' generation mix. Moreover, stock markets may react differently to EUA increases in comparison to decreases, thus asymmetrically.

By using daily data from January 2008 to July 2014, this article analyses long-run equilibrium relations and short-run interactions between the aggregated electricity industry stock market returns and EUA price changes. Moreover, we test if the relationship between EUA price variations and electricity stock returns is asymmetric and if the carbon price effect and the asymmetry are power firm-specific.

Adding to earlier studies, we initially provide an inspection of the individual impact of EU ETS Phase II and on-going Phase III; followed by a comparative analysis between power firms which core activity relies on renewable energy sources and those whose sources are fundamentally non-renewable ones.

A statistically significant positive long-run impact of EU ETS on the aggregated power sector stock market return is found concerning Phase II and works asymmetrically. Moreover, evidence is provided demonstrating that asymmetry and EUA effects are power firm-specific.

1. Introduction

The European Union launched the European Union Emission Trading System (EU ETS) aiming to reduce greenhouse gas (GHG) emissions by at least 20% of 1990 levels by 2020 (European Commission, 2010).

The sectors covered by EU ETS include: electricity industry; oil refineries; ferrous metallurgy; cement clinker or lime; glass including glass fibre; ceramic products by firing and pulp, paper and board.

In that sense, the electricity industry is one of the most important sectors in the scheme, accounting for 42% of the world carbon dioxide (CO_2) emissions (International Energy Agency, 2014).

European Union carbon emissions allowances (EUA) price fluctuations can affect power companies' stock market values through cash flows and carbon cost volatility: Carbon dioxide prices could influence cash flows of companies as they can

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http://dx.doi.org/10.1016/j.enpol.2016.01.005
0301-4215/

incorporate their carbon emission allowance costs in their sale offers. Therefore, a variation in EUA prices would be reflected in output prices as well as in costs. It is highlighted, that EUA price fluctuations can affect stock market values of power companies differently depending on their energy mix. EUA price changes can alter the preferred input mix that firms use in their power production processes (such as fuels) and, hence, the firms' profitability.

Then, the final influence of EUA prices on power firms' profitability is ambiguous, as it not only depends on the pass-through of costs to consumers, but also on firms' technology or generation mix.

Capital Market Theory provides a framework to analyse how investors consider the effect of EUA prices on firms' profitability and so on firms' stock market (for instance, a rising price in emission allowances could revise downwards the power based-coal firms' investors' expectations of future profits, leading to lower stock market share prices of the company). Moreover, investors could react asymmetrically to EUA price changes. For example, stock market returns could suffer stronger impacts as a result of EUA price increase than from decrease, given that, with carbon price increase, investors would expect that emitting companies would have to buy additional allowances leading to profitability reduction.

The existing empirical studies do not converge to a shared position about the effect of EUA price changes on power stock markets as many of the studies are country (or region) specific and results also rely on the modelling approach, and on the studied EU ETS phase on the market structure and on the used econometric tool, among others.

Some scholars have concluded that the EU ETS has had a positive effect on power companies: Oberndorfer (2009), Veith et al. (2009), Keppler and Cruciani (2010a), Mo et al. (2012) and Chan et al. (2013) found that EUA price variations and stock returns or revenue of the European electricity corporations are shown to be positively correlated. However, the particular effect of EUA price variations on electricity corporations' stock returns might vary with country (Oberndorfer 2009 found a significantly small negative relationship for Spain), EU ETS phase (Mo et al. (2013) found a positive and negative correlation during phase I and II respectively), allocation of allowances over time (emission based or generation benchmark based) and power generation technology (Bode (2006) found that lignite-fired power plant operators had the highest positive impact by using an emission based approach, whereas the gas-fuelled plant operators obtained it by using a generation benchmark as basis for the allocation).

Moreover, the particular effect of EUA price variations on power stock returns could be asymmetric, so that stock markets could react differently to EUA appreciations in comparison to depreciations. For example, Mo et al. (2013) found a positive price change has a positive impact in Phase I and a negative one in Phase II. By analysing the impact of EUA price developments on German wholesale electricity prices, Zachmann and von Hirschhausen (2008) found evidence for an asymmetric cost pass-through in a sense that rising EUA prices affect electricity prices more strongly than falling EUA prices. However, looking at the electricity industry, Oberndorfer (2009) found that the effect does not work asymmetrically.

In the context of this debate, this article analyses whether and to what extent the EUA prices may be linked with the power sector stock market returns in Spain by using daily data from January 2008 to July 2014. We compare the obtained results under Phase II and Phase III.

We focus on the multifactor market model, which has been widely used to study the effect of EUA prices (and others variables as fuel prices and electricity prices) on power stock market returns (Mo et al., 2013; Veith et al., 2009; Oberndorfer, 2009).

We analyse long-run equilibrium relations and short-run interactions between the aggregated electricity industry stock market returns and carbon emission prices by using a vector error correction model (VECM). Moreover, by using a panel data econometric approach we test if the relationship between European Union carbon emissions allowances price variations and electricity stock returns is power firm-specific.

We also test if the relationship between European Union carbon emissions allowances price variations and electricity stock returns is asymmetric and if there are differences at firm-level in the asymmetry.

In contrast to other studies using multifactor market model (Mo et al., 2013; Veith et al., 2009; Oberndorfer, 2009)[1], which refer to the first and/or earlier years of the second commitment period (where EUA were given free of charge), the novelty of our research relies on the analysis of the total second commitment period and on the expansion of the analysis to the most up-to-date information of EU ETS Phase III (where emission allowances are auctioned). Furthermore, we expand the existing analysis by testing long-run and short run causalities through VECM and by testing if asymmetry and EUA effects are firm-specific. Besides, as the final effect of EUA prices on power firms' stock market returns could depend on firm technology, we have expanded the sample data to power companies stating that their main or core activity relies on renewable energy sources (RES). This allows comparing the effect of EUA prices changes on stock market returns by EU ETS phases and by technologies (RES versus non-RES companies).

Vector error correction model estimations show that EUA price changes does not have an effect on stock market returns of the power sector in both EU ETS phases in the short run. Moreover, while long-run relationships between EUA price change and stock market price change for power sector are positive during Phase II, they are not significant during Phase III. When power companies are grouped in renewable (RES) companies and non-RES companies, EUA price changes solely affect the stock price change of non-RES power companies during phase II and only RES power companies during phase III. Likewise, panel data estimations show that there is an asymmetric reaction of electricity stock returns to EUA price changes. We also find evidence that asymmetry and EUA effects are firm-specific. The estimated EUA firm effects are negative for nearly all non-RES companies and positive for all RES companies. In contrast, there is no clear evidence of differences in the asymmetric effect of the EUA price changes on electricity stock returns between non-RES power companies and RES power companies represented in our sample.

The remainder of the paper is organized as follows. Section 2 presents a brief description of the used methodology including the multifactor model specification, the cointegrated Vector Error Correction Model analysis and the extension of the multifactor model with panel data; Section 3 describes the used data and Section 4 reports the major empirical findings related to the Hypothesis testing. Finally, Section 5 contains some concluding remarks, policy recommendations and explores some international experiences.

2. Methodology: a cointegrated vector error correction model and a panel data model.

Multifactor market models are widely used to study the effect

[1] For example, Oberndorfer (2009) used 12 power companies data from 4 August 2005 until 19 June 2007, Veith et al. (2009) used 22 power companies and the estimation period spanned from 25 April 2005 to 31 August 2007 and used 12 power generating companies and yearly data from 2006 to 2009.

of any possible factor on corporate value change. In fact, Veith et al. (2009), Oberndorfer (2009) or Mo et al. (2013) have used multifactor market models to investigate the impact of EUA price variations on firms' stock returns. The basic model employed takes the following form:

$$R_t = \alpha + \beta_1 R_{mt} + \beta_2 P_t^{EUA} + \epsilon_{it} \tag{1}$$

Being R_t the return on the stock index in the power sector, R_{mt} the return of the market portfolio, P_t^{EUA} the price of EUA and ϵ_{it} a disturbance term with $E(\epsilon_{it}) = 0$, $\text{var}(\epsilon_{it}) = S^2$, all at time t.

Many empirical results have shown that stock return is closely related to the price of oil (Lee et al. (2012) or Moya-Martínez et al. (2014) for Spanish case) and gas (Acaravci et al. 2012) so other influencing factors, as fuel prices are also included in the basic model. For example, Veith et al. (2009) include oil and natural gas prices as control variables and Oberndorfer (2009) also includes the electricity price in the regression equation; we notice that electricity prices are very important for Spanish industry, as electricity usually represents a significant proportion of total energy cost for industry (51.7% of the total energy consumption-Spanish Statistical Institute, 2013).

Additionally, authors like Lee et al. (2012) or Moya-Martínez et al. (2014) include the long-term interest rate in order to incorporate market expectation.

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

$$R_t = \alpha + \beta_1 R_{mt} + \beta_2 P_t^{EUA} + \beta_3 P_t^{oil} + \beta_4 P_t^{gas} + \beta_5 P_t^{coal} + \beta_6 P_t^{elect} + \beta_7 Ir_t + u_{it} \tag{2}$$

Being P_t^{coal}, P_t^{oil}, P_t^{gas} and P_t^{elect}, coal, oil, gas and electricity prices respectively and Ir_t the long-term interest rate.

Based on this multifactor market model, the Vector Error Cointegration model (VECM) allows for long-run equilibrium as well as short-run dynamics estimations.

By using VECM we test the following *Hypotheses:*

Hypothesis 1. : *EU Emission Allowance price changes affect power stock market returns.*

Hypothesis 1i. : *EU Emission Allowance price affect power stock market returns in the short-run.*

Hypothesis 1ii. : *EU Emission Allowance price affect power stock market returns in the long-run.*

However, VECM is only possible if the variables satisfy the cointegration property. The cointegration concept means that a linear combination of two or more non stationary variables (with the same order of integration) may converge to a stationary process (Engle and Granger, 1987). Such process reflects the long-run equilibrium relationship, and is referred to as the cointegration equation.

If variables exhibit cointegration relations, then the VECM is specified as:

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{p-1} A_i \Delta y_{t-1} + \mu_t + \varepsilon_t \tag{3}$$

Where Δ is 1st difference operator, y_t represents a vector of k non-stationary endogenous variables ($R_{m,}$ $_{\text{Rpower}}$, P^{EUA}, P^{elec}, P^{oil}, P^{gas}, P^{coal} and Ir), A_i is a matrix of unknown coefficients, p is the number of lags included in the model, μ_t is a vector of deterministic terms (constants and trend) and ε_t is a column vector of errors $\varepsilon_t \sim Niid(0, \Sigma)$. Π is a matrix containing information about the long-run relationship among endogenous variables and is called the error correction term. It can be decomposed as $\Pi = \alpha\beta'$, where β represents the cointegration vectors and α the matrix with the estimations on the adjustment speed to the equilibrium, which are also called error correction terms (EC). The rank of matrix Π (r) determines the long-run relationship. If it is zero, then there is no long-run relationship and the model above is equal to a Vector Auto-regressive (VAR) model in differences. If the matrix Π has the full rank ($r = k$), the processes y_t is stationary I(0) and a normal VAR in levels can be used. If the rank of Π is positive and $0 < r < k$ there exists matrices α and β with dimensions $(k \times r)$ such that the equation $\Pi = \alpha \times \beta'$ holds.

The VECM provides two channels to test *Hypothesis* 1: (a) short-run effects (estimated in the matrix A_i ; (b) and the long-run effects which enter the model with the term Πy_{t-1} or $\alpha \times \beta' y_{t-1}$.

We additionally apply a panel data approach, taking into account disaggregated stock returns R of all power firms (see for example Baltagi (1995) for detailed description of the technique). The Eq. (2) can thus be formulated as:

$$R_{it} = \alpha_i + \beta_0 + \beta_1 R_{mt} + \beta_2 P_t^{EUA} + \beta_3 P_t^{OIL} + \beta_4 P_t^{GAS} + \beta_5 P_t^{COAL} + \beta_6 P_t^{ELEC} + \beta_7 Ir_t + \mu_{it} \tag{4}$$

where i is stands the power firm i (i=1,…,N) and α_i parameters denote firm effects which are included in the model in order to take account of any possible firm-specific factors that may have an influence on stock market returns beyond the explanatory variables included. The disturbances of this model are denoted by u_{it} and are assumed to be independently and identically distributed random variables with mean zero and variance σ_u^2.

By applying a panel data approach we test the following *Hypotheses:*

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

Hypothesis 3. : *The effect of EU Emission Allowance price variations on stock market returns depends particularly on firm-specific characteristics.*

Hypothesis 4. : *The asymmetric relationship between EU Emission Allowance price variations and stock returns depend particularly on firm-specific characteristics.*

In order to test possible asymmetric stock market effects from the EUA market (Hypothesis 2), following Oberndorfer (2009) we create an indicator variable (*Asy*) taking the value of one when EUA price variations are positive (and zero, otherwise).

Thus, the model can be specified as:

$$R_{it} = \alpha_i + \beta_0 + \beta_1 R_{mt} + \beta_2 P_t^{EUA} + \beta_3 P_t^{OIL} + \beta_4 P_t^{GAS} + \beta_5 P_t^{COAL} + \beta_6 P_t^{ELEC} + {} + \beta_7 Ir_t + \beta_8 Asy_t + \varepsilon_t \tag{5}$$

In order to identify the most suitable panel model specification, the proposed models (4 and 5) have been estimated considering both fixed and random effects. According to the fixed effects model, α_i is considered a regression parameter while the random effects model treats it as a component of the random disturbance. In order to establish whether the fixed or the random effects estimator is more appropriate, a Hausman test is performed (Hausman, 1978). Further, the existence of firm-specific effect is checked though the F test (for fixed effects) or though the Breuch–Pagan test (for random effects). In both cases the null hypothesis is the existence of equal α_i for all the power firms. If the individual firm effect α_i is assumed to be equal across all companies, then the pooled Ordinary Least Square is consistent and efficient.

To test if the amplitude of the effect of EUA price variations on power stock market returns depends particularly on firm-specific characteristics (Hypothesis 3) the basic panel framework is augmented by interaction terms between the EUA price and firm-specific indicator variables.

Table 1
Summary descriptive statistics.

Variable	Units	EU ETS Phase II					EU ETS Phase III				
		Mean	Median	Min.	Max.	Stnd. Dev.	Mean	Median	Min.	Max.	Stnd. Dev.
Ir	%	4.77	4.54	3.62	7.50	0.84	4.12	4.22	2.58	5.43	0.73
P^{EUA}	€/ton	9.43	11.45	0.01	16.84	5.63	4.84	4.78	2.68	7.11	0.85
P^{elec}	€/MWh	47.95	48.04	3.13	82.13	12.75	43.29	46.20	0.79	91.89	16.34
P^{gas}	€/MWhgas	3.43	2.97	1.34	8.42	1.47	3.05	3.03	2.33	5.85	0.51
P^{oil}	€//BBL	67.49	68.75	24.25	99.04	17.67	81.68	81.10	75.12	90.52	3.24
P^{coal}	€/ton	75.73	73.77	43.50	142.18	19.97	59.74	59.23	53.03	69.30	4.18
R_m		1028.00	1026.70	602.56	1642.00	211.69	940.29	945.42	760.72	1143.30	105.47
R_{power}	€	9.34	8.98	5.78	13.87	2.33	10.45	9.43	7.93.	15.30	2.27

To test for sector-specific asymmetries (Hypothesis 3) the indicator variable (Asy) is also interacted with firm indicator variables.

Thus, the model can be specified as:

$$R_{it} = \alpha_i + \beta_1 R_{mt} + \beta_2 P_t^{EUA} + \beta_3 P_t^{OIL} + \beta_4 P_t^{GAS} + \beta_5 P_t^{COAL} + \beta_6 P_t^{ELEC} + \beta_7 Ir_t + \beta_8 Asy_t + + \sum_{j=2}^{n} \phi_j P_{it}^{EUA} D_{ijt} + \sum_{j=2}^{n} \delta_j Asy_{it} D_{ijt} + \varepsilon_t \quad (6)$$

where D_{ij} which is a firm- dummy variable taking the value of 1 when $i=j$, or zero otherwise.

3. Data and variables

The daily sample period used in our analysis ranges from 2008 to July 2014. It covers the second phase of the EU ETS (1st January 2008–31st December 2012) and the first year and a half year of the third phase[2] of the EU ETS (1st January 2013–1st July 2014). We compare the obtained results under Phase II to those under Phase III.

Information on daily stock price during 2008–2014 was extracted from the Datastream Database. We used the adjusted close price corrected by capital increases and splits. Company data capitalization has been obtained in Bolsas y Mercados Españoles (www.bolsasymercados.es). We chose the daily stock market price of companies affected by EU ETS. We have also included those power companies that state as their main or core activity of the corporation renewable energy sources (RES), as they may be linked to companies that own thermal generation. Even if the RES companies are not formally linked to any non-RES company, their returns may be linked to the EUA price anyway. There is a potential direct effect (the higher the EUA price, the more profitable their RES activity is) and an indirect effect, through the shift of the production from thermal generation.

The total final sample consisted of thirteen power companies, with four of them, *Enernis*, *Empresa Nacional de Electricidad*, *Endesa* and *Iberdrola* representing 80% of the total market capitalization. Regarding the renewable power firms included in our sample (four firms), the most important is *Enel Green Power* representing 8% of the total market capitalization of the overall power sector (85% of the total market capitalization of the RES power sector).

The power sector weighted daily return was calculated using as a weighting factor the market capitalization of each company at year-end, compared to the market capitalization of all companies at the power sector.

This process allowed us to obtain an aggregate daily stock market return for the power sector (R_{power}).

The proxy for the return of the market portfolio (R_m) used is the *Índice General de la Bolsa de Madrid*, the broadest Spanish market index and the yield on 10-year Spanish Treasury bonds is used to assess the interest rate (Ir).

The time series P^{elec} (€/MWh), from OMEL, is the base Spanish spot electricity price (€/MWh). P^{gas} (€/MMBtu) is the spot natural gas price of Henry Hub, the coal price P^{coal} (€/ton.) is the spot index API#2 (CIF ARA Delivered to the Amsterdam/Rotterdam/Antwerp region) and the oil Crude price P^{oil} (€/BBL) is the Oil Dated Brent.

The EUA price series P^{EUA} (€/ton. CO_2) is the spot price[3] quoted at EEX – European Energy Exchange (Leipzig, Germany).

Table 1 summarizes the main descriptive statistics of the variables.

We transformed the price variables into their natural logarithms to reduce variability.

4. Empirical results

4.1. *Long-run and short-run relationship between the power stock prices and EUA prices variations*

In order to test the long-run and short-run relationship between stock and carbon emission prices, the estimation method proceeds as follows: (i) unit root tests are conducted to find the order of integration in individual price series, (ii) assuming the tests conclude that the series are I(1), we explore the long run relationships between the variables by using a cointegration test and the cointegration rank is determined (iii) a VECM for the overall power sector is then estimated.

4.1.1. *Preliminary test: unit-root-testing*

Before deciding in either VAR or VECM we need to test for the presence of unit roots. The series in the current study are tested for the presence of unit root by the Augmented Dickey–Fuller unit root prior test. The null hypothesis for this test is the presence of a

[2] We are aware of the fact that low frequency data (monthly or weekly) is often preferred, in comparison to daily data, in order to circumvent errors in variable problems in terms of irregularities; However, given that the sample period for the Phase III is only one year and a half, daily data is the only realistic frequency to conduct a serious time series analysis. We use daily data for working days.

[3] Oberndorfer (2009) used as CO_2 price the EUA settlement price from European Energy Exchange (EEX). Veith et al. (2009) realized two different analysis one using emission rights spot prices from EEX and respective futures prices from European Climate Exchange (ECX) and Mo et al. (2012) used EUA futures price from ECX. Following Oberndorfer (2009), we performed the analysis using EUA spot prices prices and according to Veith et al. (2009) the remaining energy prices are those set through the spot market. Also, according to Keppler and Cruciani (2010b), CO_2 spot and futures prices were well correlated in Phase I in spite of the largest futures market. Furthermore, in phase II, the importance of the spot market grew with a strong Granger causality of the CO_2 spot prices on the futures prices, justifying the use of spot price in the study herein provided.

Table 2
Unit root testing of variables using the Augmented Dickey–Fuller test (variables in natural logarithms except r)

Variable	EU ETS Phase II				EU ETS Phase III			
	Level		Diff.		Level		Diff.	
	Statist.	p value	Statist.	p value	Statist.	p value	Statist.	p value
Ir	−1.742	0.410	−10.755	0.000	−0.111	0.947	−4.363	0.000
P^{EUA}	−2.027	0.275	−37.329	0.000	−2.818	0.056	−6.172	0.000
P^{elec}	−2.613	0.090	−13.357	0.000	−2.782	0.061	−7.957	0.000
P^{gas}	−1.767	0.398	−8.073	0.000	−1.913	0.327	−5.570	0.000
P^{oil}	−1.259	0.651	−6.972	0.000	−2.240	0.192	−6.636	0.000
P^{coal}	−1.868	0.348	−6.571	0.000	−1.571	0.497	−20.083	0.000
R_m	−1.626	0.470	−9.240	0.000	−0.287	0.925	−5.032	0.000
R_{power}	−1.415	0.576	−34.951	0.000	0.467	0.985	−21.793	0.000

unit root in the time series; the alternative hypothesis is the time series being generated by a stationary process. The results of the testing are presented in Table 2.

The test indicates that at 1% of significance all the series contain a unit root (integrated of order 1) and therefore must be differentiated for the purposes of the current research.

Then, we obtain the growth rate of the relevant variables by their differenced logarithms.

4.1.2. Cointegration testing

Since the unit root tests reveal that the series are integrated of order one, a need arises to check whether these time series are cointegrated (contain a common stochastic trend).

The first step in the modelling procedure is to determine the lag length among the variable series in levels VAR (used to generate Eq. (3)). Both the Schwarz information criterion (SC) and HQ (Hannan and Quinn Criterion) loss metrics suggest that the appropriate VAR lag length is one[4] $p=1$ (Table 3).

Following, we explore the long run relationships between the variables by using a cointegration test. Since the influential work of Engle and Granger (1987) several procedures have been proposed for testing the null hypothesis that two or more non-stationary time series are not cointegrated.

One approach is to use likelihood ratio tests based on estimating a VAR. This approach was first proposed by Johansen (1988) and refined further by Johansen and Juselius (1990) and Johansen (1991, 1992·, 1994). Johansen's approach provides a unified framework for estimation and testing in the context of a multivariate VECM.

The existence of cointegration relations is showed in Table 4. The tests of cointegration were implemented with the technique based on the reduced rank regression introduced in Johansen (1991). Since the VAR model contains exogenous variables, the Osterwald-Lenum (1992) and Johansen (1995) asymptotic critical values are no longer valid, and we therefore use the asymptotic critical values provided in Mackinnon et al. (1999).

The null hypothesis states that the amount of cointegrating vectors is equal to r; the alternative hypothesis is that the number of cointegrating vectors is greater than r.

Estimation typically proceeds in two stages: first, a sequence of tests is run to determine r, the cointegration rank. Then, for a given rank the parameters of Eq. (3) are estimated. The rank of Π (row rank of β) determines the number of cointegration vectors.

Usually two tests on the eigenvalues are used to determine r: Trace Test and $\lambda_{\max}$ Statistics.

As it is showed in Table 4, all tests indicate that there are three

Table 3
Lag length in endogenous variables.

Lags	Phase II			Phase III		
	AIC	SC	HQ	AIC	SC	HQ
0	−39.29	−38.65	−39.05	−13.46	−13.38	−13.43
1	−28.68	−28.36*	−28.56*	−33.51	−32.75*	−33.21*
2	−28.69	−28.11	−28.47	−33.57	−32.13	−33.00
3	−28.69*	−27.86	−28.38	−33.58*	−31.47	−32.74

Note: Model with constant and a maximum of 20 lags.

Table 4
Cointegration tests EU ETS Phase II and III.

Phase	Ho:	Trace test			$\lambda_{\max}$ – Max eigenvalue test		
	$r=$	Statistics	Critical value	p-values	Statistics	Critical value	p-values
II	1	265.039	125.615	0.000	15.675	46.231	0.000
	2	108.285	95.754	0.000	44.490	40.078	0.015
	3	63.795	69.819	0.138	25.181	33.877	0.373
III	1	142.987	125.615	0.003	59.595	46.231	0.001
	2	83..393	95.754	0.260	31.949	40.078	0.306
	3	51..443	69.819	0.574	24.371	33.877	0.429

Notes: 5% significant level for critical values; p-values calculated using the software in Mackinnon et al. (1999), Model with unrestricted constant, one lags in endogenous variables.

cointegrating vectors for Phase II and two cointegrating vectors for Phase III.

4.1.3. Econometric model: VECM

Given the order of integration of the variables used (all are integrated of order 1) and the existence of cointegration relations, a general VECM specification can be formulated as:

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{p-1} A_i \Delta y_{t-1} + \Phi Z_t + \mu_t + \epsilon_t \tag{7}$$

1. Where y_t is a (8×1) vector of endogenous variables measured at time t: $y_t = [Ir_t, R_{mt,} R_{powert}, P_t^{EUA}, P_t^{elec}, P_t^{oil}, P_t^{gas}, P_t^{coal}]$. Natural logarithms are taken of each variable except interest rate (r_t), α and β are $(8 \times r)$ matrices,[5] where β and α represent the cointegrating vectors and the matrix with the estimations on the speed of adjustments to the equilibrium (EC), respectively.
2. Where A_i is a (8×8) matrix with the estimations of short-run

[4] As the VAR is specified in first differences, the number of lags in the VECM should be $(k-1)$.

[5] Where r is the number of cointegrating vectors.

parameters relating variable changes in lagged i periods. Where Φ is a (8×1) matrix of coefficients associated with the (8×1) vector Z_t that represents the exogenous variables. The VECM approach was extended by Harbo et al. (1998) and by Pesaran et al. (2000) to include exogenous variables in the model. In our case, we include a dummy variable taking the value of one for year 2008 and zero for the rest as during this year the price of EUA took values extremely low and price changes taking the value of zero.

Where μ_t is a (8×1) vector of constants and ε_t is a (8×1) vector of errors $\varepsilon_t \sim Niid(0, \Sigma)$.

4.1.4. Power sector VECM estimation

With the cointegrated rank and optimum number of lags determined, the parameters of Eq. (7) for power industry can be estimated.

Following, the VECM estimations for each EU ETS affected sector in Phase II and III are presented. We only report the estimation of the coefficients, which are significant at 1% (***), 5% (**) or 10% (*) significant levels, with the exception of the coefficients related to EUA prices that are always showed. The interpretation of the results is focused in the effect of EUA change prices on stock prices variations.

The results reported in Tables 5 and 6 for the cointegrated vector β, which is normalized on lagged return on the stock index in the power sector ($R_{power t-1}$, lagged return of the market portfolio (R_{mt-1}) and lagged long-term interest rate (Ir_{t-1}), show that the EUA price change does not have an effect on stock market returns of the power sector in both EU ETS phases in the short run (Hypothesis 1a is rejected). The short run parameter corresponding to EUA price for Phase II and III are 0.0001 and −0.0041, respectively and they are not significant.

Regarding the long-run parameters, the VECM estimations show that the long-run relationships between EUA price change and stock market price change for power sector is positive (but small) during Phase II (Hypothesis 1b is not rejected for Phase II). However, a long-run link between carbon prices and stock market on power sector is found not to be significant during Phase III (Hypothesis 1b is rejected for Phase III). Since the coefficients can be interpreted as price elasticities, therefore, a EUA price rise of 1%, would, in equilibrium, be associated with a significant stock price for the sector increase of 0.0087% during phase II.

The results are similar to those found by empirical literature for Phase II. However, the effect during the current Phase III, when the allocations of emission permits are given out predominantly in auctions, is still unknown. For example, Oberndorfer et al. (2006) examined the impacts of the EU ETS on competitiveness in Europe and concluded that for the power sector the impacts were modest. In addition, Veith et al. (2009) by using a modified multifactor market similar to Eq. 2 and 2005–2007 data of 22 electricity companies estimated a stock market return percentage change of 0.006% for each 1% change in EUA price. In the same way, Chan et al. (2013) concluded that EU ETS was associated with increased material costs and revenue of the power industry during 2005–2009. By using also a Cournot representation Bonenti et al. (2013) evaluated the impact of EU ETS on the Italian electricity market profits under different allocation scenarios of allowances (free and auctions) concluding that the generators would be expected to profit in an oligopolistic market as they are able to transfer almost all their emission costs in the final price paid by consumers. De Feo et al. (2012, 2013) state that market distortions can occur due to market power in the carbon market, however, they can be also associated with market power in the output market, in this case the electricity market, which pose a possible explanation of our results.

However, not all the existing empirical studies converge with our results, as some scholars have concluded that the EU ETS had a negative effect on power companies. For instance, Mo et al. (2012) indicated that positive EUA prices generated corporate value depreciation during phase II. By using a modified multifactor model similar to Eq. (2) with 2008 and 2009 data of 48 electricity companies, they estimated a stock market return percentage change of

Table 5
VECM parameter estimates for power sector- Phase II.

Cointegration relationships								
$R_{power\ t-1}$	Ir_{t-1}	R_{mt-1}	P^{EUA}_{t-1}	P^{ELECT}_{t-1}	P^{COAL}_{t-1}	P^{OIL}_{t-1}	P^{GAS}_{t-1}	Const.
1.000	0.000	0.000	–	2.775***	−2.926***	1.055***	0.787***	–
0.000	1.000	0.000	3.087***	–	−3.953***	1.722***	–	–
0.000	0.000	1.000	−1.235***	−0.926***	1.680***	−1.158***	−0.267	–

Short run dynamics	$\Delta R_{power\ t}$	ΔIr_t	ΔR_{mt}	ΔP^{EUA}_t	ΔP^{ELECT}_t	ΔP^{COAL}_t	ΔP^{OIL}_t	ΔP^{GAS}_t
$EC1_{t-1}$	–	−0.021***	–	0.202***	−0.093***	–	–	–
$EC2_{t-1}$	–	−0.028***	–		–	0.005***	–	0.007***
$EC3_{t-1}$	−0.007*	−0.069***	–	0.496***	–	0.010**	–	0.012*
$\Delta R_{power\ t-1}$	–	0.298*	–	–	–	–	–	–
ΔIr_{t-1}	–	0.092***	–	–	–	–	–	–
$\Delta R_{m\ t-1}$	–	−0.944***	–	–	–	–	–	–
ΔP^{EUA}_{t-1}	−0.0001	–	–	–	–	–	−0.008**	–
ΔP^{ELECT}_{t-1}	–	–	–	−0.041*	−0.084***	0.008**	0.008**	0.013**
ΔP^{COAL}_{t-1}	–	–	−0.081***		–	–	–	–
ΔP^{OIL}_{t-1}	–	0.429***	–		–	–	–	0.090*
ΔP^{GAS}_{t-1}	–	–	–		–	–	–	0.050*
Const.	–	–	–	0.876***	–	−0.006*	–	−0.010*
$DT2008_t$	–	–	–	−4.189***	–	0.029*	–	0.047*

* Stands for estimates significantly different from 0 at a 10% level.
** Stands for estimates significantly different from 0 at a 5% level.
*** Stands for estimates significantly different from 0 at a 1%.

Table 6
VECM parameter estimates for power sector- Phase III

Cointegration relationships

$R_{power\ t-1}$	Ir_{t-1}	$R_{m\ t-1}$	P_{t-1}^{EUA}	P_{t-1}^{ELECT}	P_{t-1}^{COAL}	P_{t-1}^{OIL}	P_{t-1}^{GAS}	Const.
1.000	0.000	−3.728***	1.602***	1.076***	3.218***	−4.487***	1.568***	–
0.000	1.000	6.155***	−2.777***	−0.604***	−6.192***	5.762***	1.396***	–

Short run dynamics

	$\Delta R_{power\ t}$	ΔIr_t	$\Delta R_{m\ t}$	ΔP_t^{EUA}	ΔP_t^{ELECT}	ΔP_t^{COAL}	ΔP_t^{OIL}	ΔP_t^{GAS}
$EC1_{t-1}$	–	–	–	0.029***	−0.524***	0.004**	–	−0.032***
$EC2_{t-1}$	–	–	–	0.048***	−0.156*	–	–	−0.043***
$\Delta R_{power\ t-1}$	-0.186***	–	–	–	–	–	0.118*	–
ΔIr_{t-1}	–	−0.139***	0.028***	–	–	–	–	–
$\Delta R_{m\ t-1}$	0.171**	−1.517***	0.131*	−0.608**	–	–	–	−0.561**
ΔP_{t-1}^{EUA}	−0.004	–	–	0.084*	–	–	–	–
ΔP_{t-1}^{ELECT}	–	–	–	–	0.108**	−0.002*	–	−0.013**
ΔP_{t-1}^{COAL}	–	–	–	–	–	–	–	−0.714***
ΔP_{t-1}^{OIL}	–	–	–	–	–	–	–	–
ΔP_{t-1}^{GAS}	–	–	0.024*	–	–	–	–	0.158***
Const.	0.002***	−0.006*	–	–	–	–	–	–

[*] Stands for estimates significantly different from 0 at a 10% level.
[**] Stands for estimates significantly different from 0 at a 5% level.
[***] Stands for estimates significantly different from 0 at a 1%.

−0.0334% for each 1% change in EUA price. Moreover, Oberndorfer (2009) found that although EUA price variations and stock returns of the most important European electricity corporations were positively related, Spanish electricity corporations exhibit a significantly (but small as far as the size of the estimated coefficient is concerned) negative relationship.

Jaraitė and Kažukauskas (2013) found that the first years of the EU ETS (2002–2010) could not be associated with excess profits for electricity producers.

We would like to point out that in the long-run the electricity sector as a whole have modest gains from the introduction of the EU ETS instrument during Phase II, but results could change if power companies were grouped by renewable (RES) companies and non-RES companies. To go further in the analysis of the effect of the EUA price changes on stock price changes of power sector, we repeat the VECM analysis by splitting the total sample of power companies into RES companies and non-RES companies.[6] The RES power sector weighted daily return is calculated using as a weighting factor the market capitalization of each RES company at year-end compared to the market capitalization of all RES companies at the power sector. In the same way, the non-RES power sector weighted daily returns are calculated using as a weighting factor the market capitalization of each non-RES company at year-end compared to the market capitalization of all non-RES companies at the power sector.

The short-run and long-run VECM estimated parameters related to the effect of the EUA price changes on stock price changes are reported in Table 7.

When only non-RES power companies are analysed (70% of our sample) the long-run effect of the EUA price change increases considerably for Phase II. In such case, EUA price rise of 1%, would, in equilibrium, be associated with a stock price for the sector increase of approximately 0.01%.

A key element of the EU ETS is the initial allocation of emission allowances. Phase II caps were set too favourably as the economic crisis, which began in late 2008, depressed emissions, leading to a large and growing surplus of unused allowances. Thus, surplus allowances given to non-RES companies could be sold into the market to gain revenue.

In contrast, EUA price change only affects the stock price change of RES power sector in the long run during Phase III. Whilst in Phase II a given number of emission allowances were allocated to the power industry free of charge, during Phase III the power industry is required to buy the necessary emission allowances for thermal power plants. This could lead to not only a negative effect on the stock price changes of non-RES power sector, which was not observed, but also to a positive effect on the stock price changes of RES power sector. Given this, non-RES power would be more expensive to operate leaving more room for RES generation, with the associated increase in stock market returns.

We would like to point out that during Phase III the allocation of emission allowances are given out predominantly in auctions, starting from a proportion of the 20% in 2013 and reaching a 70% level in 2020 (European Commission, 2009). Thus, our results could vary as soon as greater proportion of auction allocation of allowances is reached.

Table 7
Relationships between EUA price change and Power sub-sector's stock market price change.

Power sub-sector under analysis	Long-run		Short-run[a]	
	Phase II	Phase III	Phase II	Phase III
Non-RES power sector	0.0097	–	0.0003	−0.0154
RES power sector	–	0.0019	0.0090	−0.0089
Total power sector	0.0087	–	0.0001	−0.0041

[a] The short run parameters are not significant in all analysis.

4.2. Asymmetry and EUA firm specific effects

We test if the relationship between EU Emission Allowance price variations and the Spanish power sector stock returns is asymmetric (Hypothesis 2). By having interaction terms between the EUA price variation and the asymmetry indicator variable with firm-specific indicator variables we also test if asymmetry and EUA effects are firm-specific (Hypotheses 3 and 4 respectively).

[6] For brevity, only the detailed VECM results for the total power sector are reported in this version. The other VECM results are available from authors upon request.

Table 8
EUA and asymmetry firm-specific effects: Phase II and III.

	Pooled OLS firm-specific EUA effect	Pooled OLS firm-specific EUA effect	Pooled OLS firm-specific EUA effect and asymmetry
β_0	−0.0004*	0.0003	0.0003
β_1 (interest rate)	0.0056*	0.0059*	0.0059*
β_2 (market)	0.6085***	0.6123***	0.6123***
β_3 (EUA price)	0.0030***	0.0037***	0.0042***
β_4 (gas price)	−0.0017	−0.0017	−0.0017
β_5 (oil price)	0.0761***	0.0783***	0.0784***
β_6 (coal price)	0.0470**	0.0466**	0.0466**
β_7 (electricity price)	−0.0006	−0.0006	−0.0006
β_8 (dummy2008)	0.0004	−0.0002	−0.0002
β_9 (aymmetry)	–	−0.0015**	−0.0023***
EUA firm-effect			
ϕ_2 (non- RES firm 2)	0.0029***	0.0029***	−0.0028***
ϕ_3 (non- RES firm 3)	−0.0021***	−0.0021***	−0.0024***
ϕ_4 (non- RES firm 4)	−0.0022***	−0.0022***	−0.0026***
ϕ_5 (non- RES firm 5)	−0.0001***	−0.0001***	0.0012***
ϕ_6 (non- RES firm 6)	−0.0104***	−0.0104***	−0.0118***
ϕ_7 (non- RES firm 7)	−0.0009***	−0.0009***	0.0009***
ϕ_8 (non- RES firm 8)	−0.0026***	−0.0026***	−0.0040***
ϕ_9 (non- RES firm 9)	−0.0069***	−0.0069***	−0.0080***
ϕ_{10} (RES firm 10)	0.0095***	0.0209***	0.0119***
ϕ_{11} (RES firm 11)	0.0014***	0.0014***	0.0009***
ϕ_{12} (RES firm 12)	0.0054***	0.0054***	0.0041***
ϕ_{13} (RES firm 13)	0.0020***	0.0020***	0.0001
Asym. firm-effect			
δ_2 (non- RES firm 2)	–	–	0.0000***
δ_3 (non- RES firm 3)	–	–	0.0006***
δ_4 (non- RES firm 4)	–	–	0.0006***
δ_5 (non- RES firm 5)	–	–	−0.0023***
δ_6 (non- RES firm 6)	–	–	0.0024***
δ_7 (non- RES firm 7)	–	–	−0.0032***
δ_8 (non- RES firm 8)	–	–	0.0024***
δ_9 (non- RES firm 9)	–	–	0.0020***
δ_{10} (RES firm 10)	–	–	0.0019***
δ_{11} (RES firm 11)	–	–	0.0009***
δ_{12} (RES firm 12)	–	–	0.0023***
δ_{13} (RES firm 13)	–	–	0.0035***
Obs.	21,270	21,270	21,270
R-squared	0.0563	0.0565	0.0566
F-Test Model	64.4273***	64.4273***	64.4273***
F-Test Fixed Effect	0.4541	0.4544	1.1610
Breuch-pagan	2.1073	2.1054	0.7633
F-Test on sector-specific EUA interaction term	3.5e+032***	3.8e+032***	1.7e+032***
F-Test on sector-specific Asymmetry interaction term	–	–	2.2e+029***
White test statistics	3.2667	9.9637	63.2083
Durbin–Watson	2.0394	2.0395	2.0387

White heteroskedasticity-robust Standard deviation.
* Stands for estimates significantly different from 0 at a 10% level.
** Stands for estimates significantly different from 0 at a 5% level.
*** Stands for estimates significantly different from 0 at a 1% level based on a *t*-ratio test.

It is highlighted that since the right hand variables of the multifactor market model (Eqs. (5) and (6)) economically depend on each other[7] we performed collinearity tests using variance inflation factors (VIFs). The variable price of oil exhibits the highest factors (1.15) in both specifications, but is far below critical values (10).

We would like to point out that in order to overcome any possible autocorrelation and heteroskedasticity in the error terms in the pooled models we have used the Newey–West HAC estimator (Heteroskedasticity and Autocorrelation Consistent) that provides a robust estimation of the covariance matrix of the parameters.

The results are summarized in Table 8.

First, for all specifications, the existence of firm specific effects is checked through the F test (for fixed effects) or Breuch–Pagan test (for random effects). In most of the cases the null hypothesis (existence of equal α_i for all the firms) is not rejected at the 1% level. Thus, the individual firm effect α_i is assumed to be equal across all firms, and then the pooled Ordinary Least Square estimation is appropriated.

Second, we find evidence for an asymmetric reaction of electricity stock returns to EUA price variations. The estimated coefficient of the indicator variable Asymmetry shows statistical significance. Thus, Hypothesis 2 is not rejected (the null is β_8 is zero in Eq. (6)).

Third, regarding the firm-specific effects (Hypotheses 3 and 4), the regression results indicate that the EUA effect on the stock market and the assymetry effect are firm-specific. An *F*-Test on the joint significance of power firm interaction terms with the EUA price changes leads to the rejection of the null hypothesis of no firm-specific EUA effects at any conventional level and in any especificaton (there, the null is the existence of equal ϕ_j for all the firms in Eq. (6)). All firm-specific EUA interaction term coefficients are significantly different from zero at 1% level . Thus, Hypothesis 3 is not rejected.

In addition, an *F*-Test on the joint significance of interaction terms between sector-specific indicator variables and the asymmetric EUA price change indicate the presence of such asymmetric effects (the null hypothesis is the existence of equal δ_j for all the firms in Eq. (6)). All coefficients referring to such an asymmetric firm-effect show significance at 1% level. Thus Hypothesis 4 is not rejected.

The estimated EUA firm-effects and asymmetries firm-effects[8] are showed in Table 9.

As it is showed, the estimated EUA firm effects are positive for all RES companies and negative for nearly all non-RES companies. In contrast, there is no clear evidence of differences in the asymmetric effect of the EUA price changes on electricity stock returns between non-RES power companies and RES power companies represented in our sample.

The firm with more negative EUA effect is firm 6 (Endesa), whose thermal power stations are among the biggest CO_2 polluters in Spain, according to the European Environment Agency (2014). That firm is the most significant of the non-RES power firms included in our sample, representing 21% of the total market capitalization of the total power sector. It has a 39% of coal fired power generation capacity reaching a electricity production of 33% by using this technology in 2014. This firm has consolidated its market position as a supplier of reference in the main economic sectors as it has the 32.2% of the market generation shares and it reaches a market share of 43.1% in sales to customers in the open market.

In contrast, the firm with more positive EUA effect is the RES-

[7] For example, the practice of marginal cost pricing in power generation implies that fuel prices and EUA prices play a fundamental role in the electricity price formation process through wholesale markets (see Freitas and Silva (2013, 2015) for the Iberian case) and thus final electricity prices for consumers (see Moreno et al. (2014) and Moreno and García-Álvarez (2013) for the Spanish case).

[8] In Eq. (6), firm 1 is the reference and its estimated EUA effect corresponds with β_3. The estimated EUA effect of firm j (j=2,…,13) is calculated as $\beta_3+\phi_j$. In the same way, the estimated asymmetry effect of firm 1 corresponds with β_9 and the estimated asymmetry effect of firm j (j=2,…, 13) is calculated as $\beta_9+\delta_j$.

Table 9
Estimated firm-specific effects (Eq. (6)).

Type Firm	EUA firm-effect	Asymmetry firm-effect
Non-RES firm 1	0.0042	−0.0023
Non-RES firm 2	0.0014	−0.0023
Non-RES firm 3	0.0018	−0.0017
Non-RES firm 4	0.0016	−0.0017
Non-RES firm 5	0.0054	−0.0046
Non-RES firm 6	−0.0076	0.0001
Non-RES firm 7	0.0051	−0.0055
Non-RES firm 8	0.0002	0.0001
Non-RES firm 9	−0.0038	−0.0003
Res firm 10	0.0161	−0.0004
Res firm 11	0.0051	−0.0014
Res firm 12	0.0083	0.0000
Res firm 13	0.0042	0.0012

firm 1 (*Enel Green Power*), which is a major global operator in the field of energy generation from renewable sources, with an annual production of 32 TW/h, mainly from wind, solar, hydro, geothermal and biomass. This firm represents the 8% of the total market capitalization of the Spanish total power sector and the 85% of the total market capitalization of the Spanish RES power sector.

5. Conclusions and policy implications

This paper investigates the interactions between the stock market returns of Spanish power industry and emission rights prices during Phase II and the first year and half of Phase III. Applying a cointegrated Vector Error Correction Model (VECM) we have examined both long-run equilibrium relations and short-run interactions between the stock market returns of the Spanish power sector and EUA prices. Using a panel data econometric model we investigated if the relationship between EUA price variations and electricity stock returns is power firm-specific and if this relationship is asymmetric (and if it is power firm-specific).

Obtained results indicate that the EUA price change does not have short-run effects on stock market returns of the sector during both EU ETS phases. However, different long-run impacts of EU ETS on power sector stock market return are obtained for each phase. A statistically significant positive long-run impact of EU ETS on power sector stock market return is found for Phase II where an EUA price rise of 1%, would, in equilibrium, be associated with a stock price for the power sector increases of 0.0087%. However, a long-run link between carbon prices and stock market on power sector is found not to be substantiated during Phase III. Although the electricity sector, as a whole, has modest gains in the long-run from the introduction of the EU ETS instrument during Phase II, when only non-RES power companies are analysed the long-run effect of the EUA price changes increases to 0.01% for Phase II.

The results suggest that the amplitude of EUA effect on the stock market is firm-specific. The estimated EUA firm effects are positive for all RES companies and negative for nearly all non-RES companies. Moreover, we find evidence for an asymmetric reaction of electricity stock returns to EUA price variations. There is also evidence for an asymmetric effect of the EUA price change on stock returns for all of the firms of the power sector considered.

Concerning policy implications, a key element to understand the obtained results about the size and direction of the effect of EUA price changes could be the initial allocation of emission allowances and the used system to give out emission allowances. During Phase II, the Spanish Ministry of Agriculture, Food and Environment (2012) indicated that, at the aggregate level, power sector received 17% fewer allowances than verified emissions. However, during Phase III (period 2013–2014) the Spanish power sector received 94% fewer allowances than verified emissions. This means that polluting power firms need to buy allowances to cover emissions, which negatively affects their profitability during Phase III. This could lead a positive effect on the stock price changes of RES power sector as non-RES power would be more expensive to operate leaving more room for RES generation, with the associated increase in stock market returns.

This study contributes to the environmental and energy policy debate as the EU ETS may become the model for regulating carbon emissions in North America or elsewhere. One can specultate if the EU ETS could be the prototype for a global policy regime based on a cap-and-trade scheme.

Although we have focused in EU ETS, our study could be extended to other carbon markets and the power companies they impact. While EU ETS is the oldest and largest carbon market in the world, the Regional Greenhouse Gas Initiative (RGGI) was the first cap-and-trade programme in the United States of America (USA), starting in 2008 and covering nine states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont). Also in the USA, the Californian AB32 is very recent but it is expected to become one of the largest carbon markets in the world. Throughout the world several other carbon markets begin to develop, such as China with 7 pilot programmes in view of a national emissions trading system to be established in 2016, Tokyo with the first programme addressing facilities since 2010, New Zealand, Switzerland, Kazakhstan and Korea. Several new programmes are being planned in Russia, Ukraine, Turkey, Brazil, Mexico, Chile, Japan and China as already mentioned. Further details can be found in International Carbon Action Partnership (2015).

There are additional motivating features that were not herein mentioned because they do not relate directly to the goal of our research. Nevertheless, they are central enough to be considered as subject for further studies. Future work may include an analysis of the implications that arise on structural differences between the European and Californian carbon markets. Specifically, the analysis on the impact of the existence of upper and lower limits for carbon prices in AB32, unlike in the EU ETS, in the price differential between the two markets, and the effect that may have on prices of final and primary energy and thus on stock market returns. On another view, the linkage of markets happening now, namely the connection established between the AB32 and Québec in January 2014 and the possible future link of the EU ETS to the Australian market, may also produce consequences to the price of carbon and thus stock market returns of power companies.

In sum, this study is at the cross-section of energy and environmental economics and finance. It provides empirical evidence that the EU ETS may impact the competitiveness of companies. It is believed to provide useful information to different stakeholders, such as; investors, carbon markets traders, environmental or energy regulators and policy makers. This new findings informs policy-makers and investors about the design and implications of environmental and energy regulation.

Acknowledgements

The first and third authors would like to acknowledge that This work has been supported by the Fundação para a Ciência e a Tecnologia (FCT) under project Grant UID/MULTI/00308/2013, and the Energy for Sustainability Initiative of the University of Coimbra. Moreover, authors would like to acknowledge Professor Ana Rosa Fonseca for her helpful suggestions.

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