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Do Markets Trump Politics? Fossil Fuel Market Reactions to the Paris Agreement and the US Election

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Abstract

How can event studies in financial markets best be used to evaluate policy? We take the example of climate policy and the issue of whether world climate policy is effective. Environmentalists claim too little is done. Industry argues policy is too interventionist and warns that stranding significant assets could lead to financial instability. We evaluate the impact of global climate policymaking by studying the impact of the election of President Trump and of the Paris climate agreement on the stock market value of energy sector firms. Using event study and impulse-indicator saturation methods, we show that both events had only moderate effects on the value of fossil fuel firms.

Key Words: Event study, impulse-indicator saturation, Paris climate agreement, Trump.

JEL Codes: G14, Q40, Q54

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1. Introduction

Event studies originated in accounting and finance, but their application has spread to other fields. Examples include Dube et al. (2011), who analyze the effect of CIAs covert operations in toppling foreign governments on the value of US companies in the countries concerned, and Guidolin and La Ferrara (2007), who examine the impact of the abrupt end of the Angolan civil war on the value of diamond mining firms. The key assumptions for event studies are that markets are efficient, the event's timing is exogenous, and that the event is unanticipated. In this study on stranded assets (for instance, in coal companies), we will be examining two major events that arguably differ in that one is truly unanticipated while the other is only partially unanticipated.

When it comes to climate, the 2015 Paris Agreement has been described as a big step forward, whereas the election of Donald Trump in 2016 has been characterized as a setback (see, e.g., Tricks 2016). No doubt these were exceptional events, but how important are they compared to gradual but fundamental shifts in technology trends and societal preferences? Media generally focuses public attention on high-profile events such as elections and international negotiations. In this paper, we use analytical techniques to evaluate the importance of these events to energy sector firms and climate policy.

An international policy response to climate change has been sought at least since the establishment of the UN Framework Convention on Climate Change (UNFCCC) in 1992. In 2009, the 15th Conference of the Parties (COP) in Copenhagen ended without results. A global climate agreement has looked very elusive, partly because of disagreements regarding how the burden of emissions reductions would be shared among countries. The run-up to the Paris COP was filled with conflicts, and observers voiced concerns that the Paris COP would once more fail. Nevertheless, on December 12, 2015, 195 nations did sign the Paris climate agreement. Acclaimed as a significant milestone, it united all but two of the world's countries behind a single text, and that text contained a goal that was deemed surprisingly radical: to keep warming *well below* 2°C above preindustrial levels "and to pursue efforts to limit the temperature increase even further to 1.5°C." These facts speak in favor of Paris being classified a success. On the other hand, the treaty did not allocate reductions among countries or stipulate the use of efficient policy instruments such as taxes or permit trading. Its main instrument is the required submission of intended nationally determined contributions (INDCs). There is no mechanism to ensure these contributions add up to the stated goals, nor are there any enforcement mechanisms.

The election of Donald Trump as the 45th US president on November 8, 2016, shifted expectations in the fossil and renewable energy markets. Donald Trump ran a successful presidential campaign that promised, among other things, to withdraw the United States from the Paris Agreement as well as significantly roll back domestic climate policies particularly in the coal industry. The election of Donald Trump is interesting for several reasons. First, it came as a surprise unanticipated by opinion polls and prediction markets. Second, among the many differences between the two candidates, one major difference lay in their commitments to climate change mitigation. A Clinton presidency would likely have meant a continuation of the status quo in climate policy. A Trump presidency promised however to reverse all Obama era regulations on fossil industries. Last, the United States is one of the largest sources of anthropogenic emissions of carbon dioxide. Many observers worried a global climate agreement without US participation would hinder the full participation of other reluctant countries. The Paris Agreement was itself a compromise deal among countries which insisted on binding commitments (e.g. the EU), developing countries which demanded adaptation finance as a precondition for participation and others such as the United States which was against binding commitments for example. The election a year after the announcement of the Paris Agreement threw into doubt continued US participation in global climate efforts in the medium term.

We have presented a few arguments why these events are important but really evaluating their impacts is difficult because their results in terms of mitigating or exacerbating future climate change depend on many other factors and will not be observed until many decades from now. The purpose of this paper is to seek firmer evidence by studying market effects (stock market values) of the Paris climate agreement as well as the US 2016 election.

The Paris Agreement and the US election come at a time of increasing concern about stranded assets (Carbon Tracker Initiative 2013; Leaton 2012) and central banks have warned that tough climate policies themselves have the potential to significantly affect financial stability (Batten et al. 2016; Campiglio et al. 2018; Carney 2015; Dafermos et al. 2018). Stock markets may price climate risks inefficiently without full disclosure of corporate exposures (Hong et al. 2016). With this perspective, the purpose of this study is to evaluate the effects of the Paris climate agreement and the US election by looking at their impact on the value of energy sector firms. In financial markets, information regarding environmental management is reflected by how markets assess the financial impact on a company’s performance. In efficient markets, the effect of an unexpected announcement or development will be reflected immediately by changes in asset prices. Event studies have been applied in accounting and financial economics to evaluate the impact of a range of events such as mergers and acquisitions and earnings announcements. Several studies have used event study analysis to assess the relationship between firm financial performance and the release of environment-related news (Cram and Koehler 2000; Dasgupta et al. 2001; Fisher-Vanden and Thorburn 2011; Griffin et al. 2015; Hamilton 1995; Khanna et al. 1998).

We investigate two main hypotheses: (a) The Paris Agreement (Trump election) is bad (good) for firms in the fossil industry and good (bad) for firms in renewable, clean and alternative energy industries. There are however important differences among the fossil fuels. Coulomb and Henriet (2018) and Michielsen (2014) show that under reasonable assumptions, the introduction of environmental policy such as a carbon tax should raise profits for oil and gas owners while depressing profits for owners of coal. We therefore expect that within the fossil industry, the Paris Agreement (Trump election) should negatively (positively) affect the value of coal stocks more than that of oil and natural gas. This is because the combustion of coal results in significantly larger emissions per unit of energy produced than oil, and much more than natural gas. (b) We hypothesize that the Paris Agreement and Trump election have a differential effect on firms operating in different countries. In this regard, we expect the Paris Agreement to have impacts that are more significant on firms operating in countries with an active climate policy that will feel bound to follow the Paris Agreement. The Paris Agreement might also have more effect in "Annex 1" (i.e. rich) countries that have INDCs committing to rapidly reducing reliance on fossil fuels. Following from this, differential impacts across countries may then arise depending on whether a given country is importing or exporting coal to countries that "believe in" climate change or classified as "Annex 1". We evaluate the agreement and election impact on the stock market value of firms in each specific energy sector. Using event study and impulse-indicator saturation methods, we show that these events had only moderate effects on the fossil industry. It is important to recognize that economic theory would require two factors as decisive for a significant stock market effect: first that the event is beneficial or detrimental to the industry concerned, and second, that there is an element of surprise. If the event is expected, then its positive or negative effect will already be discounted by the market. We test these hypotheses by applying the standard event study approach (see, e.g., Campbell et al. 1997) to measure the abnormal returns for a number of fossil fuel stocks in Asia, Australia, Europe, South Africa, and North America.

One may have legitimate arguments about both the efficacy of the Paris climate agreement and whether it was surprising. Hence, a determination of the presence or absence of effects must take both of these factors into account. The effects may have been moderate because the agreement was anticipated. To investigate this, we complement our study by conducting a media content analysis of articles published in one of the leading financial newspapers, the *Financial Times*, during the two months leading up to the climate negotiations and the period afterward until the end of 2015. We also report an expert survey of environmental and resource economists attending the 6th World Congress of Environmental and Resource Economists (WCERE). The rest of the paper is organized as follows: Section 2 presents the data and estimation strategy used, Section 3 contains the main empirical results and a discussion of the results, and Section 4 concludes.

2. Data and Empirical Strategy

Figure 1 shows trends in the energy sector from 2005 to end of 2016. A visual analysis of Figure 1 shows big movements but fails to identify any significant changes in the energy sector around the particular dates that the Paris climate agreement and the US presidential results were announced. A systematic approach using statistical techniques is therefore necessary. In this section, we present the data and the two main methods of analysis used in the paper: event study analysis and impulse-indicator saturation.

2.1. Timeline of Events

Table 1 sets out the timeline of events leading up to the Paris climate agreement and afterward. Prior to the climate negotiations in Paris, countries had to submit INDCs. Negotiations started on November 30, 2015, and culminated with an agreement on December 12. We are treating December 12, 2015, as the decision day, but the agreement required the fulfillment of a number of conditions before coming into force. The agreement was signed by 195 UNFCCC members in April 2016. After signing, parties had to individually ratify the agreement after consultations in their respective countries. At the time of ratification, governments could submit their first nationally determined contributions (NDCs); otherwise, the INDCs submitted ahead of Paris became their first NDCs and the first emissions targets under the Paris Agreement. The agreement was designed to go into effect one month after a “double threshold” was satisfied: (a) the agreement had to be ratified by at least 55 countries, and (b) those 55 countries should be responsible for at least 55 percent of global emissions of greenhouse gases. The first threshold was met on September 21, 2016, and the second on October 5, setting the agreement to take effect on November 4, 2016. Donald Trump won the US presidential election on November 8, 2016. On June 1, 2017, President Trump announced his intention to withdraw the United States from the Paris climate agreement, citing that the accord would undermine the US economy.

2.2. Sample Selection and Data Description

The energy industry is composed of many firms some of which are privately held institutions and thus have no active equity trading. We therefore limit our analysis to those stocks for which daily stock prices are publicly available and that trade continuously during the sample period and have non-missing estimation period returns data for at least 100 trading days. This restricts our analysis to a sample in which bankruptcy events have no influence given that five of the largest coal mining firms in the United States, for example, filed for Chapter 11 bankruptcy protection during the period under analysis.

We use two samples in our analysis. The first sample is made up of exchange-traded funds (ETFs) (see Table 2). ETFs are portfolios or baskets of securities traded on a stock exchange analogous to individual company stocks.[1] They are usually designed to replicate well-known market indices such as the S&P 500, but others also track customized indices (See Technical Appendix for a detailed discussion on ETFs). The ETFs in our samples are composed of firms operating in countries responsible for significant global carbon emissions. For example, in the case of coal, the ETF gives us coverage of 12 different countries and includes the largest global coal firms in terms of market capitalization. For renewable energy, the ETFs allow us to capture up to 17 countries in the case of wind energy (Table 2, column 4). These countries are leading in renewable energy and host operations for the largest firms by market capitalization (Table 2, column 3). In terms of the number of firms in each energy industry, the ETFs allows us to capture a large number of the largest publicly listed firms in each of the industries (Table 2, column 2). The analysis using ETFs therefore allows us to analyze the aggregate global reaction to the Paris Agreement and the US election.

The ETFs in our sample are based on equities and follow a particular index composed of a number of stocks. We exclude ETFs based on commodities or futures contracts as they may respond differently to events similar to the ones under consideration.[2] In addition, movements in commodity prices might be heavily influenced by many short-term factors. We also exclude exchange-traded notes, since their value is at times influenced by the credit rating of the issuer.

The second sample includes individual firms in the coal industry across a number of countries (see Table 3). These countries account for significant global coal production or consumption and carbon emissions. We analyze the reaction of individual firms across different countries here since the coal market is largely geographical with most coal used close to source. In this case, firms may react differently depending on details of political or market landscape in their country of operation. A country-level analysis therefore allows us to directly test for this.

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[1] Our choice to use ETFs is motivated by the fact that ETFs trade like individual stocks on major stock exchanges and can therefore be bought or sold throughout the trading day. In addition, ETFs provide an efficient way to analyze a wide variety of securities listed in different countries and also allow us to detect effects that are likely to have caused stock prices of all companies to move in the same direction. Also, there are no obvious commodity markets for nuclear and renewable energy to study, and there are many different types of oil and coal; therefore, we prefer to analyze stock prices.

[2] While the value of commodity firms is heavily influenced by the commodity price, Gorton and Rouwenhorst (2006) show the correlation between commodity futures returns and commodity equity returns was only 0.40 between the period 1961 and 2003. This implies investing in commodity futures is not a close substitute to investing in commodity company stocks. In that case, an analysis based on a portfolio combining ETFs based on both equities and commodity futures may not be appropriate.

The analysis is conducted using daily financial data from January 2015 to January 2017 collected from the Thomson Reuters Eikon and Bloomberg databases. The daily prices of securities and ETFs used here are closing prices, the prices at which the last transaction in each of the securities occurred during the trading day.

2.3. Event Window Determination

The Paris Agreement was announced on December 12, 2015, a non-trading day. We therefore chose the next trading day, December 14, 2015, as the event day. For our event study analysis, we make use of several event windows. For the Paris Agreement event study, we also report results for the event window $[-10, +2]$, which coincides with the onset of the COP 21 climate negotiations in Paris. Such a window length is necessary since it is unclear when markets started to react to the possibility of a global climate agreement being announced during the negotiation period. Extending the event window beyond this however, makes it difficult to attribute any observed abnormal returns to the event due to the increased possibility of contamination.[3] We use the 225-trading-day period prior to the event window as the estimation window for the Paris announcement. Our choice of the estimation window for the Paris Agreement event study is meant to coincide with about two weeks after the 20th session of the Conference of the Parties in Lima, Peru. This is necessary to avoid contamination of the estimation period as this may bias the estimation of the return-generating process parameters (see Aktas et al. 2007). The Lima Call for Climate Action paved the way for a new global climate agreement in Paris. For the US election, we consider the day after the election as the announcement day (November 9, 2016) and analyze abnormal returns during the event window $[0, +5]$. The estimation window is taken as the 215-trading-day period prior to the event window.

2.4. Was Paris a Surprise?

In order to get some sense of the surprise in the announcement of the Paris Agreement, we carry out a media content analysis of 200 *Financial Times* articles collected from Factiva using the search strings “Paris” and “climate” and published between October 1 and December 31, 2015 (see Technical Appendix for details). The *Financial Times* is an important source of financial news internationally in contrast to other sources of financial news that service mainly a national audience such as the *Wall Street Journal*.[4] We complement this

[3] The US Solar Investment Tax Credits for example, was extended on December 18, 2015—day +4 post event day, for example.

[4] See the Global Capital Markets Survey: http://www.thinkmediaconsultancy.com/GCM/Media

data with an expert survey of environmental and resource economists attending the 6th WCERE in June 2018. The population from which we sampled is a list of about 1500 environmental and resource economists attending the congress. The survey was administered online to all participants during and after the congress (see Technical Appendix for details). The overall response rate was 38%, similar to previous surveys of economists (see May et al. 2014).

2.5. Event Study Analysis Method

Stock market event studies assume an efficient stock market in which prices fully reflect all available information and future expectations. New information about the profitability in a particular industry should change the stock prices of firms affected. In general, the event study methodology examines return behavior for a sample of firms experiencing a common event. The basic idea is that because news is unexpected, we can determine the effect on asset prices. The event might take place on the same date or at different points in time for different firms (Kothari and Warner 2007).

We use the standard event study methodology (see Campbell et al. 1997; MacKinlay 1997) to measure abnormal returns, defined as the difference between the normal return predicted by the market model for the firm and the firm's actual return on a specific date. The market model is a statistical model relating the return of any given security (r_{it}) to the return in the overall market (r_{mt}). The model assumes a stable linear relation between the market return and the stock return. For any security i, we have

$$r_{it} = \alpha_i + \beta_i r_{mt} + \epsilon_{it} \qquad (1)$$

$$E[\epsilon_{it}] = 0 \text{ and } \mathrm{Var}[\epsilon_{it}] = \sigma_{\epsilon_i}^2$$

Equation (1) is based on the assumption that in the absence of unexpected news (i.e., during the estimation period), the relationship between the returns to the firm and the returns on the market index should be unchanged; therefore, the expected value of the abnormal returns $\hat{\epsilon}_{it}$ is zero. The firm-specific parameters of the market model are estimated using ordinary least squares and are denoted by $\hat{\alpha}_i$, $\hat{\beta}_i$, and $\hat{\sigma}_{\epsilon_i}^2$.[5] Equation

[5] We also estimate equation (1) using the GARCH(1,1) specification, which represents the error term as a generalized autoregressive conditional heteroskedasticity model following Bollerslev (1986). The GARCH model has been suggested by Pynnönen (2005) as a partial remedy for shifts in the level of volatility within the event window. (See also Corhay and Rad (1996) for an earlier application of the GARCH model in event studies.) Often the GARCH(1,1) specification has been found to sufficiently capture stock return volatility.

(1) is usually referred to as the single-factor model because it controls only for the market return. The abnormal return ($\hat{\epsilon}_{it}$) for firm i is generated on a given event-related day t when unexpected news affects the return for the firm (r_{it}) without affecting the market return (r_{mt}).[6] The abnormal return $\hat{\epsilon}_{it}$ for the ith firm at time t is then given as $\hat{\epsilon}_{it} = r_{it} - \left(\hat{\alpha}_i + \hat{\beta}_i r_{mt}\right)$. Normally, one can use several event windows (i.e., intervals around the event date over which markets are likely to have incorporated changing expectations). This is important because if the event was partially expected, some of the abnormal return behavior should show up in the pre-event period. Likewise, some period post-event is included in the event window if markets are inefficient and respond with a lag.

From the estimated residuals in equation (1), the cumulative abnormal return (CAR_{it}) is generated as $CAR_{i,(t_0,t_1)} = \sum_{t=t_0}^{t_1} \hat{\epsilon}_{it}$, where t_0 is the first day of the event window. The cumulative average abnormal return ($CAAR_{(t_0,t_1)}$) for a sample of *N* stocks over the event window is given as $CAAR_{(t_0,t_1)} = \frac{1}{N}\sum_{i=1}^{N} CAR_{i,(t_0,t_1)}$. More elaborate models, such as multifactor models and the capital asset pricing model, are available, but in the context of event studies, experience has seldom shown these models to be superior, especially for short event windows (Brown and Warner 1980, 1985; Campbell et al. 1997; MacKinlay 1997). We therefore prefer the standard one-factor market model for our analysis.

We assess whether (a) the Paris climate agreement and (b) the US election had any impact on fossil fuel markets by formally testing the null hypothesis that the events had no impact on stock returns. We want to be ambitious in terms of details. It is possible that there would be differential effects in different countries depending on details of the political or market landscape. We therefore conduct the analysis at the global level for all energy sources, as well as in greater detail at the country level for coal. The country-level analysis includes coal companies from North America, Asia, Africa, Australia, and Europe.

Event studies analyzing stock reaction to events affecting a number of firms simultaneously, for example regulatory events, are characterized by cross-sectional correlation among the abnormal returns.[7] The presence of event clustering means the abnormal returns and the cumulative abnormal returns are no longer independent across securities thus affecting inference. Kolari and Pynnönen (2010) show that event clustering

[6] In the next section, we consider instead $r_{st} - r_{ct}$ as the dependent variable, with r_{st} as the return on solar stocks and r_{ct} as the return on coal stocks.

[7] Traditional event studies have tended to focus on firm-specific events such as stock splits and the release of earnings reports. A survey of the top four finance journals by Kolari and Pynnönen (2010) finds only 76 studies with potential event clustering for the period from 1980 to mid-2007.

can lead to over-rejection of the null hypothesis of zero average abnormal returns when it is true even in cases in which the cross-sectional correlation of abnormal returns is relatively mild. We address this problem through making use of the test statistic presented in Brown and Warner (1980, 1985) which corrects for event clustering by using the portfolio time-series standard deviation. This procedure termed Crude Dependence Adjustment by Brown and Warner (1980, 1985) estimates the standard deviation from the time series of sample (portfolio) average abnormal returns during the pre-event period (see Technical Appendix for details).

2.6. Indicator Saturation Method

The event study approach outlined so far is based on imposing the event of interest from the onset. In this section, we enhance the traditional event study approach by introducing a more powerful and flexible outlier and structural break detection method that can help detect any relevant significant events. In our case, events of interest include the announcement of the Paris climate agreement, ratification of the agreement by key countries, the November 2016 US election, as well as other events not identified a priori. The evidence of an effect can be seen as stronger if the dates of interest are identified without being imposed a priori. The returns to holding fossil fuel stocks can be influenced by any number of random events, such as oil spills, wars, and business news. If these other shocks are not identified and dealt with, they may bias the overall analysis (see Aktas et al. 2007). In this regard, traditional event studies as currently used are potentially misspecified and indicator saturation addresses this shortcoming in event studies by identifying and controlling for outliers and shifts (structural breaks) during the sample period. Indicator saturation has the added advantage in that it allows one to test directly for model misspecification given that no shifts or outliers should be detected outside the event window if an event study is well specified.

Instead of including the event from the onset in a model, we propose to search for outliers/breaks in our dependent variable and check whether any detected outliers/breaks coincide with the announcement of the Paris climate agreement and other significant climate news or to combine models that impose shocks and those that detect them automatically. There are several approaches to detecting outliers and structural breaks, including the step- and impulse-indicator saturation (SIS and IIS) methods and the Chow test (see Castle et al. 2015; Chow 1960; Hendry and Johansen 2015; Santos et al. 2008).

IIS treats every data point in the time series as a potential impulse shock (outlier). The technique saturates the entire sample period with a full set of impulse indicators and removes all but the significant ones at a selected level of significance α. IIS treats the detection of outliers as a model selection exercise. While multiple breaks of different forms, such as impulses and changing trends, can also be identified by this technique, we seek to detect impulses because a climate agreement is unlikely to result in step shifts in stock returns. It is more likely that we would see a step in stock values, but this corresponds to an impulse in returns. Indicator saturation (IIS and SIS), a flexible and robust break detection technique, is thus suitable for this task, as it does not require prior knowledge of the location of the breaks/outliers and does not impose a limit on the number of breaks/outliers that can be identified or the length of such breaks. Breaks/outliers can also be allowed to occur at the beginning or end of the sample. This is an advantage over techniques that do not accommodate breaks/outliers at the start or end of the sample. To overcome the identification problem that is often attributable to insufficient observations (because of dates too near the start or the end of the sample), these techniques often recommend trimming the sample by 15 percent on either side (Andrews 1993).

We consider an augmented market model of the following form under the null of no outliers:

$$r_{sct} = \beta_0 + \beta_1' x_t + u_t \qquad (2)$$

where u_t is a random error term with zero mean and variance δ_u^2 and x_t is a vector of conditioning variables that include the market return (r_{mt}).[8] r_{sct} is the difference between the performance of renewables (proxied by the MAC Global Solar Energy Index) and the performance of coal (proxied by the Stowe Global Coal Index)—in other words, the difference in returns ($r_{st} - r_{ct}$) for these two sectors where r_{st} is the index return for solar at time *t* and r_{ct} is the index return for coal at time *t*. r_{sct} can be interpreted as an index of climate (or conversely, coal) sensitivity. We are thus using the fact that the timing of the shocks is expected to coincide, but the signs are opposite. By looking at the difference in stock returns, we create a more sensitive indicator of policy and maximize the chance of finding some evidence. In addition, given that we are working with daily data, taking the difference in stock returns can help us obtain greater precision in the model estimation. As in Castle et al. (2015), we add a full set of impulse indicators to equation (2) to get

$$r_{sct} = \beta_0 + \beta_1' x_t + \sum_{j=1}^{T} \delta_j \, 1_{\{t=j\}} + u_t \qquad (3)$$

Equation (3) is analyzed using IIS to identify outliers. We use the *gets* package in R (Pretis et al. 2018; Sucarrat et al. 2018). On average, αT indicator variables are retained by chance for a significance level α and T observations. We set α very low at 0.001 and 0.0005. The period of analysis covers a total of $T = 503$ daily return observations from January 2015 to January 2017. Therefore, under the null hypothesis that no indicators are needed, 0.5 (or 0.25 with $\alpha = 0.0005$) of an indicator will be significant by chance on average.

[8] The error term is likely to be non-normal, heteroskedastic, and only a martingale difference sequence rather than an independent sequence. The simplest case is when the error term is assumed to be iid normal.

While there are several specifications of impulse indicators, Castle et al. (2015) argue that this should have little impact on the detection of impulses. With IIS, theory-based conditioning variables (x_t) can be retained without selection and the distribution of their estimates will be unaltered by selection over the orthogonalized set of candidates (Hendry and Johansen 2015). However, using IIS with additional conditioning variables means that we have more candidate variables than the number of observations. IIS therefore applies a general-to-specific selection over the impulse functions. Nonetheless, even with such a large number of potential regressors, only a few are retained for the analysis, demonstrating the power of IIS to control for the false positive rate using a low enough value of α. This, according to Castle et al. (2015), suggests that overfitting is not a major issue with IIS.

3. Market Effects of the Paris Agreement and the US Election

In this section, we first present results from the event study analysis. We then present and discuss the results for the Paris Agreement and the US 2016 election using the impulse-indicator saturation method. Last, we present some robustness tests.

3.1. Stock Market Reaction to the Paris Announcement

Table 4 (see Figure 3 for a plot of the cumulative average abnormal returns) shows the results for all the energy sectors studied and for different event windows. We find no statistically significant mean abnormal returns for fossil fuel industries on the Paris Agreement announcement day. When we look at solar energy, we find sizable and significant positive abnormal returns on the event day, and the significance of the cumulative average abnormal returns persists even as the event window is lengthened to include the entire period of negotiations. For coal, where we expect the strongest effect, we find no significant effect for the event day as well as the post announcement period. To capture ex ante reactions as a result of market expectations, we also include days prior to the announcement date in the calculation of the abnormal returns. We do find some significant cumulative average abnormal returns for fossil fuel stocks when we extend the event window to consider the preannouncement period. Contrary to our prior expectations, these effects are significantly larger for natural gas and oil compared to coal and more statistically significant for natural gas. An analysis of the cumulative average abnormal returns in Table 4 over the announcement and post announcement periods shows that they are largely indistinguishable from zero. These results are in line with the Bank of England results for a limited subsample of energy firms in France, Germany, the UK, and the United States (Batten et al. 2016).

To corroborate our results and deepen the analysis, we also look at various energy stock indices (Table 5). While we do not find any strong post announcement effects for a range of renewable and nonrenewable energy stocks except for solar energy, the Paris climate agreement if deemed credible and sufficiently ambitious, should depress coal stocks given coal's large contribution to carbon emissions (even compared with other fossil fuels).

We therefore repeat the analysis of the coal sector using country-level subsamples of coal stocks listed in all the major coal-producing countries. For this analysis, our sample includes firms that satisfy the following criteria: (a) is listed in one of the major markets and (b) is continuously traded over the sample period, has not filed for bankruptcy protection during this period, and has non-missing estimation period returns data for at least 100 trading days. Criterion *b* restricts the analysis to a sample in which bankruptcy or listing events have no influence on the results.[9] These criteria leave us with a sample of 140 companies in 14 different stock markets (Table 3). Most of these companies are constituents of major global coal stock indices and exchange-traded funds.

For most nations, the Paris accord has had no effect on domestic coal markets (Tables 6a and 6b). There is, however, a negative statistically significant effect in Australia and South Africa around announcement time as well as in Indonesia for the event window $[-10, +2]$ coinciding with the onset of the COP 21 climate negotiations in Paris. These three countries are among the biggest coal exporters in the world and probably their reliance on coal exports may expose them to other countries' climate policies that may affect future exports. India on the other hand is likely to respond differently. They are in per capita terms very small emitters of CO_2, and mainly use their own domestic coal. They probably do not feel Paris implies that they have to stop or reduce their emissions. Globally, the coal industry has been struggling because of a combination of deteriorating prices and weak demand (because of increased energy efficiency, slowing economic growth in major coal-consuming countries, and increasing environmental regulations). There has already been substantial disinvestment from coal, even in the absence of a global climate agreement. Companies operating in North America and Europe also face increasing pressure from falling natural gas prices. The Paris climate agreement comes at a time when the coal industry is in decline and has been for several years (see Figure 1).[10] Tightening environmental regulations (for example the mercury regulations in the US) have slowed future investments in coal while reducing the economic viability of existing ones. At the same time, increasing environmental awareness concerning global warming has led to a general preference for renewable energy. This coincides with the significant fall in the cost of solar energy in recent years largely

[9] Including firms that go bankrupt is not feasible in most cases because they have no market values. During the period of analysis, Patriot Coal Corp (May 12, 2015), Walter Energy Inc. (July 15, 2015), Alpha Natural Resources Inc. (August 3, 2015), Arch Coal Inc. (January 11, 2016) and Peabody Energy Corp (April 13, 2016) filed for Chapter 11 bankruptcy protection. Peabody Energy and Alpha Natural Resources were both valued at more than $10 billion at the time of filing for bankruptcy protection. Firms that later became bankrupt are included in the sample up to the point they filed for bankruptcy protection. We note that because of this exclusion, our methodology may understate how badly a given sector is faring. In Table 9b, as part of robustness tests, we include Peabody Energy Corporation, which filed for Chapter 11 bankruptcy protection in April 2016 but continued trading on the over-the-counter markets. Indeed, it appears that it is more of an outlier compared with how other firms responded to the US election.

[10] See Kolstad (2017) for a brief on the reasons behind the decline of the US coal industry.

driven by technological change (see Kåberger 2018; Wagner et al. 2015). It is against this background that we should interpret the lack of further, statistically significant, negative effects of the accord itself.

The observed results for the coal industry however remain a puzzle. There are several reasons why we would expect a significant reaction from coal. First, coal emits more carbon per unit of energy and we would therefore expect significant stranding of coal assets because of credible and sufficiently ambitious climate policy. Second, the rents from coal are small compared with oil, which has large rents due to very low extraction costs and market power. Policies to subsidize renewable energy or introduce a carbon tax can therefore easily eliminate coal rents and lead to the substitution of coal by cleaner energy. Indeed, the discovery of coal resources does not make countries rich in the same way as oil discoveries. By contrast, the marginal cost of oil extraction is generally so low that a carbon tax cannot completely erode rents. Even with an oil price below $40/barrel in 2015, oil-exporting countries continued to bring more oil to the market. Many oil producers actually welcomed the Paris climate agreement. One interpretation of this is that they understand that climate policy will be more detrimental to coal while they may even benefit (see Coulomb and Henriet 2018; Michielsen 2014). Oil producers may also want the predictability that comes with a climate agreement. Third, the coal market unlike solar, wind and alternative energy markets is largely geographical with most coal used close to source. Therefore, firms may fail to react to a global climate agreement like Paris reacting more instead to changes in country-level operating conditions.

The significance of carbon emissions from coal have meant that global efforts to address climate change have largely focused on reducing reliance on coal. In addition, the remaining coal reserves are sizable compared with oil reserves. Proven coal reserves can last up to 150 years at current extraction rates (BP 2017). If exploited, this would result in significant carbon emissions. Bauer et al. (2016) present evidence showing that any ambitious climate target will have a drastic impact on coal, resulting in a large part of the reserve remaining unused.[11] The fact that we do not find major effects on coal stocks might be interpreted as meaning that investors either predicted the Paris Agreement or doubt its credibility. Indeed, investor skepticism regarding the practicality of scaling back fossil fuel demand within an economically meaningful horizon might contribute to a weak market response (Griffin et al. 2015).

[11] A related idea is that of unburnable carbon and stranded assets, defined as assets that cannot maintain their value or that turn into liabilities well ahead of the end of their expected economic life (see Carbon Tracker Initiative 2013; Griffin et al. 2015; Leaton 2012).

In interpreting our results, there are two key concepts: *surprising* and *strong*. It is only when both of these apply simultaneously that we expect to see a strong reaction in the fossil fuel markets on any particular day.[12] Our detailed media content analysis of 200 *Financial Times* articles collected from Factiva using the search strings "Paris" and "climate" and published between October 1 and December 31, 2015, turned up only four articles which framed the announcement of the Paris Agreement as surprising (see Technical Appendix for details). The results from the expert survey of environmental and resource economists at the 6th WCERE shows that the Paris Agreement was a surprise to about 28% of the surveyed experts and one might therefore conclude the agreement was anticipated to a greater degree (see Technical Appendix for details). Given that we do not find strong support for the surprise here, we attribute the surprise in other media to the agreement perhaps exceeding expectations, at least when it comes to its ambitions and given that previous climate change negotiations failed to achieve any common ground. Nevertheless, surprise alone is not sufficient; the agreement needs to be strong—that is, it should provide solutions for anthropogenic climate change. However, current commitments in the INDCs on which the Paris climate agreement is anchored are not consistent with temperature increases below the 2°C and 1.5°C stipulated in the agreement.[13]

Given that these commitments were public knowledge leading up to the Paris climate agreement, markets might already have formed expectations in anticipation of an agreement based on the INDCs. In the presence of partial anticipation by investors, Malatesta and Thompson (1985) argue that the standard event study approach may underestimate the abnormal stock returns, because the announcement of the event only captures the change in the firm's value due to the resolution of the uncertainty regarding the timing of the event. Indeed, this uncertainty has been significant when it comes to climate change negotiations because, despite huge expectations, previous COP meetings, such as COP 15 in Copenhagen, failed to deliver a global climate agreement. We have tried to incorporate this aspect by considering a longer event window for the analysis of the Paris climate agreement. The best way to cast light on the role of surprise is to look at an event that really was unexpected and therefore, in the next section, we present results from an analysis of the US election—an outcome largely unexpected and crucial for global climate policy.

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[12] It can be said that it is necessary but not sufficient that the announcement of the agreement be *surprising* for markets to react in the first place. For a large reaction to be realized, the agreement has to be *strong* as well.

[13] The shortcomings of voluntary contributions toward optimal provision of a public good have been studied elsewhere in the literature (see Marwell and Ames 1981). We do not necessarily mean, in this context, to be disparaging concerning the power of the bottom-up approach. The optimists will argue that this was the best approach available and that the political dynamics created will eventually lead to new rounds of ratcheting up the commitments.

3.2. Stock Market Reaction to the US Election

The US climate change debate has been characterized by a lack of political consensus (see Brenan and Saad 2018). The disagreements in the US climate debate have been intense. Politicians such as President Trump and many other Republicans are significantly more aligned with coal (and other fossil) industry interests than are their Democratic counterparts. The 2016 presidential election produced a result that was not expected by opinion polls or prediction markets (see Figure 2) and therefore presents us with a perfect case where there is a strong element of surprise as well as an unambiguous event in favor of fossil fuels.[14] Again, we note that globally, fossil fuels do not appear to have benefited from the election of Trump (Table 7 columns 1 through 3 and Table 8 columns 1 and 2), despite his express desire to promote fossil industries such as coal. We could interpret this as indicating the United States' limited power to influence global climate policies. Alternatively we can interpret Trump's policy as favoring mainly the production and consumption of coal in the United States rather than favoring the production and use of coal internationally. This would lead to a positive reaction mainly among US coal companies. Our results do suggest that a change in US climate policy in favor of its domestic fossil fuel industry in response to the Paris Agreement might indirectly hurt coal companies in *other* countries.

We do, however, see that renewables and clean energy experienced statistically significant negative abnormal returns on the announcement day (Table 7 columns 4 through 6 and Table 8 columns 3 and 4). These results persist even as the event window is extended to include five days post announcement. The observed negative (positive) reaction by renewable stocks to the US election (Paris Agreement) demonstrate two key points: (a) the renewable energy sector is more global than the fossil industry (especially coal and natural gas) and therefore responds more to global events.[15] (b) The reliance of the renewable energy sector on state support makes it more responsive to political events associated with changes in governments or global climate policy. The small size of the renewables sector also means that any given change in capacity will be a much bigger percentage change than what is observed in the coal sector. From the ongoing analysis, our results seem to provide support for the hypothesis that globally the Paris Agreement (Trump election) is good

[14] As late as Election Day, a *New York Times* feature reviewed polling data and gave Mr. Trump a 15 percent chance of winning (Katz 2016).

[15] As noted earlier on, the oil sector firms possesses significant market power that may affect how it responds to the events under consideration.

(bad) for renewables. However, we find little support at the global level for the hypothesis that the Paris Agreement (Trump election) is bad (good) for coal.

At the country level, the election of Donald Trump as the 45th US president benefited US coal companies (Tables 9b and 9c). We also report significant positive abnormal returns for South Africa, Thailand and Indonesia (at the 10% level of significance) around the announcement of the US election results (Table 9a). All three countries are coal exporters and might benefit from a more positive policy at least on the *use* of coal (policies that encourage US *production* of coal would actually have the opposite effect for competitors). Results in Table 9a (and 6a) show that not all firms operating in significant coal exporting countries (e.g. Poland and Russia) reacted significantly to the US election (and the Paris Agreement).

The country-level results presented in Tables 6a and b and 9a and b lend support to the hypothesis that the Paris Agreement (Trump election) has a heterogeneous effect across countries. Firms operating in coal exporting countries significantly reacted to the Paris Agreement and the Trump election, but we find no significant reaction if the operating country is a coal importer. The degree of commitment to tackling climate change matters less. However, being a coal exporter within a region with already existing ambitious climate targets such as the EU appear to mute firm reaction to the events under consideration.

3.3. Identifying Crucial Dates

The method employed so far has involved looking for an effect on stock prices at a given date. There is a methodological risk in this approach since we pre-specify the date and do not know if there are many other dates with significant positive or negative movements. A stronger empirical approach involves conducting the analysis within a unified framework that seeks to combine the analysis of both the Paris meeting and the election without imposing the events a priori. In Table 10, we present results for several specifications using the IIS method. IIS helps us to identify and control for significant events not identified a priori from theory. Specification I is an augmented market model that includes a dummy variable *Paris* equal to 1 on the day the Paris climate agreement was announced and 0 otherwise. The variable *US Election* is equal to 1 on the day the 2016 US presidential election results were announced. From specification I, we note that both the dummy variables' coefficients are statistically significant and show a strong positive reaction by US coal stocks. Using IIS, five additional dates are picked up in specification I and when an autoregressive term is added in specification II, we can detect up to four of these additional impulses. In specifications III and IV, we allow IIS to detect the relevant events on its own (i.e., no variables are retained in the model without selection). Again, using our index of climate sensitivity, the two most important climate-related political events during the two-year period are retained—namely, the Paris climate agreement and the US election. Specification V is similar to IV, but selection is carried out at an even tighter level of significance ($\alpha = 0.0005$). All the previously retained dates are picked up in this last specification except March 4, 2015. Through the above empirical model discovery exercise, IIS allows us to learn from the data. While embedding theory in a broader model can result in chance retention of some residuals from selection, this should not be a major issue, provided one chooses a reasonably low level of significance for selection. In our case, we set $\alpha = 0.001$ and 0.0005. This gives us a fairly negligible number of false positives.

From Table 10, the most striking result is the robustness of our estimates. All specifications tested show a similar pattern, with a positive shock from Paris and a negative shock from the US election for the difference between renewables and coal stock indices. Using IIS, we find the Paris Agreement and the US election to be equally important among a set of other things.

IIS identifies a number of dates, all in 2015, when our simple index of climate compatibility picks up significant impacts. We find positive impacts on March 4 and 5, 2015, as well as December 16, 2015 (Figure 4 and Table 10). On May 20 and June 19, 2015, there was an impact of the opposite sign—good for coal or bad for renewables (Figure 4 and Table 10). We have searched systematically for explanations by reading the relevant news telegrams from a news service, Retriever,[16] using the search words "climate," "renewables," "coal," and "solar." These searches returned a fairly large number of news articles, but we know that we are looking for large and unexpected events of international significance.

As a start, we note the absence of some dates considered significant, such as ratification by various countries or the Paris climate agreement's entry into force on November 4, 2016. These are not detected by IIS. Given that the Paris climate agreement was unanimous, one might argue that ratification was anticipated. Evidence from the history of international climate agreements such as the 1997 Kyoto Protocol suggests that ratification almost always follows the signing of the agreements.

We turn now to the dates identified by IIS. For March 4 and 5, 2015, we find several interesting and quite plausible news items that could be contributing elements. The most striking of these is that the Chinese government released plans for further restricting its consumption of coal. At the opening session of the National People's Congress, Premier Li Keqiang said Beijing would move forward with a proposal to reduce energy intensity and hold down coal consumption growth in "key areas" (Yap 2015). This news is also

[16] http://web.retriever-info.com.

corroborated by other news on the same day, in which the National Development and Reform Commission of China announced, in its just published annual report, that it would implement policies aimed at further promoting solar and wind investments, reducing coal consumption, and controlling the number of energy-intensive projects in polluted regions (Aizhu et al. 2015; Green 2015). On March 5, 2015, Bloomberg also reported that energy storage in the United States would more than triple in 2015 as regulators allowed use of the technology by utilities and homeowners. Analysts were quoted as saying that this would strengthen Tesla, with its Gigafactory for batteries that can store solar energy from day to night.

For December 16, 2015, the other date with an impact that was positive for solar and negative for coal, we found news articles on how global temperatures are at a record high, as well as articles on solar energy, but nothing that was obviously of a magnitude that sticks out as an important factor. Considering the proximity to the Paris Agreement, the impact we see might be a delayed result of the negotiations. We note that this date is not picked up in the models that allow for autoregressive terms.

We find quite strong evidence of concern for the climate on May 20. President Hollande gave an important speech at UNESCO voicing concern for how difficult the Paris negotiations would be and how urgent the process was (AFP 2015). On the same day, big losses were reported for two large solar panel producers in Hong Kong (The Telegraph 2015). On June 19, negative returns for renewables using our indicator of climate sensitivity could be explained by several pieces of bad news for wind power in the UK, including large protests against investments and news of important reductions in UK subsidies (The Scotman 2015).

3.4. Additional Robustness Tests

In this section, we present additional robustness tests. So far we have shown that our results are robust when the event dates are not imposed a priori. To demonstrate our findings are not influenced by model choice, we also analyze raw returns in which expected returns are set to zero. We find broadly similar results to those estimated using the market model thus demonstrating that our findings do not depend on the choice of the underlying model for expected returns. In addition, we also estimate abnormal returns using a market model with a GARCH(1,1) error process to estimate the normal return. (The results are presented in the Online Appendix.) We show that our results are essentially unchanged in all cases.

4. Conclusions

This paper presents some evidence of the reaction of stock markets in the energy sector to the announcement of the Paris climate agreement, the US 2016 presidential election, and other climate-related political events. If the Paris Agreement is good for the climate, then we would expect significant negative (positive) abnormal returns for the fossil industry (renewable energy) stocks across the major markets on the announcement date. We find significant effects for renewable stocks but only moderate effects for the fossil stocks in comparison with the acclaimed importance of the Paris accord. The lack of a stronger reaction for the fossil fuel sectors might be due to the agreement being either anticipated or considered weak by investors in this sector. It suggests that the concern for stranded assets is somewhat exaggerated. It seems that the sensitivity of stock value in these sectors to climate policy is moderate.

Turning to the results of the US presidential election, we know that we have an event that is unexpected and positive (negative) for coal and other fossil fuels (renewables). With carefully designed methods, we are able to find some results, particularly for renewables, but again, they are moderate and perhaps smaller than expected—particularly for coal. In this case, a careful analysis is required to evaluate competing explanations.

Thanks to the IIS technique, we were able to confirm that the Paris and US Election dates are indeed significant and we also found some additional dates including notably that an important event—the Chinese decision to reduce coal—had important effects on global energy markets. The lack of a stronger reaction by global coal markets to Paris and the US Election may be a sign that major events have somewhat less importance than generally believed in the media. One possible interpretation is that underlying fundamentals are most important, such as technological developments that have systematically been making renewables and natural gas cheaper in relation to coal over the past decades (see Kåberger 2018; Wagner et al. 2015). A natural conclusion then, for both media and policymakers is to turn more of their attention to long-run changes in technology and maybe other parameters such as tastes or resource availability. As for Paris, the world might not consider it so very important or not so very surprising—hence it may largely have been discounted. As for the Trump election we do think there is strong evidence it was unexpected—but it may have less importance than generally thought compared to the long run factors mentioned.

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Tables and Figures

Table 1. Timeline of Paris Agreement and Recent Climate Policy Events

Date	Event
December 12, 2014	COP 20 in Lima ends
March 31, 2015	Countries start submitting INDCs
June 1, 2015	Europe's six largest oil and gas companies write an open letter in support of carbon pricing
October 1, 2015	Deadline for submitting INDCs
November 30, 2015	Climate negotiations start in Paris (COP 21)
December 12, 2015	Agreement reached by 195 countries
April 22, 2016	Paris Agreement opened for signature on Earth Day
April 22, 2016	15 countries submit their instruments of ratification
September 3, 2016	United States and China ratify
September 21, 2016	55 countries ratify the agreement (first threshold passed)
October 2, 2016	India ratifies
October 5, 2016	EU ratifies (second threshold passed)
November 4, 2016	Agreement enters into force
November 7, 2016	COP 22 begins in Marrakech
November 8, 2016	Donald Trump elected US president
December 8, 2016	Scott Pruitt officially nominated to lead the Environmental Protection Agency
June 1, 2017	President Trump announces intention to withdraw from Paris Agreement

Table 2. Descriptive Statistics for Exchange-Traded Funds

	Number of ETFs	Average # of stocks	Mean ETF size (millions US$)	Average # of countries
Natural gas	4	51	94	3
Coal	1	31	102	12
Oil	4	57	325	3
Nuclear energy	1	51	34	9
Clean and alternative energy	7	47	61	12
Solar energy	2	31	89	9
Wind energy	1	46	75	17

Note: These are the equity-based exchange-traded funds (ETFs) that form our global sample. Our clean and alternative energy subsample is made up of firms involved in conservation, energy efficiency, and advancing renewable energy. This includes developers, distributors, and installers in one of the following: advanced materials that enable clean energy or reduce the need for petroleum products; energy intelligence, storage and conversion; or renewable electricity generation (e.g., solar, wind, geothermal). The remaining subsamples comprise companies involved in direct operations (production, mining, and drilling), transportation, production of mining or drilling equipment, and provision of energy as a final output. For a firm to be included in an ETF, these activities should account for a large proportion of the firm's revenues and assets. Column 1 lists the average number of stocks in each of the ETF subsamples. Column 4 shows the average number of countries covered by the different ETFs in each energy sector.

Table 3. Descriptive Statistics for Coal Stocks by Country

Number	Country	Number of Stocks	Mean firm size (millions US$)
1	China	52	
	Shanghai	24	4,717
	Hong Kong	21	172
	Shenzhen	7	1,972
2	Australia	24	4,945
3	Indonesia	17	1,184
4	United States	15	1,170
5	South Africa	9	3,646
6	India	5	5,912
7	Thailand	5	707
8	Japan	4	142
9	Russia	4	394
10	Philippines	3	1,150
11	Poland	2	1,443

Table 4. Effects of Paris Climate Agreement on Energy Sector Using ETFs

	Coal	Oil	Natural gas	Solar	Wind	Alternative energy	Nuclear
$CAAR_{-2,0}$	–4.23%	–1.74%	–3.86%	3.63%	–1.14%	–0.22%	–1.37%
	(–2.01)**	(–0.61)	(–1.23)	(1.20)	(–0.75)	(–0.18)	(–1.01)
$CAAR_{-1,0}$	–3.09%	–2.55%	–4.91%	3.74%	–0.26%	0.55%	–0.56%
	(–1.80)*	(–1.10)	(–1.92)*	(1.51)	(–0.21)	(0.54)	(–0.51)
$CAAR_{0,0}$	–1.48%	–0.39%	–2.13%	4.45%	0.79%	0.76%	–0.55%
	(–1.22)	(–0.24)	(–1.18)	(2.55)**	(0.90)	(1.04)	(–0.70)
$CAAR_{0,+1}$	–1.88%	1.74%	–0.82%	7.06%	0.39%	1.28%	0.34%
	(–1.10)	(0.75)	(–0.32)	(2.86)***	(0.32)	(1.24)	(0.31)
$CAAR_{0,+2}$	–0.35%	–1.90%	–4.68%	12.91%	2.15%	4.20%	1.10%
	(–0.17)	(–0.67)	(–1.49)	(4.26)***	(1.41)	(3.31)***	(0.81)
$CAAR_{-1,+1}$	–3.49%	–0.42%	–3.60%	6.35%	–0.66%	1.08%	0.33%
	(–1.66)*	(–0.15)	(–1.15)	(2.10)**	(–0.43)	(0.85)	(0.24)
$CAAR_{-2,+2}$	–3.10%	–3.26%	–6.42%	12.09%	0.22%	3.22%	0.28%
	(–1.14)	(–0.89)	(–1.59)	(3.10)***	(0.11)	(1.97)**	(0.16)
$CAAR_{-10,+2}$	–8.36%	–11.20%	–15.80%	18.01%	1.94%	4.74%	0.79%
	(–1.91)*	(–1.89)*	(–2.42)**	(2.86)***	(0.61)	(1.79)*	(0.28)
Number of ETFs	1	4	3	2	1	7	1

Note: This table reports cumulative average abnormal returns (CAARs) for renewable and nonrenewable energy ETF subsamples for the Paris climate agreement announcement. The market model is estimated using ordinary least squares (OLS), and the market index is the S&P 500. The estimation period includes trading days –235 to –11 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as December 14, 2015, the first day markets opened following the announcement of the Paris climate agreement on Saturday, December 12, 2015. Portfolio time-series t-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Some of our ETFs are short ETFs which means that they move in the opposite direction from the index they track and seek to deliver results that correspond to the inverse of the index they track on a daily basis. Before including them in the analysis, we reverse the sign of each estimation-period and event-period security return for the security event. After the sign reversal, we make no further distinction between short and long ETFs. The event study calculations thus proceed by treating the sample as an equally weighted portfolio of securities held long. The negative weights of shorted securities are implied by the sign reversal.

Table 5. Effects of Paris Climate Agreement on Energy Sector Using Energy Stock Indices

	Coal	Oil and gas	Solar	Alternative Energy
$CAAR_{-2,0}$	−3.06%	−0.50%	3.40%	−0.48%
	(−1.25)	(−0.28)	(1.20)	(−0.27)
$CAAR_{-1,0}$	−2.05%	−1.00%	4.11%	1.07%
	(−1.02)	(−0.67)	(1.77)*	(0.72)
$CAAR_{0,0}$	−1.97%	0.16%	3.92%	1.53%
	(−1.39)	(0.15)	(2.39)**	(1.46)
$CAAR_{0,+1}$	−2.77%	1.82%	5.51%	2.33%
	(−1.38)	(1.22)	(2.37)**	(1.57)
$CAAR_{0,+2}$	−1.44%	−0.35%	11.70%	5.84%
	(−0.59)	(−0.19)	(4.12)***	(3.21)***
$CAAR_{-1,+1}$	−2.84%	0.65%	5.70%	1.86%
	(−1.16)	(0.36)	(2.00)**	(1.02)
$CAAR_{-2,+2}$	−2.53%	−1.01%	11.18%	3.82%
	(−0.80)	(−0.43)	(3.05)***	(1.63)
$CAAR_{-10,+2}$	−7.47%	−6.74%	18.76%	6.09%
	(−1.46)	(−1.78)*	(3.17)***	(1.61)

Note: In this table, we corroborate our results in Table 4 by reporting the cumulative average abnormal returns (CAARs) for the widely followed global energy stock indices. Coal is made up of an equally weighted average of the two main coal stock indices, the Dow Jones US Coal Index (DJUSCL) and the Stowe Global Coal Index (COAL). Oil and gas is represented by the Dow Jones US Oil and Gas Index (DJUSEN). Solar is made up of two stock indices, the MAC Global Solar Energy Index (SUNIDX) and the Ardour Solar Energy Index (SOLRX). Alternative energy is represented by the S&P Global Clean Energy Index (SPGTCED). The market model is estimated using OLS, and the market index is the S&P 500. The estimation period includes trading days −235 to −11 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as December 14, 2015, the first day markets opened following the announcement of the Paris climate agreement on Saturday, December 12, 2015. Portfolio time-series t-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6a. Effects of Paris Climate Agreement on Coal Stocks in Other Countries

		China										
	Australia	Hong Kong	Shanghai	Shenzhen	India	Indonesia	Japan	Philippines	Poland	Russia	Thailand	South Africa
$CAAR_{-2,0}$	−3.87%	1.77%	1.53%	1.51%	5.37%	−2.08%	−0.33%	−3.24%	3.47%	0.24%	−2.43%	−3.25%
	(−1.23)	(0.37)	(0.57)	(0.46)	(1.69)*	(−1.27)	(−0.24)	(−0.96)	(0.71)	(0.07)	(−0.89)	(−1.03)
$CAAR_{-1,0}$	−3.41%	0.60%	1.32%	2.09%	5.17%	−0.24%	0.10%	−3.80%	2.03%	−0.44%	−0.14%	−5.81%
	(−1.32)	(0.15)	(0.60)	(0.77)	(1.99)**	(−0.18)	(0.09)	(−1.38)	(0.51)	(−0.16)	(−0.06)	(−2.26)**
$CAAR_{0,0}$	−2.55%	1.19%	0.63%	1.37%	2.81%	−0.04%	0.82%	−2.29%	1.79%	−0.28%	−1.25%	−3.68%
	(−1.40)	(0.43)	(0.40)	(0.72)	(1.53)	(−0.04)	(1.02)	(−1.18)	(0.63)	(−0.15)	(−0.79)	(−2.03)**
$CAAR_{0,+1}$	−5.94%	2.06%	−0.23%	0.02%	1.28%	1.09%	0.28%	−1.61%	−0.47%	−0.57%	−2.49%	−2.44%
	(−2.31)**	(0.53)	(−0.10)	(0.01)	(0.49)	(0.82)	(0.25)	(−0.58)	(−0.12)	(−0.21)	(−1.12)	(−0.95)
$CAAR_{0,+2}$	−5.19%	−2.45%	−0.39%	0.17%	−0.89%	−0.08%	−0.27%	−5.35%	−1.53%	−0.33%	−2.81%	2.86%
	(−1.65)*	(−0.51)	(−0.14)	(0.05)	(−0.28)	(−0.05)	(−0.20)	(−1.59)	(−0.31)	(−0.10)	(−1.03)	(0.91)
$CAAR_{-1,+1}$	−6.76%	1.47%	0.46%	0.75%	3.64%	0.89%	−0.44%	−3.11%	−0.22%	−0.73%	−1.39%	−4.57%
	(−2.14)**	(0.31)	(0.17)	(0.23)	(1.14)	(0.54)	(−0.31)	(−0.92)	(−0.05)	(−0.22)	(−0.51)	(−1.45)
$CAAR_{-2,+2}$	−6.39%	−1.91%	0.52%	0.31%	1.68%	−2.12%	−1.41%	−6.30%	0.14%	0.19%	−3.99%	3.30%
	(−1.57)	(−0.31)	(0.15)	(0.07)	(0.41)	(−1.01)	(−0.79)	(−1.45)	(0.02)	(0.04)	(−1.13)	(0.81)
$CAAR_{-10,+2}$	−9.63%	−5.24%	−2.27%	−1.08%	−0.33%	−7.37%	0.54%	−1.67%	−6.64%	−1.18%	−4.38%	−6.02%
	(−1.47)	(−0.52)	(−0.40)	(−0.16)	(−0.05)	(−2.17)**	(0.19)	(−0.24)	(−0.65)	(−0.17)	(−0.77)	(−0.92)
Number of stocks	23	21	22	7	5	16	4	3	2	4	5	9

Note: This table reports country-level cumulative average abnormal returns (CAARs) for the major coal-producing and coal-exporting countries. We make use of the Thomson Reuters Business Classification (TRBC) to construct our country-level subsamples, and we focus on primary quotes. The TRBC is a market-based classification system in which companies are assigned an industry based on the end market they serve rather than the products or services they offer. Market-based classification emphasizes the usage of a product rather than the materials used for the manufacturing process. The TRBC recognizes that the market served is a key determinant of firm performance and thus groups together firms that share similar market characteristics. The market model is estimated using OLS, and the market is proxied by the local market index. The estimation period includes trading days −235 to −11 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as December 14, 2015, the first day markets opened following the announcement of the Paris climate agreement on Saturday, December 12, 2015. Portfolio time-series t-statistics are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table 6b. Effects of Paris Climate Agreement on US Listed Coal Stocks

	United States		
	Full sample	NYSE	NASDAQ
$CAAR_{-2,0}$	−4.63%	−5.02%	−4.47%
	(−0.91)	(−0.98)	(−0.58)
$CAAR_{-1,0}$	−5.00%	−6.20%	−2.93%
	(−1.21)	(−1.49)	(−0.47)
$CAAR_{0,0}$	−3.76%	−5.06%	−1.30%
	(−1.28)	(−1.72)*	(−0.29)
$CAAR_{0,+1}$	−3.84%	−3.95%	−3.63%
	(−0.93)	(−0.95)	(−0.58)
$CAAR_{0,+2}$	−3.72%	−2.05%	−6.90%
	(−0.73)	(−0.40)	(−0.90)
$CAAR_{-1,+1}$	−5.09%	−5.09%	−5.26%
	(−1.00)	(−1.00)	(−0.69)
$CAAR_{-2,+2}$	−4.60%	−2.01%	−10.07%
	(−0.70)	(−0.31)	(−1.02)
$CAAR_{-10,+2}$	−14.39%	−11.79%	−20.26%
	(−1.36)	(−1.11)	(−1.27)
Number of stocks	15	10	5

Note: This table reports cumulative average abnormal returns (CAARs) for the US coal industry firms. The market model is estimated using OLS, and the market index is the S&P 500 Index for the NYSE subsample and Dow Jones Industrial Average for the NASDAQ sample. We use the S&P 500 for the full sample. The estimation period includes trading days –235 to –11 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as December 14, 2015, the first day markets opened following the announcement of the Paris climate agreement on Saturday, December 12, 2015. Portfolio time-series *t*-statistics are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table 7. Effects of US Election on Energy Sector Using Energy ETFs

	Coal	Oil	Natural gas	Solar	Wind	Alternative energy	Nuclear
$CAAR_{-5,-1}$	−2.81%	−1.79%	−3.49%	−1.33%	−2.88%	−0.76%	−1.43%
	(−0.83)	(−0.48)	(−0.44)	(−0.41)	(−1.52)	(−0.50)	− (0.92)
$CAAR_{0,0}$	0.45%	0.84%	1.02%	−6.44%	−4.38%	−2.83%	−4.49%
	(0.29)	(0.50)	(0.29)	(−4.48)***	(−5.17)***	(−4.18)***	(−6.41)***
$CAAR_{0,+1}$	−1.71%	0.98%	0.45%	−6.76%	−7.46%	−3.55%	−3.73%
	(−0.80)	(0.42)	(0.09)	(−3.33)***	(−6.23)***	(−3.71)***	(−3.77)***
$CAAR_{0,+2}$	−2.50%	−1.19%	−2.26%	−8.17%	−8.00%	−2.88%	−5.06%
	(−0.95)	(−0.41)	(−0.37)	(−3.28)***	(−5.46)***	(−2.46)**	(−4.17)***
$CAAR_{0,+5}$	−6.26%	1.93%	2.22%	−6.10%	−10.88%	−2.77%	−4.42%
	(−1.69)*	(0.47)	(0.26)	(−1.74)*	(−5.25)***	(−1.67)*	(−2.58)***
Number of ETFs	1	4	4	2	1	7	1

Note: This table reports cumulative average abnormal returns (CAARs) for the ETF subsamples for the US presidential election. The market model is estimated using OLS, and the market index is the S&P 500. The estimation period includes trading days −220 to −6 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series *t*-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Some of our ETFs are short ETFs which means that they move in the opposite direction from the index they track and seek to deliver results that correspond to the inverse of the index they track on a daily basis. Before including them in the analysis, we reverse the sign of each estimation-period and event-period security return for the security event. After the sign reversal, we make no further distinction between short and long ETFs. The event study calculations thus proceed by treating the sample as an equally weighted portfolio of securities held long. The negative weights of shorted securities are implied by the sign reversal.

Table 8. Effects of US Election on Energy Sector Using Energy Stock Indices

	Coal	Oil and gas	Solar	Alternative energy
$CAAR_{-5,-1}$	−0.39%	−1.08%	−1.26%	−2.35%
	(−0.11)	(−0.44)	(−0.40)	(−1.05)
$CAAR_{0,0}$	−0.42%	0.25%	−6.12%	−5.88%
	(−0.26)	(0.23)	(−4.33)***	(−5.87)***
$CAAR_{0,+1}$	1.92%	0.21%	−6.06%	−7.97%
	(0.84)	(0.14)	(−3.03)***	(−5.62)***
$CAAR_{0,+2}$	2.01%	−1.27%	−7.22%	−8.81%
	(0.72)	(−0.67)	(−2.95)***	(−5.08)***
$CAAR_{0,+5}$	−3.78%	0.23%	−7.04%	−9.16%
	(−0.96)	(0.09)	(−2.03)**	(−3.73)***

Note: In this table, we corroborate the results in Table 7 by reporting the cumulative average abnormal returns (CAARs) for the widely followed global energy stock indices. Coal is made up of an equally weighted average of the two main coal stock indices, the Dow Jones US Coal Index (DJUSCL) and the Stowe Global Coal Index (COAL). Oil and gas is represented by the Dow Jones US Oil and Gas Index (DJUSEN). For solar, we use two stock indices, the MAC Global Solar Energy Index (SUNIDX) and the Ardour Solar Energy Index (SOLRX). Alternative energy is represented by the S&P Global Clean Energy Index (SPGTCED). The market model is estimated using OLS, and the market index is the S&P 500. The estimation period includes trading days −220 to −6 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series *t*-statistics are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table 9a. Effects of US Election on Coal Stocks in Other Countries

	Australia[a]	China: Hong Kong	China: Shanghai	China: Shenzhen	India	Indonesia	Japan	Philippines	Poland	Russia	Thailand	South Africa
$CAAR_{-5,-1}$	−2.65%	−1.36%	0.17%	−0.52%	−3.20%	6.70%	−1.48%	0.19%	0.77%	−1.01%	1.16%	−1.37%
	(−0.79)	(−0.37)	(0.06)	(−0.12)	(−0.93)	(1.53)	(−0.629)	(0.04)	(0.12)	(−0.25)	(0.34)	(−0.39)
$CAAR_{0,0}$	−4.34%	−0.63%	1.20%	1.39%	1.68%	0.48%	−0.47%	−0.22%	−1.42%	−0.52%	3.58%	1.52%
	(−2.88)***	(−0.38)	(0.90)	(0.71)	(1.10)	(0.25)	(−0.443)	(−0.10)	(−0.49)	(−0.29)	(2.34)**	(0.96)
$CAAR_{0,+1}$	−1.39%	0.71%	−0.05%	0.52%	1.50%	4.66%	0.04%	2.18%	2.55%	1.42%	3.39%	4.64%
	(−0.65)	(0.30)	(−0.03)	(0.19)	(0.69)	(1.69)*	(0.028)	(0.71)	(0.62)	(0.55)	(1.56)	(2.08)**
$CAAR_{0,+2}$	−0.73%	1.56%	1.19%	3.78%	2.43%	6.16%	−1.24%	3.12%	4.33%	2.15%	4.05%	6.46%
	(−0.28)	(0.54)	(0.52)	(1.12)	(0.91)	(1.82)*	(−0.681)	(0.83)	(0.86)	(0.68)	(1.53)	(2.37)**
$CAAR_{0,+5}$	−3.51%	1.80%	0.64%	4.38%	−3.55%	0.46%	0.16%	3.88%	4.54%	3.20%	0.18%	1.56%
	(−0.95)	(0.44)	(0.20)	(0.92)	(−0.94)	(0.10)	(0.063)	(0.73)	(0.64)	(0.72)	(0.05)	(0.41)
Number of stocks	24	20	23	5	4	15	4	3	2	4	5	8

Note: This table reports country-level cumulative average abnormal returns (CAARs) for the major coal-producing and coal-exporting countries. The market model is estimated using OLS, and the market is proxied by the local market index. The estimation period includes trading days −220 to −6 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series t-statistics are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

[a] On November 9, 2016, the Queensland Parliament passed the Environmental Protection (Underground Water Management) and Other Legislation Amendment Act, which seeks to tighten groundwater license requirements for mines.

Table 9b. Effects of US Election on US Listed Coal Stocks

	United States				
	Full sample		NYSE		NASDAQ
	I	II[a]	III	IV[a]	V
$CAAR_{-5,-1}$	−2.84%	−2.91%	−3.50%	−3.69%	−1.36%
	(−0.51)	(−0.57)	(−0.54)	(−0.65)	(−0.27)
$CAAR_{0,0}$	10.74%	7.72%	10.07%	5.46%	12.24%
	(4.30)***	(3.39)***	(3.48)***	(2.15)**	(5.41)***
$CAAR_{0,+1}$	11.92%	7.82%	11.28%	5.05%	13.36%
	(3.38)***	(2.43)**	(2.75)***	(1.41)	(4.17)***
$CAAR_{0,+2}$	12.17%	9.47%	10.44%	6.17%	16.07%
	(2.82)***	(2.40)**	(2.08)**	(1.40)	(4.10)***
$CAAR_{0,+5}$	10.03%	6.42%	9.83%	4.39%	10.48%
	(1.64)	(1.15)	(1.39)	(0.71)	(1.89)*
Number of stocks	13	12	9	8	4

Note: This table reports cumulative average abnormal returns (CAARs) for the US coal industry firms. The market model is estimated using OLS, and the market index is the S&P 500 Index for the NYSE subsample and Dow Jones Industrial Average for the NASDAQ subsample. We use the S&P 500 Index for the full sample. The estimation period includes trading days −220 to −6 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series *t*-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[a] Columns II and IV represent results excluding Peabody Energy, which filed for Chapter 11 bankruptcy protection in April 2016 but whose stocks continued trading on the over-the-counter market. Its stock price increased by 50% on the announcement of the 2016 US presidential election results. We feel it is more of an outlier than the norm for US listed coal stocks, and our results show a much higher abnormal return when it is included in the sample.

Table 9c. Effects of US Election on US Listed Coal Stocks (Mean Abnormal Returns)

	United States				
	Full sample		NYSE		NASDAQ
	I	II[a]	III	IV[a]	V
−5	−0.91%	−0.88%	−0.94%	−0.90%	−0.83%
	(−0.36)	(−0.39)	(−0.33)	(−0.35)	(−0.37)
−4	1.96%	2.00%	2.23%	2.33%	1.33%
	(0.78)	(0.88)	(0.77)	(0.92)	(0.59)
−3	0.80%	0.88%	−0.16%	−0.15%	2.95%
	(0.32)	(0.39)	(−0.05)	(−0.06)	(1.30)
−2	−3.62%	−3.99%	−3.15%	−3.66%	−4.66%
	(−1.45)	(−1.75)*	(−1.09)	(−1.44)	(−2.06)**
−1	−1.07%	−0.92%	−1.48%	−1.31%	−0.15%
	(−0.43)	(−0.41)	(−0.51)	(−0.52)	(−0.07)
0	10.74%	7.72%	10.07%	5.46%	12.24%
	(4.30)***	(3.39)***	(3.48)***	(2.15)*	(5.41)***
+1	1.18%	0.10%	1.21%	−0.41%	1.12%
	(0.47)	(0.04)	(0.42)	(−0.16)	(0.49)
+2	0.25%	1.65%	−0.84%	1.12%	2.71%
	(0.10)	(0.73)	(−0.29)	(0.44)	(1.20)
+3	2.28%	1.55%	3.01%	2.01%	0.63%
	(0.91)	(0.68)	(1.04)	(0.79)	(0.28)
+4	−3.77%	−3.96%	−2.88%	−3.06%	−5.78%
	(−1.51)	(−1.74)*	(−0.99)	(−1.20)	(−2.55)**
+5	−0.65%	−0.64%	−0.75%	−0.74%	−0.44%
	(−0.26)	(−0.28)	(−0.26)	(−0.29)	(−0.20)
Number of stocks	13	12	9	8	4

Note: This table reports mean abnormal returns for the US coal industry firms. The market model is estimated using OLS, and the market index is the S&P 500 Index for the NYSE subsample and Dow Jones Industrial Average for the NASDAQ subsample. We use the S&P 500 for the full sample. The estimation period includes trading days –220 to –6 relative to the event. The null hypothesis is that the mean abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series t-statistics are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.
[a] Columns II and IV represent results excluding Peabody Energy.

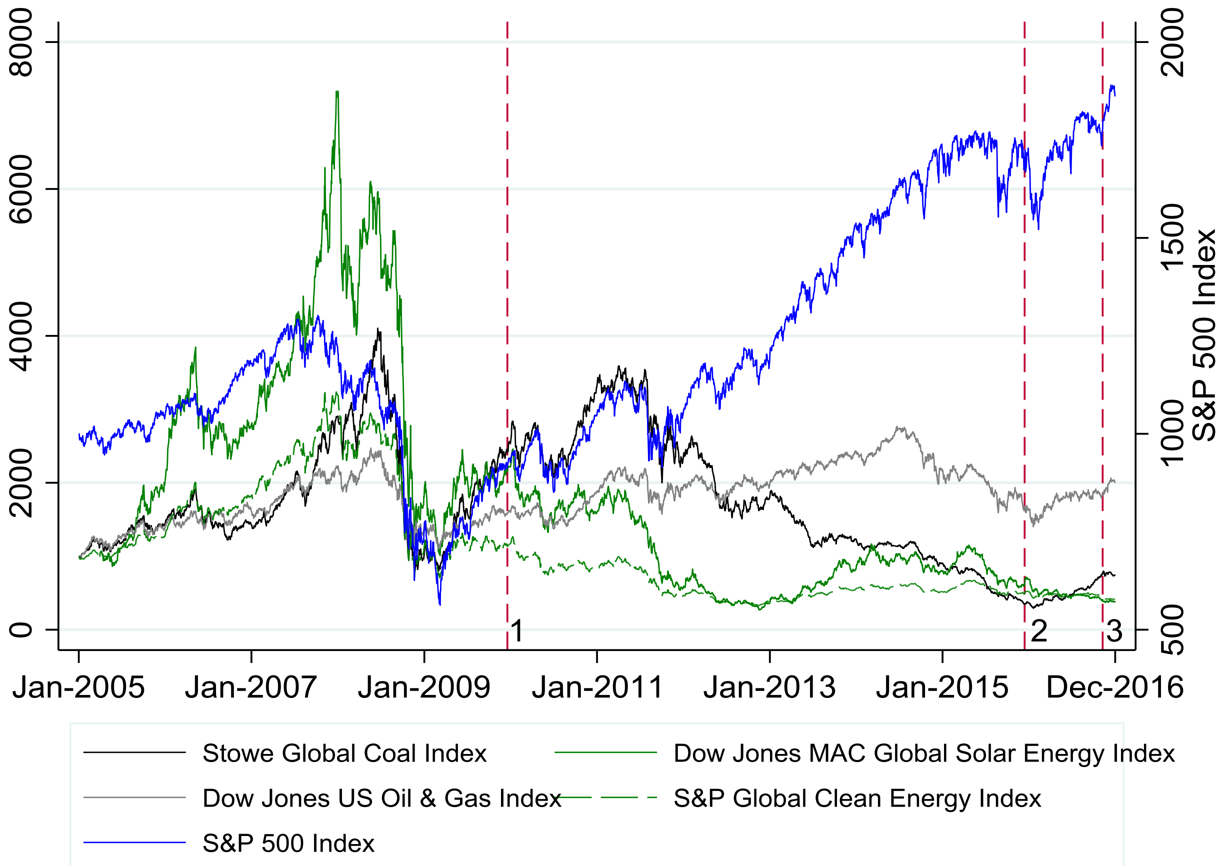
Table 10. Output from Impulse-Indicator Saturation to Detect Relevant Climate-Related Political and Market Events between January 2015 and 2017

	I	II	III	IV	V
Market returns	0.3123***	0.3194***	0.3332***	0.3194***	0.3116***
	(0.0837)	(0.0840)	(0.0844)	(0.0840)	(0.0850)
Paris	0.0668***	0.0664***	0.0666***	0.0664***	0.0663***
	(0.0169)	(0.0169)	(0.0171)	(0.0169)	(0.0171)
US election	−0.0611***	−0.0635***	−0.0615***	−0.0635***	−0.0637***
	(0.0169)	(0.0169)	(0.0171)	(0.0169)	(0.0171)
$r_{\mathrm{sc(t-1)}}$		0.1419***		0.1419***	0.1528***
		(0.0412)		(0.0412)	(0.0416)
March 4, 2015	0.0648***	0.0604***	0.0648***	0.0604***	
	(0.0169)	(0.0170)	(0.0171)	(0.0170)	
March 5, 2015	0.0736***	0.0644***	0.0734***	0.0644***	0.0636***
	(0.0169)	(0.0171)	(0.0171)	(0.0171)	(0.0173)
May 20, 2015	−0.0628***	−0.0634***	−0.0629***	−0.0634***	−0.0636***
	(0.0169)	(0.0169)	(0.0171)	(0.0169)	(0.0171)
June 19, 2015	−0.0597***	−0.0619***	−0.0597***	−0.0619***	−0.0622***
	(0.0169)	(0.0169)	(0.0171)	(0.0169)	(0.0171)
December 16, 2015	0.0596***				
	(0.0169)				
Constant	−0.0013*	−0.0010	−0.0012	−0.0010	−0.0009
	(0.0008)	(0.0008)	(0.0008)	(0.0008)	(0.0008)
Ljung-Box AR(2)	11.5635	0.2920	13.2523	0.2920	0.3335
	[0.0007]	[0.8642]	[0.0003]	[0.8642]	[0.8464]
Ljung-Box ARCH(1)	0.5828	0.0365	0.7776	0.0365	0.0114
	[0.4452]	[0.8484]	[0.3779]	[0.8484]	[0.9148]
Jarque-Bera	7.5473	7.9635	7.9783	7.9635	9.4766
	[0.0230]	[0.0187]	[0.0185]	[0.0187]	[0.0088]
Log-likelihood	1,344.38	1,340.95	1,338.15	1,340.95	1,334.58

Note: This table presents results from several specifications using IIS. Specifications I and II include two additional regressors, Paris and US Election, retained without selection in addition to the market returns. The dummy variable Paris equals 1 on the day the Paris Agreement was announced and 0 otherwise. The variable US Election equals 1 on the day the 2016 US presidential election results were announced and 0 otherwise. Specification II adds some dynamics to I by allowing for an autoregressive term. In specification III, no outliers are imposed on the model in advance and no autoregressive term is included, while specification IV includes an additional autoregressive term not included in III. Selection in specifications I–IV is carried out at the significance level $\alpha = 0.001$. Specification V is similar to IV, but selection is carried out at a very tight significance level, $\alpha = 0.0005$. All the selected regressors in specifications I–IV are retained without selection in specification VI except the date March 4, 2015. The dependent variable used is the stock return differential between solar and coal. The AR and ARCH tests are Ljung and Box (1978) tests of the standardized residuals. The diagnostics suggests the residuals are uncorrelated and homoscedastic for all our specifications that include some dynamics. The number in parenthesis indicates the lag at which the tests are conducted. Standard errors are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

† *p*-values in square brackets.

Figure 1. Energy Stock Indices vs. Global Benchmarks

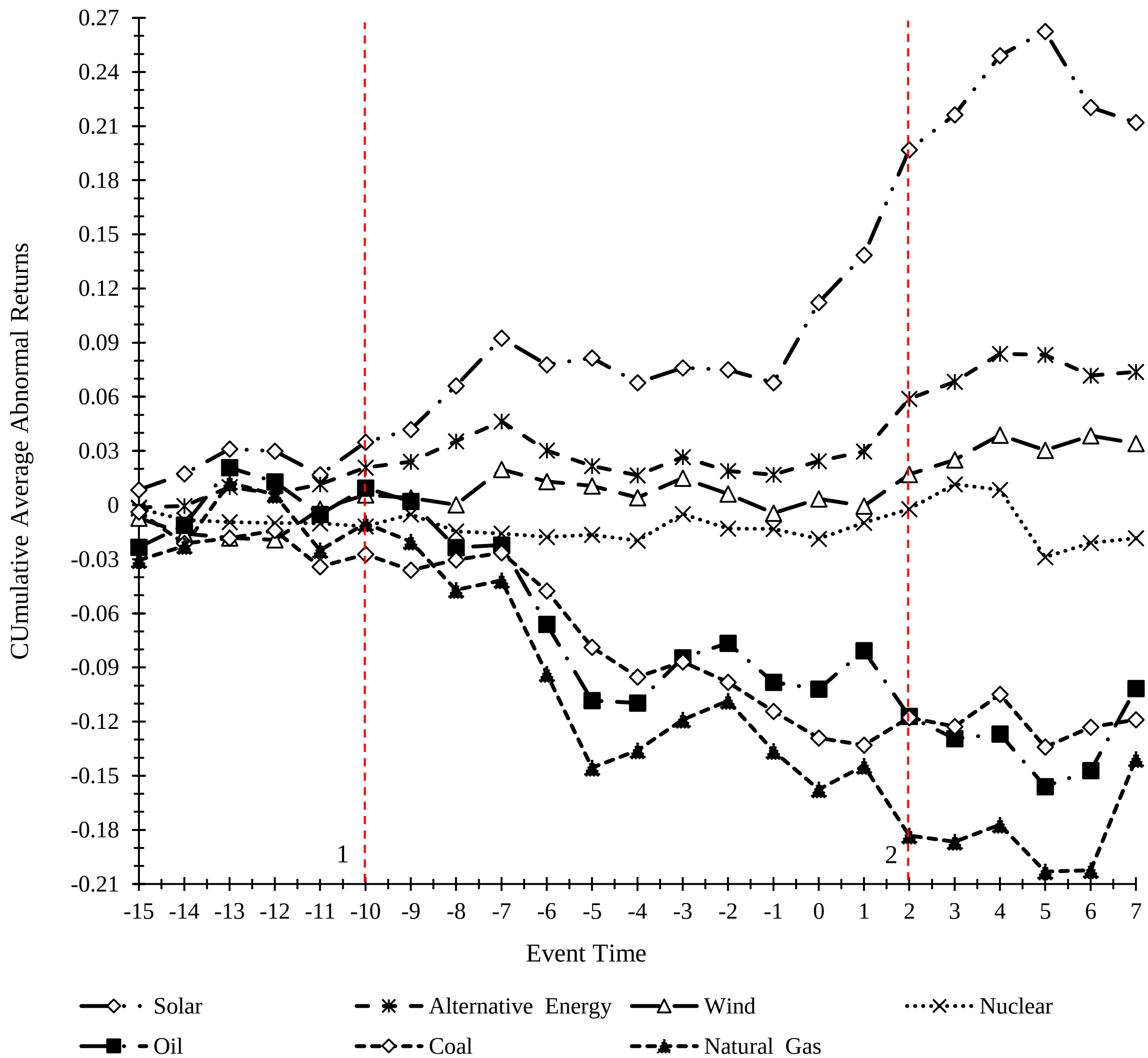


Note: Figure 1 shows the performance of several energy stock indices against the S&P 500. The red dashed lines mark dates with significant climate-related political events: (1) December 18, 2009, the Copenhagen Climate Change Conference comes to an end. (2) December 12, 2015, the Paris climate accord is announced. (3) November 8, 2016, Donald Trump wins the US presidential election.

Figure 2. US Election Clinton Victory Probability

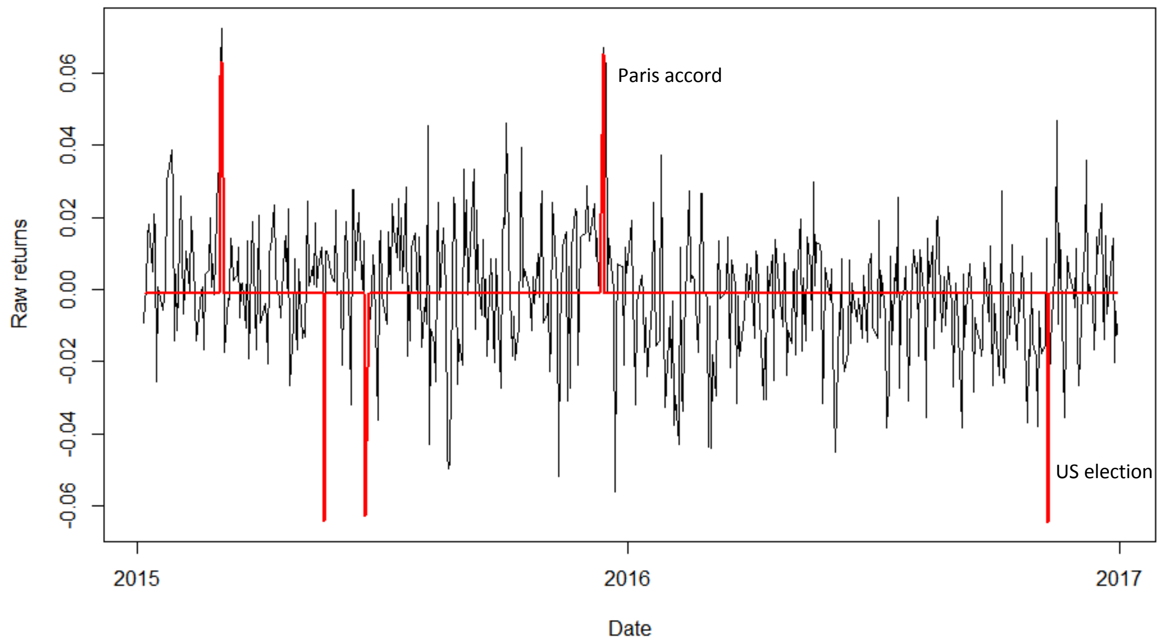
Source: https://predictwise.com
Note: The red dashed lines mark days with significant election-related events: (1) September 26, 2016, first presidential debate is won by Hillary Clinton. (2) October 7, 2016, the Washington Post releases a video of an outtake from Access Hollywood. (3) November 8, 2016, Donald Trump wins the US presidential election.

Figure 3: Paris Climate Agreement Announcement Cumulative Average Abnormal Returns for Renewable and Nonrenewable Energy



Note: This figure plots the cumulative average abnormal returns from day −15 to day +7. The abnormal returns are calculated using the market model. The relevant event period is the window $[-10, +2]$. The red dashed lines mark the beginning and end of our event window: (1) November 30, 2015, climate negotiations start in Paris and (2) December 16, 2015, end of the event window.

Figure 4. Impulse-Indicator Saturation Detected Climate-Related Political and Market Events between January 2015 and December 2017



Technical Appendix

This section provides additional material to complement the analysis in the main paper.

A.1. Exchange-Traded Funds (ETFs)

Exchange-traded funds (ETFs) are portfolios or baskets of securities traded on a stock exchange analogous to individual company stocks. They are similar to mutual funds, but unlike mutual funds, which are bought and sold only at the end of the day through mutual fund companies, ETFs trade all day, and investors transact through brokerage firms as done with individual stocks. ETFs are usually designed to replicate well-known market indices such as the S&P 500, but others also track customized indices. Customized indices are not market indices, as their intention is not to measure the value or performance of financial markets or sectors. To this extent, customized indices can be considered investment strategies designed for a specific task.

While the supply and demand for ETF shares are driven by the values of the underlying securities in the indices they track, Ferri (2011) also points out that other factors can and do affect ETF market prices. Since ETF shares are based on an underlying portfolio of securities, when their prices deviate from those of the underlying securities, authorized participants step in and drive ETF prices higher through arbitrage. Because of this process, short sellers are unable to manipulate ETF prices.

ETFs can be actively managed, in which case they may not necessarily follow a particular index, but rather invest in a portfolio of securities that are chosen at the discretion of the fund manager. The idea is that better performance can be attained through active management than by following a particular index. Since actively managed ETFs invest in a portfolio with securities directly selected by the fund manager, the composition of the portfolio therefore changes more frequently than that of other ETFs tracking an index (Ferri 2011). For this reason, actively managed funds are therefore required to disclose their holdings daily.

Leveraged and Short ETFs

Short ETFs move in the opposite direction from the index they track and seek to deliver results that correspond to the inverse of the index they track on a daily basis. For example, in our sample, the ProShares Short Oil and Gas ETF (DDG) is a short ETF that "seeks daily results, before fees and expenses, that correspond to the inverse (–1x) of the daily performance of the Dow Jones US Oil and Gas Index."[17] Short ETFs can also be leveraged, in which case they are designed to magnify the inverse of an index's performance. For example, the ProShares UltraShort Oil and Gas ETF (DUG) in our sample is a leveraged short ETF designed to produce results two times the inverse (–2x) of the Dow Jones US Oil and Gas Index's daily performance.

The Direxion Daily Natural Gas Related Bull 3X Shares (GASL) is a leveraged ETF that seeks returns that are three times (3X) the ISE-Revere Natural Gas Index's daily performance. The target index in this case turns out to be a customized index.

It is important to note that leveraged and short ETFs are actively managed and therefore seek to rebalance their investment strategies on a daily basis. In our sample, we have three actively managed ETFs confined to the oil and natural gas sectors. Movements in the stock prices of these ETFs can thus reflect to some extent the active management by the fund managers behind them. We feel, however, that this should not significantly affect our results, since actively managed ETFs make up just 50 percent of our natural gas portfolio and 33 percent of the oil sector sample. Our event study analysis makes adjustment for short ETFs. We do not make any distinction as to whether an ETF follows a customized index or a traditional market index.

A.2. Media Framing of Climate Negotiations

An important requirement in event studies is that news announcement should come as a surprise to market participants for one to detect a significant stock price reaction in affected markets. However, it is often hard to measure the impacts of news announcements due to anticipation in markets. In this section, we investigate this issue by conducting a media content analysis of articles published in one of the leading financial newspapers, *Financial Times* during the two months leading up to the Paris climate negotiations through the year end (with December 31 2015 as the last day). The Paris climate negotiations started on November 30, 2015, and ended with the announcement of a climate agreement on December 12, 2015.

The intuition behind media content analysis is that newspaper publishers aim to attract and maintain readership in order to maximize profits. In this regard, they have an interest to report timely on issues of interest to their target audience. Since readers are interested in events that may affect their economic wellbeing, newspapers will optimally choose to report these events. As such, changes in government taxes, unanticipated political events, significant climate change related news, financial crisis and so on will cause the

[17] http://www.proshares.com

number of articles that report on them to increase (Alexopoulos and Cohen 2015). A number of papers in the economics literature have used indicators created from newspaper coverage (see Alexopoulos and Cohen 2015; Baker et al. 2016; Gentzkow and Shapiro 2010).

Here we seek to understand how the Paris climate negotiations process was framed by the news media particularly the *Financial Times*—an international daily newspaper that places special emphasis on business and economic news coverage and has been in circulation since 1888. We focus particularly on three aspects: (*i*) framing of the *preconditions* for reaching an agreement, (*ii*) framing of the actual *negotiations* taking place during the summit, and (*iii*) framing of the actual agreement or *final treaty*. The overall purpose is to analyze the extent to which the agreement was framed as surprising or unexpected.

Data Summary

The analysis is based on 200 *Financial Times* articles collected from Factiva using the search strings "Paris" and "climate" and consisting of 2,940 paragraphs. The average number of paragraphs per article is 14.7 with a standard deviation of 7.6. The shortest article consist of just a single paragraph and the longest article analyzed has 57 paragraphs. We first analyze the framing of the preconditions for reaching an effective agreement. When we consider the preconditions as framed positively, 48 percent of the articles analyzed have a positive frame. When we consider the preconditions as framed negatively, 56 percent of the articles have a negative framing. Roughly, half of the articles frame the negotiations as proceeding positively. In terms of the *surprise* of the agreement, 28 articles explicitly address this aspect. Of these, only four (nine paragraphs) framed the agreement as a surprise. The rest of the articles (172 articles comprising 2,674 paragraphs) do not address this issue explicitly.

The inclusion of the objective "to pursue efforts to limit the temperature increase even further to 1.5°C" in the final agreement was taken as a surprise by many observers since previous climate negotiations have centered around the goal of 2°C. However, only 27 *Financial Times* articles published after the announcement of the Paris Agreement explicitly mentions the inclusion of 1.5°C in the final agreement. Of these, only three paragraphs within two articles frame the inclusion of this lower temperature limit as a surprise. In terms of the agreement's credibility, our search strings identifies 27 articles explicitly referring to the agreement's credibility. Of these, 13 articles explicitly question the credibility of the agreement. In terms of paragraphs, these 27 articles consist of 265 paragraphs with only 33 of them explicitly questioning the agreement's credibility.

A.3. Expert Survey of Environmental and Resource Economists

In order to ascertain the surprise in the announcement of the Paris Agreement, we complement the media content analysis with an expert survey of environmental and resource economists attending the 6th WCERE in June 2018. The WCERE takes place every four years and brings together three environmental and resource economists associations from Europe, America and East Asia but also representations from Africa and Australia. The survey population is a list of about 1500 environmental and resource economists attending the WCERE. We administered the online survey to all participants during and after the congress. The overall response rate was 38%, similar to previous surveys of economists (see May et al. 2014).

The survey included questions about the experts' own reaction to the announcement of the Paris Agreement as well as their perception of the public's reaction at the announcement time. We also seek to understand expert reaction to the inclusion of the 1.5°C temperature target, unanimity of the agreement, its feasibility and credibility. The survey also included questions seeking to understand perceived weaknesses of the agreement in terms of the most disappointing aspects concerning the lack of specific policies to attain the agreement's specified targets. In terms of surprise, 45% of respondents who answered this question think the announcement of the agreement came as a surprise to the public while 28% of the respondents reported the agreement's announcement came as a surprise to themselves with another 33% neither surprised nor unsurprised and the remainder unsurprised. The inclusion of the 1.5°C goal came as a surprise for 49% of the respondents with 21% neither surprised nor unsurprised and 30% unsurprised. About 56% of the respondents were surprised the agreement was reached unanimously. A majority of the respondents (53%) felt the goals of the agreement were feasible while 28% felt the agreement was credible. The majority of the respondents (85%) were disappointed the agreement lacked specifics on how to reach the targets. The lack of individual targets (binding agreement) and detailed commitments were the most disappointing aspects for 57% of the respondents while only 11% reported being disappointed by the absence of a price on carbon. From the survey results, we cannot rule out the presence of anticipation of the Paris Agreement's announcement but note that the survey results suggests some degree of surprise which varied across the different aspects of the agreement. The presence of anticipation means that we likely underestimate firms' reaction to the announcement of the Paris Agreement.

A.4. Hypothesis Testing in Event Studies

In this section, we present the test statistic used to assess the likelihood that the abnormal returns we observe do not arise purely by chance. Given total clustering, the test statistic presented in Brown and Warner

(1985, 1980) accommodates event clustering by estimating the standard deviation from the time series of sample (portfolio) average abnormal returns from the pre-event period t $= -235$ to -11. The test statistic is constructed as the ratio of the event day average abnormal returns to the estimated standard deviation of those average abnormal returns. For any given day t, the test statistic is given as

$$\bar{\epsilon}_t / \hat{S}(\bar{\epsilon}_t), \qquad (1)$$

where, for notational convenience, $\bar{\epsilon}_t = \bar{\hat{\epsilon}}_t$ and

$$\bar{\epsilon}_t = \frac{1}{N}\sum_{i=1}^{N} \hat{\epsilon}_{it}$$

$$\hat{S}(\bar{\epsilon}_t) = \sqrt{\left(\sum_{t=-235}^{t=-11} (\bar{\epsilon}_t - \bar{\bar{\epsilon}})^2\right) \Big/ 224}$$

$$\bar{\bar{\epsilon}} = \frac{1}{225}\sum_{t=-235}^{t=-11} \bar{\epsilon}_t$$

where N is the number of stocks. The test statistic presented in equation (1) follows a Student-t distribution under the null hypothesis if the $\hat{\epsilon}_t$ are assumed to be independent and identically distributed (iid) as normal (see Brown and Warner 1985, 1980). According to Brown and Warner (1985, 1980), this test statistic is assumed unit normal when the degrees of freedom exceed 200. For event windows greater than a single day, the test statistic is presented as $CAAR_{(t_0,t_1)} \Big/ \left(\sqrt{(t_1 - t_0)} \times \hat{S}(\bar{\epsilon}_t)\right)$. While a range of nonparametric tests have been employed in the literature, parametric tests work well with daily data, whereas nonparametric tests often perform poorly (Berry et al. 1990; Brown and Warner 1985; Dyckman et al. 1984).

Thin Trading

Thin trading arises when stocks do not trade every day and presents problems of its own. While this is not a major problem with the US-listed ETFs we analyze, it is a potential problem with some of our country-level analysis (e.g., for Canada and the UK). It is standard for most data sets to treat nontrading days by repeating the last realized transaction price from the previous day. Calculating daily returns from the recorded price series therefore gives zero returns for nontrading days. In addition, when trading takes place, the absolute value of realized returns tends to be relatively large.

When requesting data from Thomson Reuters Eikon, one can choose how missing prices have to be treated when downloading the data. When one chooses the price on nontrading days to be reported as missing, any remaining zero raw returns are assumed to be a result of unchanging prices on two consecutive days. Alternatively, if some of the nonmissing prices are a result of using the average of bid and ask quotes on days with no trade, a zero return can arise when market makers do not adjust their bid and ask quotes on two consecutive days. Treating missing prices by repeating the last realized price generates zero returns, often called lumped returns. The presence of numerous zeros in the return series, however, results in the underestimation of the variance of returns and may lead to incorrect inference regarding abnormal performance.

Other methods used include the uniform returns procedure, in which lumped returns are first computed, and thereafter the average daily return is allocated to each day within the multiperiod interval between two subsequent trades. This, however, leads to some smoothing of returns and ultimately to the same issues with lumped returns. A third alternative, the trade-to-trade procedure, involves first calculating the returns over periods with nonmissing prices. Trade-to-trade returns are then calculated for the market index over the same interval. These two sets of return series are then used to estimate the market model before computing the abnormal returns. Trade-to-trade returns yield better results than the other methods of treating missing returns (Bartholdy et al. 2007) and are therefore used in this paper. In terms of estimating the benchmark model, when an estimation period contains one or more missing values, we do not use the first succeeding nonmissing return. This is because it is a multiperiod return whose inclusion can lead to unexpected consequences in estimating parameters of the benchmark model. We therefore treat the first nonmissing return following a sequence of missing estimation period returns as a missing value. In cases where the nonmissing return occurs in the event window, we adjust the abnormal returns to account for the multiperiod character of the first postmissing return.

Online Appendix

In this section, we provide as part of robustness tests, results from the market model estimated using the GARCH(1,1) error process.

Table A1. Effects of Paris Climate Agreement on Energy Sector Using ETFs

	Coal	Oil	Natural gas	Solar	Wind	Alternative energy	Nuclear
$CAAR_{-2,0}$	−4.21%	−1.72%	−3.89%	3.64%	−1.17%	−0.19%	−1.37%
	(−2.01)**	(−0.61)	(−1.24)	(1.20)	(−0.77)	(−0.15)	(−1.01)
$CAAR_{-1,0}$	−3.09%	−2.56%	−4.97%	3.75%	−0.29%	0.59%	−0.56%
	(−1.80)*	(−1.10)	(−1.94)*	(1.52)	(−0.24)	(0.57)	(−0.51)
$CAAR_{0,0}$	−1.45%	−0.35%	−2.08%	4.44%	0.79%	0.75%	−0.55%
	(−1.20)	(−0.21)	(−1.15)	(2.54)**	(0.90)	(1.03)	(−0.70)
$CAAR_{0,+1}$	−1.82%	1.84%	−0.69%	7.05%	0.40%	1.26%	0.34%
	(−1.06)	(0.79)	(−0.27)	(2.85)***	(0.33)	(1.21)	(0.31)
$CAAR_{0,+2}$	−0.24%	−1.73%	−4.45%	12.89%	2.17%	4.15%	1.10%
	(−0.12)	(−0.61)	(−1.42)	(4.26)***	(1.43)	(3.27)***	(0.81)
$CAAR_{-1,+1}$	−3.46%	−0.37%	−3.58%	6.36%	−0.68%	1.09%	0.33%
	(−1.65)*	(−0.13)	(−1.14)	(2.10)**	(−0.45)	(0.86)	(0.24)
$CAAR_{-2,+2}$	−3.00%	−3.11%	−6.26%	12.08%	0.21%	3.21%	0.28%
	(−1.11)	(−0.84)	(−1.55)	(3.09)***	(0.11)	(1.96)*	(0.16)
$CAAR_{-10,+2}$	−8.20%	−11.07%	−15.81%	16.88%	1.85%	4.78%	0.79%
	(−1.88)*	(−1.87)*	(−2.42)**	(2.68)***	(0.59)	(1.81)*	(0.28)
Number of ETFs	1	4	3	2	1	7	1

Note: This table reports cumulative average abnormal returns (CAARs) for renewable and nonrenewable energy ETF subsamples for the Paris climate agreement announcement. The market model is estimated using a GARCH(1,1) specification, and the market index is the S&P 500. The estimation period includes trading days −235 to −11 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as December 14, 2015, the first day markets opened following the announcement of the Paris climate agreement on Saturday, December 12, 2015. Portfolio time-series *t*-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Some of our ETFs are short ETFs which means that they move in the opposite direction from the index they track and seek to deliver results that correspond to the inverse of the index they track on a daily basis. Before including them in the analysis, we reverse the sign of each estimation-period and event-period security return for the security event. After the sign reversal, we make no further distinction between short and long ETFs. The event study calculations thus proceed by treating the sample as an equally weighted portfolio of securities held long. The negative weights of shorted securities are implied by the sign reversal.

Table A2. Effects of Paris Climate Agreement on Energy Sector Using ETFs (Mean Abnormal Returns)

Day relative to event date (Day 0 = December 14, 2015)	Coal		Oil		Natural gas		Solar		Wind		Alternative energy		Nuclear	
−10	0.69% (0.57)	0.69% (0.57)	1.78% (1.08)	1.77% (1.08)	2.01% (1.11)	1.97% (1.09)	1.30% (0.75)	1.33% (0.76)	0.80% (0.91)	0.79% (0.90)	0.93% (1.28)	0.95% (1.29)	−0.17% (−0.22)	−0.17% (−0.22)
−9	−0.88% (−0.73)	−0.85% (−0.70)	−0.74% (−0.45)	−0.68% (−0.41)	−1.01% (−0.56)	−0.93% (−0.51)	0.71% (0.41)	0.71% (0.40)	−0.17% (−0.19)	−0.16% (−0.18)	0.31% (0.43)	0.30% (0.41)	0.67% (0.86)	0.67% (0.86)
−8	0.57% (0.47)	0.56% (0.46)	−2.56% (−1.55)	−2.57% (−1.56)	−2.67% (−1.48)	−2.73% (−1.51)	2.42% (1.39)	2.43% (1.39)	−0.39% (−0.45)	−0.41% (−0.47)	1.14% (1.55)	1.16% (1.58)	−0.94% (−1.20)	−0.94% (−1.20)
−7	0.39% (0.32)	0.37% (0.31)	0.14% (0.09)	0.11% (0.07)	0.53% (0.29)	0.46% (0.25)	2.64% (1.51)	2.65% (1.52)	1.97% (2.24)**	1.94% (2.21)**	1.11% (1.51)	1.14% (1.55)	−0.13% (−0.16)	−0.13% (−0.16)
−6	−2.10% (−1.74)*	−2.05% (−1.69)*	−4.40% (−2.68)***	−4.31% (−2.62)***	−5.19% (−2.87)***	−5.05% (−2.79)***	−1.48% (−0.85)	−1.50% (−0.86)	−0.67% (−0.76)	−0.64% (−0.73)	−1.62% (−2.21)**	−1.65% (−2.26)**	−0.18% (−0.23)	−0.18% (−0.23)
−5	−3.12% (−2.58)**	−3.12% (−2.58)**	−4.22% (−2.57)**	−4.22% (−2.57)**	−5.19% (−2.87)***	−5.21% (−2.88)***	0.37% (0.21)	0.38% (0.22)	−0.24% (−0.28)	−0.26% (−0.29)	−0.86% (−1.18)	−0.85% (−1.16)	0.12% (0.15)	0.12% (0.15)
−4	−1.66% (−1.37)	−1.66% (−1.37)	−0.13% (−0.08)	−0.13% (−0.08)	0.95% (0.52)	0.92% (0.51)	−1.38% (−0.79)	−1.37% (−0.79)	−0.65% (−0.74)	−0.67% (−0.76)	−0.52% (−0.71)	−0.50% (−0.69)	−0.33% (−0.42)	−0.33% (−0.42)
−3	0.85% (0.70)	0.85% (0.70)	2.51% (1.53)	2.50% (1.52)	1.71% (0.94)	1.68% (0.93)	0.82% (0.47)	0.83% (0.47)	1.07% (1.21)	1.05% (1.19)	1.03% (1.40)	1.04% (1.42)	1.47% (1.88)*	1.47% (1.88)*
−2	−1.14% (−0.94)	−1.12% (−0.92)	0.80% (0.49)	0.83% (0.52)	1.05% (0.58)	1.08% (0.59)	−0.10% (−0.06)	−0.11% (−0.06)	−0.88% (−1.00)	−0.88% (−1.00)	−0.78% (−1.06)	−0.78% (−1.06)	−0.81% (−1.04)	−0.81% (−1.04)
−1	−1.61% (−1.33)	−1.64% (−1.35)	−2.16% (−1.31)	−2.21% (−1.34)	−2.78% (−1.54)	−2.89% (−1.60)	−0.71% (−0.41)	−0.70% (−0.40)	−1.05% (−1.19)	−1.08% (−1.23)	−0.20% (−0.28)	−0.17% (−0.23)	−0.01% (−0.02)	−0.01% (−0.02)
0	−1.48% (−1.22)	−1.45% (−1.20)	−0.39% (−0.24)	−0.35% (−0.21)	−2.13% (−1.18)	−2.08% (−1.15)	4.45% (2.55)**	4.44% (2.54)**	0.79% (0.90)	0.79% (0.90)	0.76% (1.04)	0.75% (1.025)	−0.55% (−0.70)	−0.55% (−0.70)
+1	−0.40% (−0.33)	−0.36% (−0.30)	2.13% (1.29)	2.19% (1.33)	1.31% (0.72)	1.39% (0.77)	2.62% (1.50)	2.61% (1.49)	−0.39% (−0.45)	−0.38% (−0.44)	0.52% (0.71)	0.51% (0.69)	0.89% (1.14)	0.89% (1.14)
+2	1.53% (1.26)	1.58% (1.30)	−3.64% (−2.22)**	−3.57% (−2.17)**	−3.86% (−2.14)**	−3.76% (−2.08)**	5.84% (3.34)***	5.83% (3.34)***	1.75% (1.99)**	1.77% (2.01)**	2.92% (3.99)***	2.90% (3.95)***	0.76% (0.97)	0.76% (0.97)
Number of ETFs	1	1	4	4	3	3	2	2	1	1	7	7	1	1
GARCH error	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Note: This table reports mean abnormal returns for renewable and nonrenewable energy ETF subsamples for a 13-day period surrounding announcement of the Paris climate agreement. The market model is estimated using OLS and the GARCH(1,1) specification, and the market index is the S&P 500. The estimation period includes trading days −235 to −11 relative to the event. The null hypothesis is that the mean abnormal returns are zero. The announcement date ($t = 0$) is taken as December 14, 2015, the first day markets opened following the announcement of the Paris climate agreement on Saturday, December 12, 2015. Portfolio time-series t-statistics are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Some of our ETFs are short ETFs which means that they move in the opposite direction from the index they track and seek to deliver results that correspond to the inverse of the index they track on a daily basis. Before including them in the analysis, we reverse the sign of each estimation-period and event-period security return for the security event. After the sign reversal, we make no further distinction between short and long ETFs. The event study calculations thus proceed by treating the sample as an equally weighted portfolio of securities held long. The negative weights of shorted securities are implied by the sign reversal.

Table A3. Effects of US Election on Energy Sector Using Energy ETFs

	Coal	Oil	Natural gas	Solar	Wind	Alternative energy	Nuclear
$CAAR_{-5,-1}$	−2.85%	−1.56%	−2.80%	−1.58%	−2.84%	−0.82%	0.24%
	(−0.84)	(−0.42)	(−0.36)	(−0.49)	(−1.50)	(−0.54)	(0.15)
$CAAR_{0,0}$	0.48%	0.89%	1.40%	−6.58%	−4.37%	−2.86%	−4.51%
	(0.32)	(0.53)	(0.40)	(−4.57)***	(−5.16)***	(−4.22)***	(−6.44)***
$CAAR_{0,+1}$	−1.69%	1.08%	0.95%	−6.95%	−7.44%	−3.59%	−3.75%
	(−0.79)	(0.46)	(0.19)	(−3.42)***	(−6.21)***	(−3.75)***	(−3.79)***
$CAAR_{0,+2}$	−2.50%	−1.04%	−1.75%	−8.37%	−7.97%	−2.92%	−5.08%
	(−0.96)	(−0.36)	(−0.29)	(−3.36)***	(−5.44)***	(−2.49)**	(−4.19)***
$CAAR_{0,+5}$	−6.30%	2.22%	3.09%	−6.45%	−10.83%	−2.83%	−4.47%
	(−1.70)*	(0.54)	(0.36)	(−1.83)*	(−5.22)***	(−1.71)*	(−2.61)***
Number of ETFs	1	4	4	2	1	7	1

Note: This table reports cumulative average abnormal returns (CAARs) for energy ETF subsamples for the US presidential election. The market model is estimated using a GARCH(1,1) specification, and the market index is the S&P 500. The estimation period includes trading days –220 to –6 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series t-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Some of our ETFs are short ETFs which means that they move in the opposite direction from the index they track and seek to deliver results that correspond to the inverse of the index they track on a daily basis. Before including them in the analysis, we reverse the sign of each estimation-period and event-period security return for the security event. After the sign reversal, we make no further distinction between short and long ETFs. The event study calculations thus proceed by treating the sample as an equally weighted portfolio of securities held long. The negative weights of shorted securities are implied by the sign reversal.

Table A4. Effects of US Election on Energy ETFs (Mean Abnormal Returns)

Day relative to event date (Day 0 = November 9, 2016)	Coal		Oil		Natural gas		Solar		Wind		Alternative energy		Nuclear	
–1	–1.59%	–1.59%	–0.79%	–0.74%	–1.90%	–1.73%	0.81%	0.72%	–1.47%	–1.46%	–0.08%	–0.10%	–0.17%	–0.18%
	(–1.05)	(–1.05)	(–0.47)	(–0.44)	(–0.54)	(–0.49)	(0.57)	(0.50)	(–1.73)*	(–1.72)*	(–0.12)	(–0.14)	(–0.24)	(–0.25)
0	0.45%	0.48%	0.84%	0.89%	1.02%	1.40%	–6.44%	–6.58%	–4.38%	–4.37%	–2.83%	–2.86%	–[a]	–[a]
	(0.29)	(0.32)	(0.50)	(0.53)	(0.29)	(0.40)	(–4.48)***	(–4.57)***	(–5.17)***	(–5.16)***	(–4.18)***	(–4.22)***		
+1	–2.16%	–2.17%	0.14%	0.19%	–0.57%	–0.45%	–0.32%	–0.37%	–3.08%	–3.07%	–0.73%	–0.74%	–4.49%	–4.51%
	(–1.43)	(–1.44)	(0.09)	(0.11)	(–0.16)	(–0.13)	(–0.23)	(–0.26)	(–3.63)***	(–3.63)***	(–1.08)	(–1.09)	(–6.41)***	(–6.44)***
+2	–0.78%	–0.82%	–2.16%	–2.12%	–2.72%	–2.69%	–1.41%	–1.43%	–0.54%	–0.53%	0.67%	0.67%	0.75%	0.75%
	(–0.52)	(–0.54)	(–1.30)	(–1.27)	(–0.77)	(–0.77)	(–0.98)	(–0.99)	(–0.64)	(–0.63)	(0.99)	(0.99)	(1.08)	(1.08)
+3	–0.84%	–0.86%	0.96%	1.00%	1.73%	1.79%	0.98%	0.95%	–0.89%	–0.88%	0.33%	0.33%	–1.32%	–1.33%
	(–0.56)	(–0.57)	(0.58)	(0.60)	(0.49)	(0.51)	(0.68)	(0.66)	(–1.05)	(–1.04)	(0.49)	(0.48)	(–1.89)*	(–1.90)*
+4	–3.58%	–3.56%	2.66%	2.71%	3.68%	3.95%	–0.40%	–0.49%	–0.77%	–0.77%	0.07%	0.04%	0.63%	0.62%
	(–2.37)**	(–2.35)**	(1.60)	(1.63)	(1.05)	(1.12)	(–0.28)	(–0.34)	(–0.92)	(–0.91)	(0.10)	(0.07)	(0.90)	(0.89)
+5	0.66%	0.63%	–0.50%	–0.45%	–0.92%	–0.91%	1.49%	1.47%	–1.22%	–1.21%	–0.28%	–0.28%	–0.34%	–0.34%
	(0.44)	(0.42)	(–0.30)	(–0.27)	(–0.26)	(–0.26)	(1.04)	(1.02)	(–1.44)	(–1.44)	(–0.41)	(–0.41)	(–0.49)	(–0.49)
Number of ETFs	1	1	4	4	4	4	2	2	1	1	7	7	1	1
GARCH error	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Note: This table reports mean abnormal returns for a seven-day period around the US election using renewable and nonrenewable energy ETF subsamples. The market model is estimated using OLS and the GARCH(1,1) specification, and the market index is the S&P 500. The estimation period includes trading days –220 to –6 relative to the event. The null hypothesis is that the mean abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series t-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Some of our ETFs are short ETFs which means that they move in the opposite direction from the index they track and seek to deliver results that correspond to the inverse of the index they track on a daily basis. Before including them in the analysis, we reverse the sign of each estimation-period and event-period security return for the security event. After the sign reversal, we make no further distinction between short and long ETFs. The event study calculations thus proceed by treating the sample as an equally weighted portfolio of securities held long. The negative weights of shorted securities are implied by the sign reversal.

[a] Denotes a day in the event window with missing returns.

Table A5. Effects of Paris Climate Agreement on Energy Sector Using Energy Stock Indices

	Coal	Oil	Solar	Alternative energy
$CAAR_{-2,0}$	−2.92%	−0.53%	3.40%	−0.37%
	(−1.19)	(−0.29)	(1.20)	(−0.20)
$CAAR_{-1,0}$	−1.97%	−1.04%	4.11%	1.13%
	(−0.98)	(−0.70)	(1.77)*	(0.76)
$CAAR_{0,0}$	−1.91%	0.19%	3.91%	1.58%
	(−1.35)	(0.18)	(2.38)**	(1.51)
$CAAR_{0,+1}$	−2.64%	1.89%	5.49%	2.45%
	(−1.32)	(1.27)	(2.37)**	(1.65)*
$CAAR_{0,+2}$	−1.25%	−0.20%	11.67%	6.02%
	(−0.51)	(−0.11)	(4.11)***	(3.31)***
$CAAR_{-1,+1}$	−2.70%	0.66%	5.69%	1.99%
	(−1.10)	(0.36)	(2.00)**	(1.10)
$CAAR_{-2,+2}$	−2.27%	−0.92%	11.16%	4.07%
	(−0.72)	(−0.39)	(3.04)***	(1.73)*
$CAAR_{-10,+2}$	−6.84%	−6.67%	18.71%	6.67%
	(−1.34)	(−1.76)*	(3.16)***	(1.76)*

Note: This table reports the cumulative average abnormal returns (CAARs) for the widely followed global energy stock indices. Coal is made up of an equally weighted average of the two main coal stock indices, the Dow Jones US Coal Index (DJUSCL) and the Stowe Global Coal Index (COAL). Oil and gas is represented by the Dow Jones US Oil and Gas Index (DJUSEN). Solar is made up of two stock indices, the MAC Global Solar Energy Index (SUNIDX) and the Ardour Solar Energy Index (SOLRX). Alternative energy is represented by the S&P Global Clean Energy Index (SPGTCED). The market model is estimated using a GARCH(1,1) specification, and the market index is the S&P 500. The estimation period includes trading days −235 to −11 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as December 14, 2015, the first day markets opened following the announcement of the Paris climate agreement on Saturday, December 12, 2015. Portfolio time-series t-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A6. Effects of US Election on Energy Sector Using Energy Stock Indices

	Coal	Oil	Solar	Alternative energy
$CAAR_{-5,-1}$	−0.50%	−0.90%	−1.67%	−2.52%
	(−0.14)	(−0.37)	(−0.53)	(−1.12)
$CAAR_{0,0}$	−0.42%	0.32%	−6.29%	−5.94%
	(−0.26)	(0.29)	(−4.44)***	(−5.93)***
$CAAR_{0,+1}$	1.89%	0.31%	−6.30%	−8.07%
	(0.83)	(0.20)	(−3.15)**	(−5.69)***
$CAAR_{0,+2}$	1.95%	−1.15%	−7.50%	−8.93%
	(0.70)	(−0.61)	(−3.06)**	(−5.14)***
$CAAR_{0,+5}$	−3.92%	0.45%	−7.54%	−9.37%
	(−0.99)	(0.17)	(−2.17)*	(−3.81)***

Note: This table reports the cumulative average abnormal returns (CAARs) for the widely followed global energy stock indices. Coal is made up of an equally weighted average of the two main coal stock indices, the Dow Jones US Coal Index (DJUSCL) and the Stowe Global Coal Index (COAL). Oil and gas is represented by the Dow Jones US Oil and Gas Index (DJUSEN). For Solar we use two stock indices, the MAC Global Solar Energy Index (SUNIDX) and the Ardour Solar Energy Index (SOLRX). Alternative energy is represented by the S&P Global Clean Energy Index (SPGTCED). The market model is estimated using a GARCH(1,1) specification, and the market index is the S&P 500. The estimation period includes trading days −220 to −6 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series t-statistics are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table A7. Effects of Paris Climate Agreement on Coal Stocks in Other Countries

		China										
	Australia	Hong Kong	Shanghai	Shenzhen	India	Indonesia	Japan	Philippines	Poland	Russia	Thailand	South Africa
$CAAR_{-2,0}$	−3.23%	1.01%	1.66%	1.62%	5.26%	−2.26%	−0.48%	−3.13%	2.93%	0.09%	−2.39%	−3.61%
	(−1.02)	(0.21)	(0.61)	(0.48)	(1.65)*	(−1.38)	(−0.34)	(−0.93)	(0.59)	(0.03)	(−0.87)	(−1.15)
$CAAR_{-1,0}$	−2.95%	−0.06%	1.44%	2.21%	5.10%	−0.51%	0.03%	−3.71%	0.92%	−0.64%	−0.11%	−6.04%
	(−1.15)	(−0.01)	(0.65)	(0.81)	(1.96)**	(−0.38)	(0.02)	(−1.35)	(0.23)	(−0.23)	(−0.05)	(−2.35)**
$CAAR_{0,0}$	−2.14%	0.96%	0.76%	1.54%	2.77%	−0.28%	0.72%	−2.33%	1.52%	−0.38%	−1.23%	−3.72%
	(−1.17)	(0.34)	(0.48)	(0.80)	(1.51)	(−0.29)	(0.89)	(−1.19)	(0.53)	(−0.20)	(−0.78)	(−2.05)**
$CAAR_{0,+1}$	−5.40%	1.88%	−0.09%	0.29%	1.20%	0.90%	0.09%	−1.59%	−0.16%	−0.47%	−2.45%	−2.46%
	(−2.09)**	(0.46)	(−0.04)	(0.11)	(0.46)	(0.67)	(0.08)	(−0.58)	(−0.04)	(−0.17)	(−1.10)	(−0.96)
$CAAR_{0,+2}$	−4.90%	−1.57%	−0.22%	0.50%	−1.01%	−0.12%	−0.36%	−5.52%	−0.46%	−0.17%	−2.75%	3.01%
	(−1.55)	(−0.32)	(−0.08)	(0.15)	(−0.32)	(−0.07)	(−0.26)	(−1.63)	(−0.09)	(−0.05)	(−1.00)	(0.96)
$CAAR_{-1,+1}$	−6.16%	0.86%	0.60%	0.96%	3.53%	0.67%	−0.60%	−2.97%	−0.76%	−0.73%	−1.33%	−4.78%
	(−1.95)*	(0.17)	(0.22)	(0.29)	(1.11)	(0.41)	(−0.43)	(−0.88)	(−0.15)	(−0.22)	(−0.49)	(−1.52)
$CAAR_{-2,+2}$	−5.85%	−1.52%	0.68%	0.57%	1.48%	−2.12%	−1.56%	−6.32%	0.94%	0.30%	−3.90%	3.12%
	(−1.44)	(−0.24)	(0.20)	(0.13)	(0.36)	(−1.00)	(−0.87)	(−1.45)	(0.15)	(0.07)	(−1.10)	(0.77)
$CAAR_{-10,+2}$	−8.15%	−4.44%	−1.92%	−0.69%	−0.77%	−7.71%	0.13%	−1.63%	−8.52%	−1.52%	−4.17%	−6.86%
	(−1.24)	(−0.43)	(−0.34)	(−0.10)	(−0.12)	(−2.26)**	(0.04)	(−0.23)	(−0.83)	(−0.22)	(−0.73)	(−1.05)
Number of stocks	23	21	23	7	5	16	4	3	2	4	5	9

Note: This table reports country-level cumulative average abnormal returns (CAARs) for the major coal-producing and coal-exporting countries. We make use of the Thomson Reuters Business Classification (TRBC) to construct our country-level subsamples and focus on primary quotes. The TRBC is a market-based classification system in which companies are assigned an industry based on the end market they serve rather than the products or services they offer. Market-based classification emphasizes the usage of a product rather than the materials used for the manufacturing process. The TRBC recognizes that the market served is a key determinant of firm performance and thus groups together firms that share similar market characteristics. The market model is estimated using a GARCH(1,1) specification, and the market is proxied by the local market index. The estimation period includes trading days −235 to −11 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as December 14, 2015, the first day markets opened following the announcement of the Paris climate agreement on Saturday, December 12, 2015. Portfolio time-series t-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A8. Effects of US Election on Coal Stocks in Other Countries

		China											
	Australia[a]	Hong Kong	Shanghai	Shenzhen	India	Indonesia	Japan	Philippines	Poland	Russia	Thailand	South Africa
$CAAR_{-5,-1}$	−2.52%	−0.81%	0.41%	0.09%	−3.06%	8.18%	−1.42%	0.61%	0.99%	−1.06%	1.66%	−1.23%
	(−0.74)	(−0.22)	(0.14)	(0.02)	(−0.89)	(1.87)*	(−0.60)	(0.13)	(0.15)	(−0.26)	(0.49)	(−0.35)
$CAAR_{0,0}$	−4.03%	−0.55%	1.28%	1.54%	1.68%	0.69%	−0.57%	−0.79%	−1.38%	−0.55%	3.68%	1.63%
	(−2.66)***	(−0.34)	(0.96)	(0.79)	(1.09)	(0.35)	(−0.54)	(−0.36)	(−0.47)	(−0.31)	(2.40)**	(1.03)
$CAAR_{0,+1}$	−1.45%	0.93%	0.03%	0.73%	1.56%	5.25%	0.11%	1.96%	2.63%	1.36%	3.59%	4.92%
	(−0.68)	(0.40)	(0.02)	(0.27)	(0.72)	(1.90)*	(0.08)	(0.63)	(0.64)	(0.53)	(1.66)*	(2.20)**
$CAAR_{0,+2}$	−0.82%	1.87%	1.30%	4.09%	2.44%	6.83%	−1.15%	2.53%	4.46%	2.08%	4.33%	6.49%
	(−0.31)	(0.65)	(0.57)	(1.21)	(0.92)	(2.01)**	(−0.63)	(0.67)	(0.88)	(0.66)	(1.63)	(2.37)**
$CAAR_{0,+5}$	−3.24%	2.43%	0.90%	5.04%	−3.51%	1.85%	0.38%	3.32%	4.80%	3.10%	0.71%	1.65%
	(−0.87)	(0.60)	(0.28)	(1.05)	(−0.93)	(0.37)	(0.15)	(0.62)	(0.67)	(0.70)	(0.19)	(0.43)
Number of stocks	24	20	23	5	4	15	4	3	2	4	5	8

Note: This table reports country-level cumulative average abnormal returns (CAARs) for the major coal-producing and coal-exporting countries. The market model is estimated using a GARCH(1,1) specification, and the market is proxied by the local market index. The estimation period includes trading days −220 to −6 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series t-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[a] On November 9, 2016, the Queensland Parliament passed the Environmental Protection (Underground Water Management) and Other Legislation Amendment Act, which seeks to tighten groundwater license requirements for mines

Table A9. Effects of Paris Climate Agreement on US Listed Coal Stocks

	United States		
	Full sample	NYSE	NASDAQ
$CAAR_{-2,0}$	−4.34%	−4.87%	−3.29%
	(−0.85)	(−0.95)	(−0.43)
$CAAR_{-1,0}$	−4.73%	−6.05%	−2.10%
	(−1.14)	(−1.45)	(−0.34)
$CAAR_{0,0}$	−3.76%	−5.08%	−1.13%
	(−1.28)	(−1.72)*	(−0.26)
$CAAR_{0,+1}$	−3.92%	−4.04%	−3.69%
	(−0.95)	(−0.97)	(−0.59)
$CAAR_{0,+2}$	−3.92%	−2.24%	−7.27%
	(−0.77)	(−0.44)	(−0.95)
$CAAR_{-1,+1}$	−4.89%	−5.01%	−4.66%
	(−0.96)	(−0.98)	(−0.61)
$CAAR_{-2,+2}$	−4.50%	−2.03%	−9.44%
	(−0.69)	(−0.31)	(−0.95)
$CAAR_{-10,+2}$	−13.66%	−11.52%	−17.94%
	(−1.29)	(−1.08)	(−1.12)
Number of stocks	15	10	5

Note: This table reports cumulative average abnormal returns (CAARs) for the US coal industry firms. The market model is estimated using a GARCH(1,1) specification, and the market index is the S&P 500 Index for the NYSE subsample and Dow Jones Industrial Average for the NASDAQ sample. We use the S&P 500 for the full sample. The estimation period includes trading days −235 to −11 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as December 14, 2015, the first day markets opened following the announcement of the Paris climate agreement on Saturday, December 12, 2015. Portfolio time-series *t*-statistics are shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A10. Effects of US Election on US Listed Coal Stocks

	United States				
	Full sample		NYSE		NASDAQ
	I	II[a]	III	IV[a]	V
$CAAR_{-5,-1}$	–2.16%	–2.91%	–2.51%	–3.68%	–1.38%
	(–0.39)	(–0.57)	(–0.39)	(–0.65)	(–0.27)
$CAAR_{0,0}$	10.99%	7.78%	10.42%	5.54%	12.26%
	(4.40)***	(3.41)***	(3.60)***	(2.18)**	(5.41)***
$CAAR_{0,+1}$	12.29%	7.87%	11.81%	5.12%	13.37%
	(3.48)***	(2.44)**	(2.88)***	(1.42)	(4.17)***
$CAAR_{0,+2}$	12.63%	9.50%	11.10%	6.21%	16.06%
	(2.92)***	(2.41)**	(2.21)**	(1.41)	(4.10)***
$CAAR_{0,+5}$	10.86%	6.43%	11.04%	4.42%	10.45%
	(1.78)*	(1.15)	(1.56)	(0.71)	(1.88)*
Number of stocks	13	12	9	8	4

Note: This table reports cumulative average abnormal returns (CAARs) for the US coal industry firms. The market model is estimated using a GARCH(1,1) specification, and the market index is the S&P 500 Index for the NYSE subsample and Dow Jones Industrial Average for the NASDAQ subsample. We use the S&P 500 for the full sample. The estimation period includes trading days –220 to –6 relative to the event. The null hypothesis is that the cumulative average abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series *t*-statistics are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

[a] Columns II and IV represent results excluding Peabody Energy.

Table A11. Effects of US Election on US Listed Coal Stocks (Mean Abnormal Returns)

Day relative to event date	United States				
(Day 0 = November 9, 2016)	Full Sample		NYSE		NASDAQ
	I	II[a]	III	IV[a]	V
−5	−0.89%	−0.94%	−0.90%	−0.98%	−0.86%
	(−0.36)	(−0.41)	(−0.31)	(−0.38)	(−0.38)
−4	2.00%	1.95%	2.31%	2.27%	1.31%
	(0.80)	(0.86)	(0.80)	(0.89)	(0.58)
−3	0.88%	0.85%	−0.03%	−0.18%	2.93%
	(0.35)	(0.38)	(−0.01)	(−0.07)	(1.30)
−2	−3.23%	−3.86%	−2.61%	−3.49%	−4.61%
	(−1.29)	(−1.70)*	(−0.90)	(−1.37)	(−2.04)**
−1	−0.92%	−0.92%	−1.26%	−1.30%	−0.15%
	(−0.37)	(−0.40)	(−0.44)	(−0.51)	(−0.07)
0	10.99%	7.78%	10.42%	5.54%	12.26%
	(4.40)***	(3.41)***	(3.60)***	(2.18)**	(5.41)***
+1	1.30%	0.09%	1.39%	−0.42%	1.11%
	(0.52)	(0.04)	(0.48)	(−0.16)	(0.49)
+2	0.34%	1.63%	−0.71%	1.09%	2.69%
	(0.14)	(0.71)	(−0.25)	(0.43)	(1.19)
+3	2.38%	1.53%	3.16%	1.99%	0.62%
	(0.95)	(0.67)	(1.09)	(0.78)	(0.27)
+4	−3.57%	−3.93%	−2.60%	−3.01%	−5.77%
	(−1.43)	(−1.73)*	(−0.90)	(−1.17)	(−2.55)**
+5	−0.57%	−0.67%	−0.62%	−0.77%	−0.46%
	(−0.23)	(−0.29)	(−0.22)	(−0.30)	(−0.20)
Number of stocks	13	12	9	8	4

Note: This table reports mean abnormal returns for the US coal industry firms. The market model is estimated using a GARCH(1,1) specification, and the market index is the S&P 500 Index for the NYSE subsample and Dow Jones Industrial Average for the NASDAQ subsample. We use the S&P 500 for the full sample. The estimation period includes trading days −220 to −6 relative to the event. The null hypothesis is that the mean abnormal returns are zero. The announcement date ($t = 0$) is taken as November 9, 2016. Portfolio time-series t-statistics are shown in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

[a] Columns II and IV represent results excluding Peabody Energy.