Barcelona School of Economics

# MASTER PROJECT

## An Event Study Analysis of the Energy Sector in Spain

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# Contents

**Abstract**

This paper studies how unexpected events affect the abnormal return of renewable companies. Exploiting firm-level data from a large sample of companies primarily operating in Spain, we seek to understand how investors in the stock markets react to three distinct unexpected events. The three events we investigate are curtailment, the Royal Decree - Law 1/2012 and the carbon policy surprises. Our findings indicate that higher levels of curtailment result in a decrease in abnormal returns for the renewable energy sector, reflecting investors' perception of curtailment as a risk factor. We also provide evidence that the Royal Decree - Law 1/2012, which suspended all in-feed tariffs guaranteed to renewable electricity producers, had adverse effects for the entire energy sector. Lastly, we show that increases in the price of carbon are associated with a reduction in the abnormal returns for the energy sector. This aligns with other research findings that tighter carbon pricing tends to suppress economic activity and investment.

# 1 Introduction

According to the IPCC's sixth assessment report on climate change, the previous decade is likely to have been the hottest period in the last 125,000 years. While the scientist community raises concerns over the climate change consequences, they also argue that global warming is reversible. To reverse centuries of high greenhouse gas emissions, a sound ecological transition towards renewable energies is part of the solution. In addressing this challenge, accurately estimating potential shocks on asset returns of companies operating in the renewable sectors is an imperative prerequisite to successfully guide investments to a green economy transition.

This paper seeks to study how unexpected events affect asset returns. Specifically, we analyse firm-level data from a large sample of companies primarily operating in Spain to understand how investors in the stock markets react to unexpected policies or climate shocks. To answer this question, we focus our analysis on three major events. Firstly, we look at curtailment, i.e. an event specific to wind farms where grid operators ask energy producers to reduce their supply because the demand is too low or there is congestion in the grid. The second event consists of the implementation of the Royal Decree - Law 1/2012, which introduced changes to the electricity tariff structure and removed subsidies for non-renewable energy projects. The third event focuses on carbon policy surprises, defined as unexpected changes in the pricing of carbon emissions.

The growing amount of wind power capacity within the Spanish electricity system significantly affects both the operation and costs of the energy system. This noteworthy impact brought about by wind power is particularly concerning due to the limited interconnections of the Iberian Peninsula Power System with other nations. In this situation, the power system's security, reliability, and stability can be significantly influenced by the curtailment of wind energy. In our study, we define curtailment as the process whereby wind energy producers are requested to reduce their output in order to balance demand and supply or to ensure grid stability. This process aims to prevent the electricity price from reaching zero due to an excess supply, which would encourage energy producers from ceasing their generation of electricity.

While wind power curtailment is commonly accepted as a suitable solution to mitigate these problems, it also constitutes a waste in green energy that could be avoided by improving storage systems or the structure of the grid. Moreover, curtailing wind energy does not only imply an underutilization of renewable energy, but it also disincentivizes investors from financing renewable energy projects. In addition, its associated cost, estimated to 807 millions euros in Germany in 2021, could also encourage the use of dirty energy production as an alternative. Considering that experts anticipate an increase in curtailment of clean energy as penetration keeps growing, our study aims to quantify the impact of this process on the stock returns of renewable energy companies in Spain.

We argue in our analysis that investors in the electricity sector exhibit a negative reaction in response to high curtailment events. These events increase uncertainty and investment risk in the renewable sector, thus encouraging investors to sell their shares in renewable companies after events of high curtailment. Consequently, we expect to observe a slight negative decline in the stock market return of renewable companies after events of high curtailment. It is noteworthy to mention that we assume investors do not factor in curtailment when making investment decisions, meaning that high curtailment levels come as a surprise to the stock market. Our findings indicate that an increase in curtailment leads to a reduction of 0.2% in the stock abnormal returns for the renewable energy sector.

The Royal Decree - Law 1/2012 enacted the 28th of January 2012 announced the complete suspension of all feed-in tariffs guaranteed to renewable electricity producers. This decision entailed the removal of specific payment rates for the electricity generated and fed into the grid by the renewable energy producers. Prior to that, payment rates were generally set higher than the market price for electricity to encourage energy production and also attract investments in the sector. As a result of the policy, renewable energy producers would no longer be financially supported to offset the higher costs associated with renewable energy technologies compared to more conventional energy sources. We claim that the Royal Decree - Law 1/2012 had negative effects on the stock abnormal returns of the renewable companies. Our findings demonstrate that the Royal Decree - Law 1/2012 had adverse effects for the entire energy sector.

In light of the COP26 objectives, carbon pricing plays a critical role in accelerating the global efforts to fight climate change. Carbon pricing operates by imposing a cost on greenhouse gas emissions, thereby incentivizing the reduction of carbon emissions. In our study, we seek to quantify how carbon policy surprises affect the stock return of renewable energy companies. To carry out our analysis, we utilize a dataset provided by Diego Känzig, where carbon policy surprises are measured as the difference in carbon price in euro relative to the prevailing wholesale electricity price and as percentage change of the carbon price. Building on the existing literature, we anticipate that carbon policy surprises would negatively impact companies in the energy sector, as evidence suggests that increases in carbon pricing tend to slow down economy growth and reduce investment (Känzig, 2023). Our findings indicate that an increase in the price of carbon is associated with a reduction in the abnormal returns for the energy sector by 0.04%.

**Roadmap:** The paper proceeds as follows. In the next section, we review the literature and contributions for each event. Section 3 details our empirical strategy. Section 4 presents the results on curtailment, the Royal Decree - Law 1/2012 and the carbon policy surprises. Section 5 covers the robustness checks. Section 6 discusses the implications of our results for climate policies and concludes our study.

# 2 Literature Review and Contributions

This study contributes to the growing literature analyzing the effects of climate events, policies and carbon pricing on stock returns. Multiple studies have investigated how unforeseen climate change events affect stock market returns. Antoniuk and Leirvik (2021) find that unexpected events related to climate significantly impact stock abnormal returns. We incorporate in our study the method they employ to compute the firms' abnormal return. The method itself was originally introduced by Sharpe (1964) and Linter (1965). In addition, they show that the presence of significant abnormal return variations indicate a delay in the market's pricing of new information. We validate this result by finding that high curtailment events have a significant impact on stock abnormal returns and that the market takes some time to adjust.

In a similar vein, Kuang et al. (2021) specifically study the effects of the 2016 Paris Agreement on investment behaviors. Using an event study methodology, they find that while the treaty had limited overall effects on green companies, its implementation appeared to have a statistically negative impact. Furthermore, U-Din et al. (2022) explore the influence of weather catastrophes on the Canadian stock market over a 20-year period. They discover that extreme weather events significantly decrease stock markets returns. Supported by these findings, Pagnottoni et al. (2022) find that climatological events have the most extreme reactions on international financial markets among disaster types. Employing an event study methodology, they examine the effects of multiple disaster types on 27 global stock market indexes from 2001 to 2019. While the impacts on stock markets differ depending on the type of disaster, climatological events predominantly exhibit significant negative effects on financial markets. The literature confirms our beliefs that stock markets are likely to respond to unexpected events.

Our study is structured into three distinct sections: curtailment, Royal Decree - Law 1/2012, and carbon policy surprises. In the following discussion, we review the literature and contributions for each of these sections.

Several studies have tried to quantify and study the consequences of wind curtailment. We reviewed the literature studying the effects of wind power curtailment on various economic aspects. Ye et al. (2018) find that the opportunity cost of wind curtailment is estimated to have exceeded $1.2 billion in China from 2004 to 2006. Joos and Staffell (2018) estimate a 27-fold increase in wind curtailment between 2010 and 2016 in Germany. Moreover, they find that the quantity and cost of wind curtailment has grown substantially in Britain, rising from 45 to 1123 GWh between 2012 and 2016, and from £5.9 million to £81.9 million. Additionally, the Spanish Wind Energy Association estimates economic losses due to curtailments from 2011 to the beginning of 2013 to be approximately €70 million (Martín-Martínez et al., 2014).

The literature suggests that stock markets would negatively react to high level of curtailment. Moreover, the costs associated to curtailment emphasize the importance of accurately estimating the effects of wind power curtailment on the renewable companies in Spain. This evaluation is crucial to guarantee the stability, reliability, and security of the grid, especially considering the expected increase in wind penetration in the future. Our contribution to the literature lies in providing new estimates of the effects of wind curtailment on the stock abnormal return of renewable energy companies primarily operating in Spain. To the best of our knowledge, this study is the first to try to evaluate the impacts of curtailment on the abnormal return of renewable companies in Spain.

The effects of policies on the economy also benefit from a wide literature. In our analysis, we investigate the impacts of the Royal Decree - Law 1/2012, announced on the $27^{th}$ January 2012 and implemented on the $28^{th}$ January 2012, that modified the tariffs structure for renewable electricity producers in Spain. To understand the response of the stock market to unexpected policies, we reviewed some studies in line with our research and methodology. Pastor and Veronesi (2012) studied how changes in government policy affect stock prices. Their findings reveal that on average, stock prices fall at the announcement of a policy change. This result indicates that the uncertainty related to new policies leads to a decrease in investment, thus resulting in negative effects on stock prices. Their finding suggests that a part of our result will probably incorporate the uncertainty associated to the policy announcement.

Furthermore, to understand the effects of the support scheme modification for renewable companies in Spain, we supported our analysis with the study of Lesser and Su (2008). They find that feed-in tariffs (FITs), when designed correctly, provide long-term financial stability for investors in renewable energy technologies (RETs). Similarly, Mitchell and Connor (2004) highlight the ability of FITs to reduce financial risks for RETs developers. We contribute to their studies by specifically analyzing the impacts of the Royal Decree - Law 1/2012 on the stock markets using an event study methodology. Supported by the literature, we expect to find that the cancellation of the feed-in tariffs scheme in Spain had a negative impact on the stock return of renewable energy companies.

Carbon pricing is a key element in achieving the carbon neutrality by 2050 set by the 2015 Paris Agreement. We reviewed the literature investigating the effects of carbon pricing surprises on the stock markets. In our analysis, we seek to evaluate the relationship between carbon policy surprises and the stock abnormal return of renewable companies. We claim that carbon pricing shocks would negatively impact companies operating in the energy sector, including renewable and non renewable companies. Previous studies demonstrate that environmental regulation can affect productivity because it forces firms to commit resources to non-productive uses such as environmental auditing, waste treatment and litigation (Gray and Shadbegian, 1995; Haveman and Christainsen, 1981). Furthermore, evidence suggest that tighter carbon pricing regime leads to significant increases in energy prices, resulting in a fall in income. This, in turn, implies a temporary fall in economic activity, as poorer households lower their consumption and investment significantly (Känzig, 2023).

In their studies, Hamilton (1995); White (1995); Klassen and McLaughlin (1996) use an event study to demonstrate that news of high toxic emission levels result in a significant reduction of the abnormal returns. This could indicate that carbon policy surprises, related to high levels of emissions, would negatively impact the abnormal return of companies in the energy sector. Finally, Ramiah et al. (2013)

find that the carbon pollution reduction scheme (CPRS) announcement, a cap-and-trade emissions trading scheme for greenhouse gases, had a significant negative impact on the Australian stock market. More specifically, they observed a 2.84% reduction in the oil and gas sector abnormal return following the announcement of the policy.

The literature tends to indicate that carbon policy surprises, measured as carbon price variations, would have significant impact on the abnormal return of energy companies. Namely, we expect the abnormal return of energy companies to negatively respond to an increase in carbon prices. In our study, we evaluate the effects of carbon policy surprises on the abnormal return of the renewable companies operating in Spain. In particular, we explore whether our results support the evidence suggested by Känzig (2023) that stricter carbon pricing regimes lead to a temporary fall in economic activity and investment, thereby leading to a decline in the abnormal return of renewable companies.

# 3 Empirical Strategy

## 3.1 Data

The data used in this paper is collected from a few sources. The main part of the data relating to the stock prices was collected from Yahoo Finance. This data includes the open price and close price for the stocks at a daily level. It is important to note that for the three analyses we conduct in this paper we use different time periods. In order to study the effects of wind energy curtailment and carbon policy surprises on the abnormal return of firms in the energy sector we look at daily stock prices for the year 2019. This decision stems from the desire to examine a period prior to the pandemic and the energy crisis in Europe, aiming to establish a baseline or reference point that reflects more "typical" or "pre-crisis" conditions. On the other hand, since the Royal Decree - Law 1/2012 was passed in January of 2012, we chose to study the daily stock prices for both years of 2011 and 2012 in order to observe a sufficient number of days in periods before and after the decree.

The sample of firms chosen for both the separate time periods varies slightly because of the limited availability of high-frequency stock data going back over 10 years to 2011. Some of the companies whose data is available in 2019 were not yet listed in 2011 and so were not included in the analysis. An interesting point to note is that we classify the sectors that the firms belong to using the classification provided by the Bolsa de Madrid or BME which is the largest stock exchange in Spain. We also obtain and use the prices associated with the IBEX35, which is the benchmark stock index of the BME. It is calculated as a weighted average of 35 of Spain's most liquid stocks. We use the returns from this stock as a benchmark to indicate average market returns in order to control for systematic shocks that affect multiple sectors or the entire economy.

For the curtailment analysis in 2019 we use a sample of 29 firms from 17 different sectors. The table 1 gives the mean and standard deviation of the open price and close price for each of the sectors for this year. Our sample consists of 3 firms in the renewable energy sector, Audax, Grenergy and Solaria-Energia. From the table we can see that the mean for the renewable energy sector is approximately 5 euros and the standard deviation is not very large since it is 3.3. The three sectors of electricity, natural gas and oil and gas together comprise the non-renewable sector. The renewable and non-renewable sectors combined represents the energy sector as a whole in Spain.

**Table 1:** Descriptive Statistics for 2019

| | No. of Firms | Open price | | Close Price | |
|---|---|---|---|---|---|
| **Sector** | | Mean | S.d | Mean | S.d. |
| Airport | 1 | 163.512 | 8.885 | 163.578 | 8.750 |
| Aviation | 1 | 5.949 | 0.881 | 5.948 | 0.886 |
| Construction | 1 | 93.621 | 6.764 | 93.718 | 6.653 |
| Consumer Defence | 1 | 18.780 | 0.589 | 18.802 | 0.582 |
| Electricity | 3 | 16.629 | 6.148 | 16.636 | 6.149 |
| Financial Services | 4 | 4.463 | 1.439 | 4.461 | 1.439 |
| Industrials | 3 | 15.115 | 5.771 | 15.140 | 5.759 |
| Infrastructure Management | 1 | 23.128 | 2.784 | 23.177 | 2.771 |
| Insurance | 1 | 2.526 | 0.103 | 2.526 | 0.103 |
| IT Services | 1 | 8.973 | 0.937 | 8.970 | 0.941 |
| Natural Gas | 2 | 23.586 | 1.852 | 23.592 | 1.849 |
| Oil and Gas | 1 | 14.437 | 0.675 | 14.428 | 0.677 |
| Pharmaceuticals | 2 | 21.285 | 3.730 | 21.299 | 3.798 |
| Real Estate | 1 | 12.170 | 0.618 | 12.175 | 0.614 |
| Renewable Energy | 3 | 5.459 | 3.285 | 5.456 | 3.280 |
| Steel | 1 | 8.756 | 0.788 | 8.750 | 0.792 |
| Telecommunications | 2 | 18.631 | 12.367 | 18.645 | 12.380 |
| IBEX35 | | 9391.356 | 432.8974 | 9387.024 | 431.654 |

Similarly, the table 2 displays some descriptive statistics for the sample of 24 firms from 14 sectors for the years of 2011-2012 that we use for the other event we analyse. In this sample we only have 2 firms in the renewable energy sector, Audax and Solaria-Energia. However, the number of firms in the non-renewable sector stays the same. From the table we see that the mean and standard deviation for the renewable energy sector are even lower than in 2019 at just approximately 1 euro and 0.5 respectively. After collecting all the data about the individual firms in each of the sectors we then appended all the data to create a panel dataset containing the daily stock price data for all the firms which we could use in our analyses.

**Table 2:** Descriptive Statistics for 2011

| | No. of Firms | Open price | | Close Price | |
|---|---|---|---|---|---|
| **Sector** | | Mean | S.d | Mean | S.d. |
| Construction | 1 | 58.450 | 12.322 | 58.447 | 12.316 |
| Consumer Defence | 1 | 14.237 | 1.183 | 14.238 | 1.183 |
| Electricity | 3 | 10.297 | 5.596 | 10.288 | 5.593 |
| Financial Services | 4 | 4.735 | 1.953 | 4.732 | 1.953 |
| Industrials | 3 | 15.815 | 13.723 | 15.787 | 13.696 |
| Infrasturcture Management | 1 | 9.063 | 0.862 | 9.063 | 0.865 |
| Insurance | 1 | 2.311 | 0.337 | 2.309 | 0.338 |
| IT Services | 1 | 10.690 | 2.571 | 10.683 | 2.571 |
| Natural Gas | 2 | 13.445 | 1.793 | 13.445 | 1.796 |
| Oil and Gas | 1 | 19.145 | 3.870 | 19.131 | 3.871 |
| Pharmaceuticals | 2 | 13.633 | 9.928 | 13.598 | 9.886 |
| Renewable Energy | 2 | 0.919 | 0.484 | 0.915 | 0.483 |
| Steel | 1 | 10.295 | 1.898 | 10.277 | 1.888 |
| Telecommunications | 1 | 13.318 | 2.915 | 13.312 | 2.903 |
| IBEX35 | | 8601.018 | 1330.215 | 8595.895 | 1329.288 |

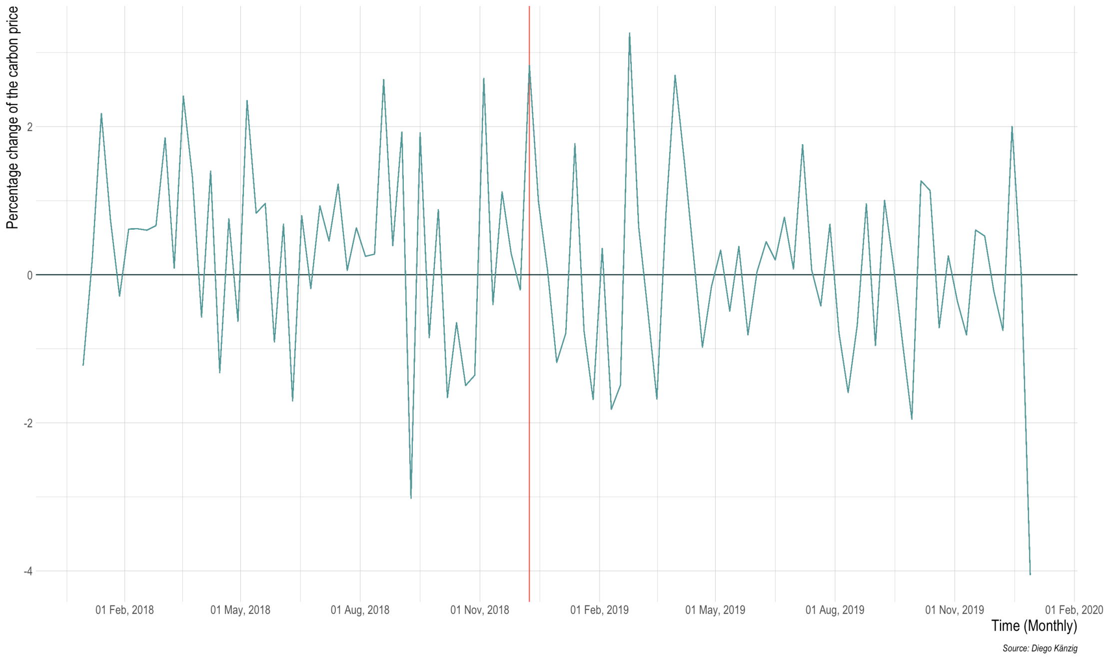
In order to analyse the effect of curtailment we needed data on the amount of energy curtailed in Spain on a daily basis for 2019. We obtained this information from the website of the Spanish electricity operator Red Electrica. Curtailment was measured as the amount of redispatched electricity in Mega Watt hours (MWh). This is the amount of energy that the operator tells the firm to curb from their production in order to not overload the grid or during periods of low demand. We had the redispatch data by wind farm for Spain at an hourly level, which we collapsed in order to get the total daily curtailment in Spain. The table 3 displays the amount of energy curtailed for the three days where curtailment occurred in 2019. Since the phenomenon occurred for so few days in the year we can assume that curtailment is a fairly random phenomenon and so provides an exogenous shock to the market. The variable of curtailment is measured as a negative value since it is a measure of the energy production being curbed. However, in our analysis we use the standardised version of this variable so its sign does not interfere with the interpretation of the results obtained.

**Table 3:** Descriptive Statistics Curtailment

| Date | Amount Curtailed (MWh) |
|---|---|
| 1 April 2019 | -102.8 |
| 5 August 2019 | -25.2 |
| 19 December 2019 | -19255.7 |

The figure 1 plots the daily carbon policy surprise variable which is a measure of the percentage change in carbon price relative to the wholesale electricity price for 2019. From the figure we can observe that there is a lot of variation seen in the data. The red line corresponds to the week of 9 December 2018 which we choose arbitrarily as the week to use while displaying our event study results. We chose this week because its average change in carbon pricing fell in the $99^{th}$ percentile of the data.

**Figure 1:** Carbon Policy Surprise




## 3.2 Abnormal Returns

Event studies, especially in finance and accountancy, focus on analysing the effect that the event has on the abnormal returns (AR) that are obtained on the stock market. Abnormal returns are defined as the difference between the actual returns obtained from the market and the expected returns for the stock based on general market trends and historical data on how the stock performed. Abnormal returns are chosen since they help identify the extra returns obtained over what is expected under normal market conditions. Also, by studying the abnormal returns we can isolate the effect that the event has on the returns obtained by a firm. In order to calculate the abnormal returns we first need to estimate the returns that a firm gets on a daily basis. The daily returns can be calculated using the following formula:

$$DailyReturns = \Big(\frac{OpenPrice - ClosePrice}{OpenPrice}\Big) \times 100$$

In order to calculate the expected returns of the stock, we use the Capital Asset Price Model (CAPM) which was introduced by Sharpe (1964) and Linter (1965). The CAPM model uses the information for how the market is performing in order to calculate the expected returns by using the estimates from the following regression.

$$R_{it} = \beta_0 + \beta_M R_{mt} + \epsilon_{it}$$

$R_{mt}$ is the returns to the market portfolio in time period $t$. In the Spanish context the market portfolio is the IBEX35. In this model, $\beta_M$ captures the systematic risk associated with the investment, and tells us how sensitive the returns of that firm are to the overall market trends. The expected returns can then be calculated using the estimates from this regression as seen in the equation below.

$$\mathbb{E}[R_{it}] = \hat{\beta}_0 + \hat{\beta}_M R_{mt}$$

Following this, the abnormal returns are calculated as the difference between the returns and the expected returns.

$$AR_{it} = R_{it} - \mathbb{E}[R_{it}]$$

where $AR_{it}$ are the abnormal returns for firm $i$ in time period $t$ and $R_{it}$ is the returns obtained from the firm $i$ in period $t$. The table 4 below displays some summary statistics for the abnormal returns calculated for the two time periods we analyse. For the events of wind energy curtailment and the carbon policy surprises in 2019 we use the weekly average of the daily abnormal returns in our analysis as displayed in the table. As for the data we use for 2011-2012 to study the effect of the RD - L 1/2012, we compute the monthly average of the daily abnormal returns in our analysis to observe a clearer trend.

| | Mean | St. Deviation |
|---|---|---|
| 2018-2019 (weekly average) | 0.007 | 0.817 |
| 2011-2012 (monthly average) | 0.005 | 0.426 |

**Table 4:** Summary Statistics for the Average of the Abnormal Returns

## 3.3 Empirical Method

In order to study the effect that the three chosen events have on the abnormal returns of firms in the energy sector in Spain, we adopt an event study methodology. This empirical method is extremely popular and often used in the literature as documented by Corrado (2011) who provide a methodological review of event studies as well as a brief summary of the empirical method. The event study allows us to capture the effect of the events of interest by isolating and separating them from the general market effects.

Since we have a panel data structure, we can exploit both firm level fixed effects as well as time fixed effects in the following estimation to capture the effect that the events would have on the abnormal returns of the renewable and non-renewable sectors. We also allow the standard errors to be clustered at the sector level. It is reasonable to assume that firms in the same sector would be affected by systematic shocks in a similar manner and so we cluster at the sector level to account for this. This is also a reasonable assumption since the main focus of our study is a sector wise analysis of the effects of the events.

While we are interested in studying the impacts of the events on the energy sector as a whole we are also interested in looking at the decomposition of their individual effects on the renewable and non-renewable sectors. We, therefore, estimate the following equation:

$$AR_{it} = \beta_0 + \beta_1 Event_t + \beta_2 Renewable_i + \beta_3 NonRenewable_i + \beta_4 (Event_t * Renewable_i) +$$

$$\beta_5 (Event_t * NonRenewable_i) + \beta_6 R_{mt} + \eta_i + \delta_t + \epsilon_{it}$$

The variables $Renewable_i$ and $NonRenewable_i$ are dummy variables that take the value 1 if the firm is in the renewable or non-renewable sector respectively, and take the value of 0 otherwise. We also control for the average market returns of the IBEX35 ($R_{mt}$) which is consistent with the literature. Finally, $\eta_i$ captures the individual firm fixed effects, $\delta_t$ captures the time specific fixed effects and $\epsilon_{it}$ captures the idiosyncratic error terms. The $Event_t$ variable takes different values depending on the event being studied.

When we are interested in analysing the effect of curtailment on the abnormal returns, the $Event_t$ variable would be the standardised value of the daily curtailment in Spain. We use the standardised value of curtailment rather than the negative value as mentioned above simply for ease of interpretation of the results later on.

When we analyse the Royal Decree - Law 1/2012, the $Event_t$ variable is a dummy variable that takes the value 1 for all dates after 28 January 2012, and 0 before that, since that was the day that this piece of legislation was implemented in Spain.

For the carbon policy surprise analysis, the $Event_t$ variable takes the values of the carbon policy surprise variable measured as the percentage change in the carbon price relative to the wholesale electricity price.

Our main estimates of interest are the coefficients $\beta_4$ and $\beta_5$ on the interaction terms. This coefficient captures the effect that the event has on firms in the renewable sector and the non-renewable sectors alone.

We use this coefficient to test our hypotheses:

> **Hypothesis 1:** Curtailment would have a small, negative effect on the abnormal returns of the firms in the renewable energy sector and a small, positive effect on firms in the non-renewable energy sector
>
> **Hypothesis 2:** RD - L1/2012 would have a negative effect on the abnormal returns of firms both in the renewable energy sector and the non-renewable energy sector
>
> **Hypothesis 3:** The carbon policy surprise would have a negative effect on firms both in the renewable energy sector and the non-renewable energy sector

We also estimate the following equation, as a way to both check the robustness of the results obtained, but also as a way to capture the effect of the events on the energy sector as a whole rather than dis-aggregating it into renewable and non-renewable.

$$AR_{it} = \beta_0 + \beta_1 Event_t + \beta_2 Energy_i + \beta_3 (Event_t * Energy_i) +$$

$$\beta_4 R_{mt} + \eta_i + \delta_t + \epsilon_{it}$$

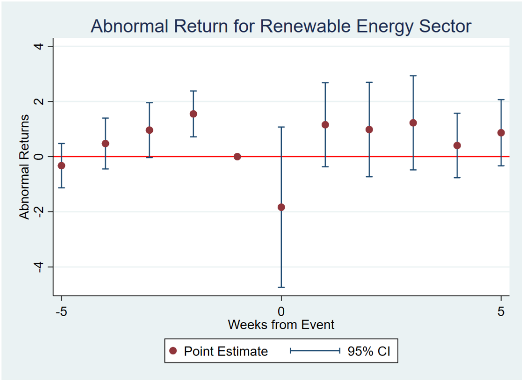
The variables here take the same values as expanded above, the only new variable is the $Energy_i$ which is a dummy which takes value 1 if the firm is in the energy sector and 0 otherwise. Our coefficient of interest in this specification is $\beta_3$ which isolates the effect of the event on the energy sector as a whole. We would expect that this coefficient be approximately the sum of the coefficients of the ones obtained for the renewable and non-renewable sectors from the previous specifications.

# 4 Results

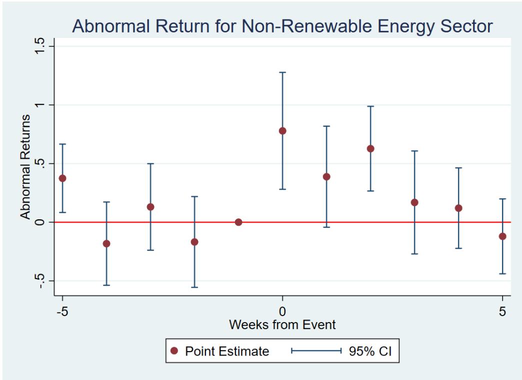
## 4.1 Curtailment

The first event that we focus on is wind energy curtailment. As a primary way to visualise the event study graphically we plot the average daily abnormal returns in the weeks surrounding the curtailment events on 31 March and 4 August 2019 for firms in the renewable energy sector and the non-renewable energy sector. We control for the market returns and the standardised value of the amount of energy curtailed. The event of curtailment on 19 December 2019, as seen in table 3, is excluded since including such an extreme event alongside the other two would bias our results. Also, since our sample is restricted to the year 2019 we would not have 5 weeks post the event in the week of 19 December 2019. The graphs display the abnormal returns for the 5 weeks before and after the curtailment occurs.

In figure 2 the plot on the left shows the results for the renewable energy sector. Time period 0 reflect the abnormal returns obtained by firms in the renewable sector in the week where curtailment occurred relative to the week -1, i.e. the week before the curtailment event occurred. All the abnormal returns plotted are standardised to week -1. From this graph we can see that in the week where curtailment occurs




**(a)** Renewable Energy Sector




**(b)** Non-Renewable energy Sector

**Figure 2:** Event Study Graphs for the Curtailment Event

the abnormal returns fall for the renewable energy sector, although this reduction is not statistically significant. This corroborates our hypothesis that curtailment leads to a reduction in the abnormal returns of firms in the renewable energy sector.

The figure on the right displays the same graph but for firms in the non-renewable energy sector. From this event study we see that in the period where curtailment occurred there was a significant increase in the abnormal returns of the non-renewable sector by approximately 0.75% compared to the abnormal returns seen in the week before the event occurred. We also observe that the effect from wind energy curtailment seems to persist for two weeks following the event from the graph before returning to levels similar to what was observed prior to the event took place. This observed trend supports our hypothesis that wind energy curtailment disincentivises investment in renewables, resulting in a shift of investment to non-renewable energy sources.

To further conduct our analysis, we estimate the results for the regressions discussed in the previous section. The results are displayed in table 5 where column (1) follows the results for the dis-aggregated energy sector into renewable and non-renewable sector, while column (2) shows the results for the energy sector as a whole. Since we are interested in isolating the effect of the event of wind energy curtailment on each of the dummy variables, we focus our attention on the estimates of the interaction terms. From the table we see that a one standard deviation increase in curtailment leads to a statistically significant reduction of 0.2% in the abnormal returns for the renewable energy sector. It also leads to a statistically insignificant increase in approximately 0.04% in the abnormal returns for firms in the non-renewable sector.

**Table 5:** Curtailment Results (1)

| | (1) FE-LS | (2) FE-LS |
|---|---|---|
| Standardised Curtailment × Energy Sector Dummy | | -0.042 |
| | | (0.071) |
| Standardised Curtailment × Renewable Sector Dummy | -0.2*** | |
| | (0.029) | |
| Standardised Curtailment × Non-Renewable Sector Dummy | 0.037 | |
| | (0.031) | |
| Standardised Curtailment | -0.034 | -0.034 |
| | (0.03) | (0.03) |
| Market Returns | -0.047 | -0.047 |
| | (0.151) | (0.151) |
| Constant | 0.006 | 0.006 |
| | (0.005) | (0.006) |
| Sector Clustered Std. Errors | Yes | Yes |
| Observations | 1,537 | 1,537 |
| $R^2$ | 0.0501 | 0.0444 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

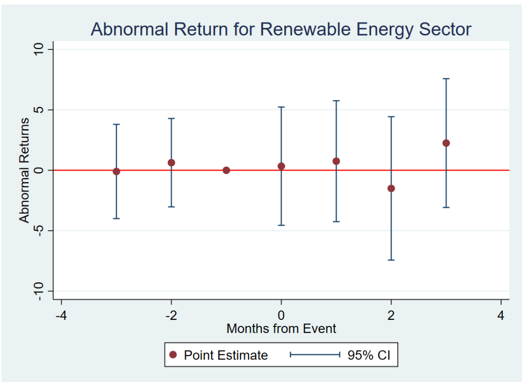
From column (2) of table 5 we see that a standard deviation increase in curtailment leads to a reduction in the abnormal returns for the energy sector as a whole by about 0.04%. We postulate this is because the phenomenon of curtailing wind energy production signals a waste of resources and so negatively impacts the entire energy sector. However, since curtailment is a rather small phenomenon we observe that most of the results are not statistically significant at a 5% level and the values of the coefficients are extremely small. This is in line with our hypothesis that curtailment is not a major consideration that investors take into account when making investment decisions.

## 4.2 Royal Decree - Law 1/2012

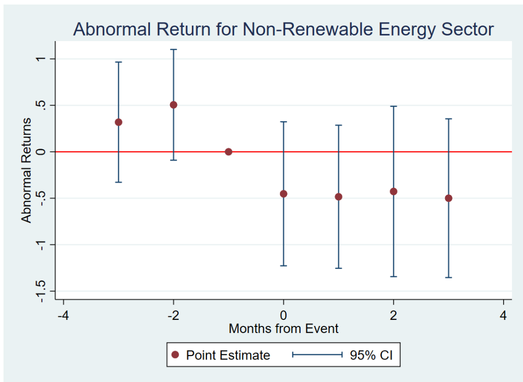
The Royal Decree - Law 1/2012 introduced many reforms into the energy sector in Spain including suppressing economic incentives and the elimination of subsidies for new renewable energy projects. This decree was implemented on $28^{th}$ January 2012. In order to study the effect of this policy change we adopt the event study methodology. We visualise the effect of this event using the graph in figure 3 which plots the average daily abnormal returns in the period 3 months leading up-to the implementation of the royal decree and then three months after its implementation.

Time period 0 corresponds to the month of February 2012 since the decree was implemented at the end of January. The baseline for the event study is time period -1, or the abnormal returns seen for the sectors in January.

The plot (a) shows the trend for the abnormal returns for the renewable energy sector. The abnormal returns seem fairly constant in this plot and do not vary too much or show much of a change from the implementation of the decree. The non-renewable sector, seen in (b), however, undergoes a reduction in their abnormal returns from the period when the policy was implemented relative to the previous period. This reduction continues to persist in the following months as well. The graph of the event study shows a systematic and persistent reduction in the abnormal returns seen for the non-renewable sector. This is in line with our hypothesis since the royal decree had negative outcomes for the energy sector and so would lead to a reduction in the returns on those firms.




**(a)** Renewable Energy Sector




**(b)** Non-Renewable energy Sector

**Figure 3:** Event Study Graphs for the Royal Decree - Law 1/2012 Event

The table 6 displays the results obtained from estimating the fixed effect least squares regression for the two equations. Similar to above, column (2) shows the results for the energy sector as a whole, while column (1) shows the results when the energy sector is dis-aggregated into the renewable and non-renewable sectors. Both columns are estimated using time and individual fixed effects and clustering the standard errors at a sectoral level. From column (2) we can see that there is an approximate decrease of 0.2% observed in the abnormal returns for firms in the energy sector, although it is not statistically significant. We see effects of similar magnitude and direction in column (1) for the renewable and non-renewable sectors as well. From the results of this table we can say that the Royal Decree - Law 1/2012 had negative effects for the entire energy sector as we had hypothesised.

**Table 6:** RD - L1/2012 Results (1)

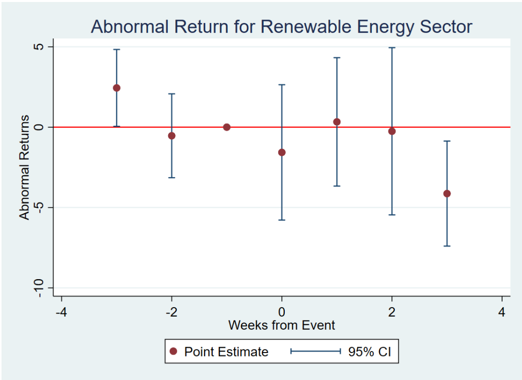
| | (1)<br>FE-LS | (2)<br>FE-LS |
|---|---|---|
| Post-Period ×<br>Energy Sector Dummy | | -0.201<br>(0.114) |
| Post-Period ×<br>Renewable Sector Dummy | -0.232** <br>(0.100) | |
| Post-Period ×<br>Non-Renewable Sector Dummy | -0.191<br>(0.126) | |
| Post-Period | 0.109<br>(0.085) | 0.109<br>(0.084) |
| Market Returns | -0.017<br>(0.128) | -0.017<br>(0.128) |
| Constant | -0.007<br>(0.035) | -0.007<br>(0.035) |
| Time fixed effect | Yes | Yes |
| Sector Clustered Std. Errors | Yes | Yes |
| Observations | 264 | 264 |
| $R^2$ | 0.1289 | 0.1288 |

Standard errors in parentheses
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

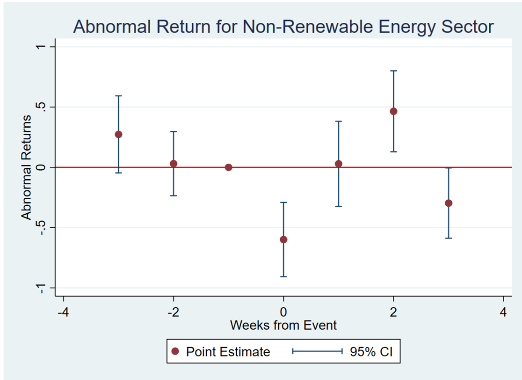
## 4.3 Carbon Policy Surprise

The carbon policy surprise variable measures the change in the carbon price relative to the wholesale electricity price. This is a continuous event as opposed to the two events studied before. Here, there is a certain change in the carbon pricing that occurs almost every day. In order to plot the graph to study the event we arbitrarily choose a week in the $99^{th}$ percentile of carbon policy surprises in order to visualise the effect of an extreme change in the carbon prices. Our chosen week is the one of 9 December 2018 which had a mean daily carbon policy surprise of 2.8%.

The figure 4 shows the two plots for the renewable and non-renewable sectors around the week we study. From the figure on the right we see a significant reduction in the abnormal returns for firms in the non-renewable sector by approximately 0.6% in the week of the event relative to those obtained in the prior week. This is consistent with our expectations since these firms are more reliant on carbon products and more likely to be affected by increases in their pricing. From the figure on the left we can see that for renewable sector there is a small and insignificant decrease in the abnormal returns in the week of the event relative to the week before. Both of these results are consistent with our hypothesis.




(a) Renewable Energy Sector




(b) Non-Renewable energy Sector

**Figure 4:** Event Study Graphs for the Carbon Policy Surprises Event

**Table 7:** Carbon Pricing Shocks Results (1)

| | (1)<br>FE-LS | (2)<br>FE-LS |
|---|---|---|
| Carbon Policy Shock × Energy Sector Dummy | | -0.04<br>(0.03) |
| Carbon Policy Shock × Renewable Sector Dummy | -0.103***<br>(0.015) | |
| Carbon Policy Shock × Non-Renewable Sector Dummy | -0.008<br>(0.016) | |
| Carbon Policy Shock | 0.015<br>(0.022) | 0.015<br>(0.022) |
| Market Returns | 0.017<br>(0.106) | 0.017<br>(0.106) |
| Constant | -0.002<br>(0.005) | -0.002<br>(0.005) |
| Sector Clustered Std. Errors | Yes | Yes |
| Observations | 3,045 | 3,045 |
| $R^2$ | 0.0338 | 0.0325 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The table 7 displays the results for the fixed effects OLS estimation of the equations as in the above two events. From the table we can see that a percentage increase in the price of carbon, as reflected by the carbon policy surprises, is associated with a reduction in the abnormal returns for the energy sector by 0.04%. Also, a one percent increase in the price of carbon leads to a reduction in the abnormal returns of 0.1% for the renewable energy sector and 0.008% for the non-renewable sector. These results are only significant for the renewable energy sector. Therefore, an increase in carbon prices has a negative effect on the energy sector. This is fairly intuitive for the non-renewable sector since they are directly reliant on carbon products like coal. However, as Känzig (2023) discusses, the increase in carbon prices leads to an increase in energy prices which could lead to an economic slowdown that negatively impacts the renewable sector as well.

## 4.4 Firm-wise Analysis

It is interesting to note that even though the BME has a classification for firms as belonging to the renewable, oil and gas, natural gas or electricity sectors, these firms do not typically have all their investments only in their sectors of classification. For example, while Iberdrola is classified by the BME as belonging to the electricity sector and enters our analysis in the non-renewable sector, the firm actually has several renewable energy investments and portfolios. We regress abnormal returns on the interaction term for the firms in the energy sector with the three events of interest controlling for general market returns, similar to the regressions estimated above. The regressions are run using heteroskedastic standard errors but without the inclusion of fixed effects. The complete results for this analysis are displayed in tables 9 - 11 in the Appendix.

From this analysis we observe that for the events of the Royal Decree - Law 1/2012 and the carbon policy surprise none of the coefficients on the interaction terms are significant. However, for the event studying curtailment, the coefficients are significant and negative for Grenergy which is a renewable energy firm and this supports our initial hypotheses. The coefficient obtained for Enagas, a natural energy firm, is significant and positive which follows from our reasoning that as curtailment increases other non-renewable forms of energy production seem to benefit. Similarly, Red Electrica also has a positive and significant coefficient, they are the Spanish Electricity grid operator and are classified in the electricity sector by BME and so have large shares of both renewable and non-renewable stock profiles. Future studies could analyse in more detail how the energy profile of each firm is affected by the various events.

# 5 Robustness Check

In order to verify the validity of our results we run some robustness checks. To validate our regression results for the three event studies, we check whether the results hold by estimating the same regressions for different time periods. We present the results of the analysis in the table 8. While checking for consistency, we verify whether the results for curtailment hold when we conduct the analysis at the daily and weekly level since we would expect this to be a more short term effect. While for the royal decree and the carbon policy surprise we conduct the robustness checks at the weekly and monthly level. The existing literature on the carbon policy surprises does indicate that the effects of this variable would be more visible in longer horizons. We can also reasonably argue that the impacts of a policy on investment decisions would become more apparent in longer time-frames.

**Table 8:** Robustness Check

| | Curtailment | | RD - L1/2012 | | Carbon Policy Surprise | |
|---|---|---|---|---|---|---|
| | Daily | Weekly | Weekly | Monthly | Weekly | Monthly |
| Energy Sector × Event | 0.437<br>(0.396) | -0.042<br>(0.071) | -0.033<br>(0.052) | -0.201<br>(0.114) | -0.04<br>(0.03) | -0.041<br>(0.031) |
| Renewable Sector × Event | -0.0002<br>(0.041) | -0.2***<br>(0.029) | 0.031<br>(0.033) | -0.232***<br>(0.100) | -0.103***<br>(0.015) | -0.117<br>(0.081) |
| Non-Renewable Sector × Event | 0.008<br>(0.044) | 0.037<br>(0.031) | -0.054<br>(0.053) | -0.191<br>(0.126) | -0.008<br>(0.016) | -0.003<br>(0.01) |
| Sector Clustered Std. Errors | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 7,395 | 1,537 | 2,520 | 264 | 3,045 | 725 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

From the table we can see that the signs and magnitudes of the different events are fairly consistent. For all the events the signs of the coefficients obtained from the interaction terms for the two fixed effects OLS regressions are displayed. All the regressions are clustered at the sector level. For the event analysing the effect of wind energy curtailment, we see that for the renewable and non-renewable sectors curtailment consistently leads to a decrease and an increase in the abnormal returns respectively. The effect is only significant at the weekly level for renewables, which may account for the change in sign for the energy sector at that same weekly level.

For the royal decree, we observe from the table that the signs on the coefficients for the non-renewable and the energy sector are the same when the analysis is conducted at the weekly level. However, neither effects are statistically significant. The effects on the renewable sector are not consistent across the robustness assessments. However, as mentioned none of the estimates at the weekly level are significant. Future studies looking to address the impact of this policy might benefit from using more robust specifications.

For the carbon policy surprises we observe that at both the weekly and monthly levels the signs are similar for all the sectors analysed. In addition to this, the magnitude of the effects are also approximately the same, even though the results are only significant for the renewable energy sector at the weekly level. From this assessment, we demonstrate that our results are fairly robust across the different time periods.

# 6 Conclusion

Climate change has become the biggest challenge humanity is poised to confront in this century. The consequences are far-reaching, as polar ice shields continue to melt and sea levels to rise. Certain regions experience more frequent extreme weather events and rainfall, while others suffer from severe heat waves and frequent droughts. The implications of climate change jeopardize various social, economic and territorial aspects of our lives. As such, it is crucial to understand the implications of climate, carbon pricing and policy events on the energy stock market, in order to effectively allocate financial resources to areas where they can generate the most significant impact. This paper contributes to that objective by providing new evidence on how particular events affect the abnormal returns of companies in the energy sector.

First, we show that abnormal returns fall for the renewable energy sector during weeks with high curtailment and this reduction is statistically significant. Moreover, from the event study we also observe that in periods where curtailment occurred there was a significant increase in the abnormal returns of the non-renewable sector. This could indicate that high curtailment events encourage investors to shift their investments from renewable energy to non-renewable energy companies. Lastly, our results suggest that curtailment is a rather small phenomenon. The majority of the results are not statistically significant at a 5% level, and the coefficient values are very small. This aligns with our hypothesis that curtailment is not a major consideration that investors take into account when making investment decisions.

Secondly, our findings indicate that the Royal Decree - Law 1/2012 had negative effects for the entire energy sector as we had hypothesized. Our results suggest that the suspension of all in-feed tariffs guaranteed to renewable electricity producers disincentivized investment in the energy sector. However, it is important to note that our results are statistically insignificant for the non-renewable sector and the energy sector as whole. They are however, significant and negative for the renewable energy sector.

Finally, we find that increase in carbon pricing leads to a significant reduction in the abnormal returns for firms in the non-renewable sector. This result aligns with our expectations that firms more reliant on carbon products would likely be more affected by increases in their pricing. For the renewable sector we observe a small and significant decrease in the abnormal returns. Our results are in line with the existing literature, which suggests that an increase in the price of carbon temporarily lowers economic activity and investment.

In future work, it would be interesting to analyse in more detail the break-down of the energy portfolios of the firms to see how they change when faced with these events. It is important in today's capitalistic society to understand and analyse how climate shocks and events affect stock markets and investment decisions especially considering the growing importance of sustainable finance as a way to mitigate and manage climate risks.

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# 7 Appendix

**Table 9:** Firmwise Break-up for Curtailment

| | (1)<br>OLS |
|---|---|
| Market Returns | -0.013 |
| | (0.299) |
| Standardised Curtailment | -0.034 |
| | (0.045) |
| Audax | 0.000 |
| | (.) |
| Enagas | -0.256 |
| | (0.291) |
| Endesa | -0.329 |
| | (0.287) |
| Grenergy | -0.279 |
| | (0.318) |
| Iberdrola | -0.367 |
| | (0.285) |
| Naturgy | -0.310 |
| | (0.288) |
| Red Electrica | -0.216 |
| | (0.286) |
| Repsol | -0.193 |
| | (0.286) |
| Solaria Energia | -0.407 |
| | (0.326) |
| Audax × Standardised Curtailment | 0.000 |
| | (.) |
| Enagas × Standardised Curtailment | 0.164*** |
| | (0.041) |
| Endesa × Standardised Curtailment | 0.012 |
| | (0.040) |
| Grenergy × Standardised Curtailment | -0.543*** |
| | (0.045) |
| Iberdrola × Standardised Curtailment | 0.044 |
| | (0.040) |
| Naturgy × Standardised Curtailment | -0.007 |
| | (0.041) |
| Red Electrica × Standardised Curtailment | 0.102** |
| | (0.040) |
| Repsol × Standardised Curtailment | 0.024 |
| | (0.040) |
| Solaria Energia × Standardised Curtailment | 0.001 |
| | (0.046) |
| Constant | 0.309 |
| | (0.274) |
| Observations | 477 |
| Adjusted $R^2$ | 0.019 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 10:** Firmwise Break-up for Royal Decree - Law 1/2012

| | (1) OLS |
|---|---|
| Market Returns | 0.085 |
| | (0.117) |
| post_period=1 | 0.182 |
| | (0.279) |
| Audax | 0.000 |
| | (.) |
| Endesa | -0.421** |
| | (0.198) |
| Enagas | -0.524*** |
| | (0.193) |
| Iberdrola | -0.482** |
| | (0.195) |
| Naturgy | -0.578*** |
| | (0.195) |
| Red Electrica | -0.430** |
| | (0.193) |
| Repsol | -0.554*** |
| | (0.195) |
| Solaria Energia | -0.286 |
| | (0.265) |
| post_period=1 × Endesa | -0.328 |
| | (0.301) |
| post_period=1 × Enagas | -0.179 |
| | (0.286) |
| post_period=1 × Iberdrola | -0.135 |
| | (0.299) |
| post_period=1 × Naturgy | -0.092 |
| | (0.298) |
| post_period=1 × Red Electrica | -0.127 |
| | (0.296) |
| post_period=1 × Repsol | 0.023 |
| | (0.294) |
| post_period=1 × Solaria Energia | -0.134 |
| | (0.478) |
| Constant | 0.434** |
| | (0.188) |
| Observations | 192 |
| Adjusted $R^2$ | 0.121 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 11:** Firmwise Break-up for Carbon Policy Surprises

| | (1) OLS |
|---|---|
| Market Returns | -0.003 |
| | (0.153) |
| Carbon Policy Surprise | -0.117 |
| | (0.224) |
| Audax | 0.000 |
| | (.) |
| Enagas | -0.146 |
| | (0.241) |
| Endesa | -0.187 |
| | (0.240) |
| Grenergy | -0.224 |
| | (0.278) |
| Iberdrola | -0.231 |
| | (0.239) |
| Naturgy | -0.247 |
| | (0.242) |
| Red Electrica | -0.133 |
| | (0.240) |
| Repsol | -0.122 |
| | (0.240) |
| Solaria Energia | -0.213 |
| | (0.295) |
| Audax × Carbon Policy Surprise | 0.000 |
| | (.) |
| Enagas × Carbon Policy Surprise | 0.095 |
| | (0.225) |
| Endesa × Carbon Policy Surprise | 0.082 |
| | (0.227) |
| Grenergy × Carbon Policy Surprise | 0.074 |
| | (0.269) |
| Iberdrola × Carbon Policy Surprise | 0.135 |
| | (0.224) |
| Naturgy × Carbon Policy Surprise | 0.111 |
| | (0.225) |
| Red Electrica × Carbon Policy Surprise | 0.091 |
| | (0.224) |
| Repsol × Carbon Policy Surprise | 0.124 |
| | (0.224) |
| Solaria Energia × Carbon Policy Surprise | -0.042 |
| | (0.257) |
| Constant | 0.163 |
| | (0.237) |
| Observations | 945 |
| Adjusted $R^2$ | -0.010 |

Standard errors in parentheses
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$