Journal of Sustainable Finance & Investment

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tsfi20

Climate change events and stock market returns

Yevheniia Antoniuk & Thomas Leirvik

To cite this article: Yevheniia Antoniuk & Thomas Leirvik (2021): Climate change events and stock market returns, Journal of Sustainable Finance & Investment, DOI: 10.1080/20430795.2021.1929804

To link to this article: https://doi.org/10.1080/20430795.2021.1929804

Published online: 09 Jun 2021.

JOURNAL OF SUSTAINABLE FINANCE & INVESTMENT
https://doi.org/10.1080/20430795.2021.1929804

Climate change events and stock market returns

Yevheniia Antoniuk and Thomas Leirvik

Nord University Business School, Bodø, Norway

ABSTRACT
Using an event study methodology, we investigate how unexpected political events affect climate-sensitive sectors. We find that events related to climate change policy have significantly impacted returns. The clean energy sector benefitted from the Paris Agreement, Climategate, and Fukushima since these events increased climate change awareness and favor toward policies related to reducing the impact of climate change. For the utilities, energy-intensive, and transport sectors, these events imply increased transition-related political and market risks, which should be compensated. Events weakening climate change policy are associated with positive abnormal returns for the fossil energy sector. We further find that stock market investors are quick to adapt to new information related to climate change. Policymakers should be aware of such events' impact on the stock market because the investors are likely to price in both climate risk and expectation about sectors' growth.

ARTICLE HISTORY
Received 25 August 2020
Accepted 7 May 2021

KEYWORDS
Climate change; stock market; returns; Paris agreement; event study; empirical finance

1. Introduction

Climate change is receiving a great deal of attention today from both policymakers and the public. During the last three decades, there has been a dramatic improvement in humanity's understanding of the drivers of Earth's climate (Hansen et al. 2005; Andreae, Jones, and Cox 2005; Matthews et al. 2009; Storelvmo et al. 2016; Phillips, Leirvik, and Storelvmo 2020). The economic consequences and societal impact of climate change have also received much attention (Nordhaus and Yang 1996; Alley 2003; Easterling et al. 2000; Hayhoe et al. 2004; Matthews, Wilby, and Murphy 2017; He and Liu 2018). The projected changes in temperature over the next century range from 1°C to more than 4°C, which will have devastating effects for many firms. Climate change and how society can and should adapt to it are severe challenges. Nordhaus (2019) discusses three possible paths and concludes that the only viable path is the one where humans reduce their emissions significantly over time.

While the effects of climate change are not observed overnight and are often neglected, investors are increasingly interested in understanding how the shift to a greener and cleaner economy affects firms; see for example He and Liu (2018), Teng and He (2020), Li et al. (2020), Alsaifi, Elnahass, and Salama (2020), Sarkodie, Adams, and

CONTACT Yevheniia Antoniuk yevhenliia.antoniuk@nord.no

Leirvik (2020), Sarkodie et al. (2020) and Qian, Suryani, and Xing (2020). In particular, Alsaifi, Elnahass, and Salama (2020) applied an event study method to determine how voluntary carbon disclosure affects firms in the UK. The authors found that firms operating in carbon-intensive industries experience a more pronounced negative reaction to voluntary carbon disclosure. Qian, Suryani, and Xing (2020) have specifically analyzed climate policy changes for Australia. The authors also applied an event study methodology and found that better carbon performance has led to significantly higher market returns during the Australian carbon tax repeal.

These studies highlight the current focus on climate risk that according to Nordhaus and Yang (1996), is a systematic risk, meaning that it affects the whole economy, not just a specific firm. Furthermore, climate risks can be broken down into (i) physical risk and (ii) transition risk (Clapp et al. 2017). The former is related to extreme weather events and their consequences, whereas the latter is related to attributes of transition to a low-carbon economy: technological shifts, policy and regulation introduction, production-level changes, and consumer behavior. Transition risk is likely to be realized in the near future; therefore, the market needs to account for it.

In this paper, we study the transition risk that stems from climate change policy and awareness. We apply an event study methodology and analyze how unexpected events related to climate change affect the stock market. We focus on the following set of events:

(1) The Climatic Research Unit email controversy (17 November 2009), also known as Climategate, which began after the leaking of the thousands of emails written by employees at the Climatic Research Unit at the University of East Anglia. The leaked information was widely used by climate change deniers who claim that climate change facts are fabricated.
(2) The Fukushima Daiichi nuclear disaster (11.03.2011; Ōkuma, Japan): The ruination of the nuclear plant's reactors after the Tōhoku earthquake and the ensuing tsunami triggered their shutdown. This accident led to revision of energy policies in Japan and other countries. Before the accident, nuclear energy, like clean energy, was an essential part of the transition to a low-carbon economy.
(3) The UN Climate Change Conference (12 December 2015; Paris, France): The adoption of the Paris Agreement (PA) that governs climate change reduction measures from 2020 onward. Given that previous negotiation at the Copenhagen Climate Change Conference in 2009 did not result in an agreement, the climate meeting in Paris was a surprise in that parties agreed on and signed a bill to reduce CO_2 emissions.
(4) The US presidential election (8 November 2016; U.S.A.): The outcome of the election (USPE) was a surprise because the winning candidate lagged behind his opponent by a large margin in poll results. The winner of the election, Donald Trump, had clear intentions to change the climate policy legislation, limit climate policy cooperation, and revive the coal industry in the U.S.A. Such policy changes are expected to affect clean energy stocks as well as oil and fossil fuel stocks.

We hypothesize that the stock market can efficiently price in new information that these events carry. We assume that the stock market reaction to this systematic risk depends on the industry, similarly to Pham et al. (2019) and Birindelli and Chiappini (2021). However, we follow the definition of climate policy-relevant sectors provided by Battiston et al. (2017) to study the response of sector-specific exchange-traded funds (ETFs) to the events relevant to the climate change discussion and climate policy.

Previous event studies on climate policies looked at the European companies' response to the Paris Agreement (Pham et al. 2019; Birindelli and Chiappini 2021), and reaction of energy stocks from Germany (Betzer, Doumet, and Rinne 2013; Sen and von Schickfus 2020), the U.S.A. (Diaz-Rainey et al. 2021), and in worldwide comparison (Ferstl, Utz, and Wimmer 2012; Mukanjari and Sterner 2018) to Fukushima and the American election. Thus, this work differs from the previous research by focusing on a sector-specific response of the US ETFs to a set of events that includes Climategate, which has not been considered before in the financial studies.

Climate change policies aim to reduce carbon emissions; thus, carbon risk should be included in investment decision making. Recent studies show that investors recognize climate risk (Krueger, Sautner, and Starks 2020), and they require higher returns from firms with higher emission levels (Bolton and Kacperczyk 2021). Additionally, the cost of debt for climate-aware firms is lower compared to firms without carbon disclosure (Jung, Herbohn, and Clarkson 2018). These findings suggest that investors require compensation for holding stocks with higher climate risks. We propose that risk premiums and changes in expectations can explain the sectors' reaction to the events. Understanding the mechanism of how individual firms and the stock market as a whole react to changes in climate policy is critical for policymakers to create the best solution possible for all parts of an economy.

1.1. Hypothesis

In connection with an event, the stock market could have a negative reaction, a positive reaction, or no reaction. If there is no reaction, a chosen event does not impact stocks. This can mean that the event is not relevant to the specific company or market or does not convey new information that should be priced in. Alternatively, an event-related change in price is significant but could have a different impact on price development. In the case of the market overreacting or underreacting, an initial price adjustment to the newly arrived information is too large or small, meaning that the market must correct for that later to trade on fair prices. The reaction can be efficient, and stock prices after incorporating an information shock remain at the new level.

Considering transition climate risks, we hypothesize that all sectors except for clean energy react negatively to climate policy-positive events, or events that take the further discussion and policy on climate change mitigation. Clean energy is supposed to benefit from such positive events since a more favorable environment for clean and renewable energy development is created alongside promoting a low-carbon economy. Because these positive events will hamper fossil fuel energy development, other sectors, which are dependent on the fossil fuel sector's energy supply (e.g. energy-intensive, transport, and, to some degree, utility sectors), will have increased uncertainty and risks. These risks would be caused by the shift and adaptation to a new sustainable energy source, which means switching to new technologies to reduce companies' carbon footprint and increase energy efficiency. Improvement of energy efficiency is also the case for the housing sector. Hypothetically, the opposite is true for climate policy-negative events. We hypothesize that climate policy-related events cause a change in investors' preferences, which affects demand for stocks and thus their prices.

We suggest that two events – Climategate and the USPE – are climate policy-negative and another two – Fukushima and the PA – are climate policy-positive. We explain this categorization below.

Climategate. The email leakage that occurred at the end of November 2009 began a discussion on the credibility of scientific research and climate change evidence. Public perception of climate change and its risks translates into expectations about the development of the market. The distributed information from the leaked emails affected public beliefs about global warming since more people began to question whether it is happening (Leiserowitz et al. 2013).

Fukushima. There is an ongoing debate about nuclear energy and whether it can be considered clean and renewable. The casualties and environmental harm caused by the Fukushima disaster made a shift toward other energy sources more urgent. The need for change was obvious for Japan, which suffered from the accident directly, but also for the rest of the world, which witnessed its consequences (Lei and Shcherbakova 2015). This event could be seen as a good point from which to reshape energy source structures to be more sustainable.

PA. There was a need for an agreement to frame climate change and emission targets after 2020 when the Kyoto Protocol would end. The Copenhagen meeting's failure to draft such an agreement led to a different negotiation approach: states were asked to send determined national contributions before the Paris meeting. Even though the meeting date was set in advance and market actors knew about it, its outcome was highly unanticipated. The polarization of the opinions of developed and developing countries made the possibility of reaching the agreement and its form (i.e. whether it would be legally binding) questionable. Thus, the written agreement stating a 1.5°C warming ceiling was 'a real positive surprise' (Christoff 2016).

USPE. For this event as well as for the previous one, the date was known in advance. However, the outcome was unexpected. According to the pre-election polls, another candidate had a higher chance to win and a higher share of electoral and popular votes according to *538 Project*. The election outcome was expected to affect climate change strategy for the U.S.A. and other parties in the UN. Trump mentioned his intention to remove the U.S.A. from the Paris Agreement and revive the coal industry. As such, his decisions were expected to increase the emission reduction burden on other countries while the U.S.A. accounted for 15% of total global emissions as of 2014 (Christoff 2016).

2. Data and method

For the analysis, we used daily price data of ETFs from July 2009 to December 2016. An ETF is a collection of stocks (i.e. a portfolio) that invests in assets in a specific market segment (e.g. stocks in companies in the clean energy sector or companies in the fossil fuel industry exclusively). As such, the ETF price can be an approximate indicator of the industry's future growth. Moreover, when including many stocks in a portfolio, the firm-specific risk is reduced, making systematic risks the main price drivers. This implies that a significant change in the price of an ETF is likely caused by a change in a systematic risk factor, such as news related to climate change.

The stock data for the study was obtained from the Center for Research in Securities Prices. We focused on equity ETFs launched in 2015 or earlier. Most of these ETFs invest in companies worldwide, though companies from the U.S.A. have a large share due to the size of the US economy, financial markets, and the companies listed in the U.S.A. We then limited ETFs to trade within the following five industries: energy (separated in this paper into fossil fuel and clean energy sectors), energy-intensive industries, housing, transport, and utilities. This focus is based on Battiston et al. (2017)'s work, which identified the former as climate-sensitive industries. The data for size and value risk factors were obtained from Kenneth R. French's data library. Returns of the S&P 500 Index were as a proxy for market returns.

Besides the wide range of sector-specific ETFs, we also have a set of ETFs that track the market as a whole. The list of ETFs is available in Table A1, see Table 1 for some descriptive statistics. Note that the energy sectors are interconnected since the covariance between fossil fuel-based and clean energy is high (0.69). Both also highly covariate with the transport sector (0.63 and 0.71, respectively).

2.1. Event study

The event study aims to define and distinguish each event's effect from exposure to a general market. The underlying idea is to test whether abnormal (excess) returns around the event dates are different from the expected returns. If the event does not carry new information for the market, there is no surprise, and thus there should be no excess returns for the event. A traditional way of testing abnormal returns (Kothari and Warner 2007) is presented below.

Abnormal returns (AR) are calculated as the difference between realized (historical) and expected returns. Expected returns can be obtained from different models: mean return, the market model, or different factor models. In this paper, we focus on the capital asset pricing model (CAPM, introduced by Sharpe (1964) and Lintner (1965)). This model relates expected returns to how the overall market behaves and is provided in Equation (1):

$$R_{it} - r_{ft} = \alpha + \beta_M (R_{Mt} - r_{ft}) + \varepsilon_t \quad (1)$$

where R_M is the return to the market portfolio, r_{ft} is a risk-free rate, and β_M measures the sensitivity for the asset i to the market. To analyze any excess returns in the event window, we compute realized abnormal returns for each observation within the event window.

Table 1. Sample statistics for sectorwise daily returns for 2009–2016. Returns are given in percentages. Columns (1) to (6) report covariance among sectors.

Type	Mean	Std.Dev	Min	Q1	Median	Q3	Max	Skewness	Kurtosis	(1)	(2)	(3)	(4)	(5)	(6)
Market (1)	0.049	1.27	−7.70	−0.50	0.084	0.67	7.57	−0.23	4.35						
Transport (2)	0.039	1.51	−9.10	−0.66	0.117	0.82	8.88	−0.22	4.19	0.76					
Utilities (3)	0.020	0.85	−5.55	−0.42	0.058	0.50	3.91	−0.37	3.07	0.58	0.48				
Energy Intensive (4)	0.040	0.86	−5.63	−0.39	0.070	0.51	3.81	−0.42	3.04	0.66	0.58	0.48			
Housing (5)	0.053	1.56	−9.09	−0.57	0.067	0.70	12.24	0.34	8.96	0.62	0.55	0.47	0.50		
Fossil fuels (6)	0.034	1.76	−8.99	−0.85	0.044	0.93	7.62	−0.19	2.24	0.71	0.63	0.50	0.52	0.45	
Clean energy (7)	0.008	1.71	−8.78	−0.81	0.048	0.96	8.85	−0.17	3.04	0.77	0.70	0.50	0.57	0.54	0.69
SP500	0.061	1.12	−6.97	−0.41	0.090	0.59	6.89	−0.20	4.29						
SMB	0.008	0.56	−2.08	−0.34	0.010	0.34	3.58	0.22	1.61						
HML	0.003	0.64	−4.22	−0.31	−0.02	0.29	4.34	0.30	7.93						

The cumulative abnormal returns (CAR) are a rolling sum of abnormal returns over the event window. The CAR is calculated as follows:

$$\mathrm{CAR}^{i}_{\tau_1,\tau_2} = \sum_{\tau=\tau_1}^{\tau_2} (R^{i}_{\tau} - E[R^{i}_{\tau}]). \tag{2}$$

In Equation 2, i corresponds to each ETF, R_τ is the return of the ETF at the time τ, and $E[R^i_\tau]$ denotes an expected return of the ETF, given by Equation (1). τ_1, τ_2 stand for the beginning and the end of the event window, respectively.

We then added the cumulative returns for all ETFs, and computed the cross-sectional average, denoted CAAR. It is used as an estimate for average industry cumulative return and it is defined as follows:

$$\mathrm{CAAR}_{\tau_1,\tau_2} = \frac{1}{N}\sum_{k=1}^{N} CAR^{k}_{\tau_1,\tau_2}. \tag{3}$$

In Equation (3), N denotes the total number of ETFs within a sector. We calculated CAAR separately for each sector. Based on similar event studies (e.g. Oberndorfer et al. 2013; Sorokina, Booth, and Thornton 2013; Qian, Suryani, and Xing 2020; Alsaifi, Elnahass, and Salama 2020), we defined the event window as 1, 3, or 5 days before and after the event. We compare the results for all event window sizes. Our chosen model is estimated based on approximately 200 observations beginning 230 trading days before the event.

Traditional testing of abnormal and cumulative abnormal returns is done based on the t-statistics for a single event and one company. For this paper, a test on standardized returns are applied to ensure that AR can be compared between companies:

$$A_{it} = \frac{\mathrm{AR}_{it}}{s_i\sqrt{1+d_t}} \tag{4}$$

In Equation (4), AR_{it} is the estimated abnormal return for the ETF i on day t, and A_{it} is the scaled abnormal returns. s_i is the regression residual standard deviation; d_t is the correction term of the form $x'_t(X'X)^{-1}x_t$ where x_t and X represent vectors of explanatory variables in the event and the estimation window, respectively.

We chose Patell's (1976) methodology for testing, which includes the number of observations in the estimation window (m) and the number of explanatory variables (p):

$$t_{\mathrm{Patell}} = \bar{A}\sqrt{\frac{n \times (m-p-3)}{m-p-1}}. \tag{5}$$

On top of this test, we apply an adjustment, suggested in Kolari and Pynnönen (2010): $\sqrt{\frac{1-\bar{\rho}}{1+(n-1)\bar{\rho}}}$, where $\bar{\rho}$ is the average of the sample cross-correlations of the estimation period residuals. After multiplying Equation (5) by this factor, we obtained a new test statistics $t_{a\mathrm{Patell}}$ that is adjusted for cross-correlation. We need to address cross-correlation, because in our case ETFs track global indices and include some of the same companies. There is also an overlap in event windows because events took place simultaneously for every ETF.

Robustness. We additionally compared our results against a more sophisticated model for returns prediction derived by Fama and French (1993). This model is called the three-factor model (*FF*3) and is as follows:

$$R_{it} - r_{ft} = \alpha + \beta_M(R_{Mt} - r_{ft}) + \beta_{\text{smb}}\text{SMB}_t + \beta_{\text{hml}}\text{HML}_t + \varepsilon_t \tag{6}$$

In Equation (6), SMB is the returns of small firms less returns on large firms, i.e. 'small minus big-cap' factor, and HML is the returns of firms with a high book-to-market value over returns of firms with a low book-to-market value; thus, it is called the 'high minus low book-to-market-ratio' factor.

According to Corrado (2011), the estimated abnormal returns in the event study are subject to cross-sectional correlation but also event-induced volatility. To address this issue, we used a scaled test statistic called BPM (t_{BMP}; see Boehmer, Musumeci, and Poulsen 1991), based on the t-test that accounts for event-induced volatility. The BPM test statistic is calculated as follows:

$$t_{\text{BMP}} = \frac{\bar{A}_{it}\sqrt{n}}{s}, \tag{7}$$

where s is the (cross-sectional) standard deviation of the event-day-scaled abnormal returns. While accounting for event-induced volatility, t_{BMP} is still prone to cross-sectional correlation. We used the method suggested in Kolari and Pynnönen (2010) to adjust also this test statistic for cross-correlation. A new measure is denoted as $t_{a\text{BMP}}$. We used BMP test for the abnormal and cumulative abnormal returns and its adjusted version for check.

3. Empirical results

We analyzed each ETF's reaction to climate-related events by running a regression (1) for each ETF accounting for each event. We made a prediction based on the regression analysis to produce abnormal returns for further testing. We then obtained abnormal returns averaged for each ETF type and calculated CAR from 10 days before the event to 20 days afterward (Figure 2).

This figure aids in understanding the ETFs' reaction to the events. As one can see, the various ETFs reacted differently in terms of both scale and direction. In the next section, we explore each event in more detail.

3.1. Climategate

The housing sector experienced statistically significant abnormal negative returns of 1.66% on the day of the event followed by a 1.34% rebound the next day (Table 2). This can be explained by a correction for the overreaction to the event. The market ETFs also reacted negatively with $-40\,bps$ (basis points) on day one and down to $-84\,bps$ over three days.

However, at the end of 2009, the real estate market was in distress after the financial crisis, so negative abnormal returns were rather expected and could be explained by factors other than Climategate. The transport ETFs did not react to Climategate since neither abnormal nor cumulative abnormal returns are significantly different from 0.

Table 2. Stock market reaction to Climategate.

Day (s)	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP
	Market ($R^2 = 0.903$)					***Transport*** ($R^2 = 0.714$)					***Utility*** ($R^2 = 0.59$)					***Energy Intensive*** ($R^2 = 0.671$)				
−3	0.11	.77	.85	.58	.74	0.89	.62	.66	.35	.44	0.24	.39	.67	.09	.46	0.44	.35	.65	.08	.50
−2	0.35	.34	.51	.09	.27	0.15	.94	.95	.65	.74	0.41	.16	.47	**.01**	.21	0.28	.26	.59	**.02**	.33
−1	−0.18	.65	.76	.41	.61	0.57	.74	.77	.38	.48	−0.38	.19	.51	**.02**	.26	−0.16	.60	.80	.12	.57
0	−0.42	.12	.27	**<.01**	**.03**	0.22	.89	.90	.24	.32	−0.12	.70	.85	.19	.58	0.07	.86	.93	.45	.79
1	−0.1	.96	.97	.90	.94	0.94	.67	.70	.69	.76	−0.08	.80	.90	.49	.77	−0.19	.48	.74	.08	.50
2	−0.29	.29	.46	.05	.20	−0.62	.74	.77	.54	.64	−0.41	.20	.52	**.01**	.24	0.03	.83	.92	.26	.68
3	−0.14	.60	.73	.24	.45	0.05	.94	.94	.75	.81	0.32	.31	.62	.06	.40	0.32	.34	.65	**.01**	.27
4	0.21	.70	.79	.46	.65	−1.07	.52	.57	**.02**	**.03**	0.25	.36	.65	.08	.44	0.09	.46	.73	.08	.51
5	−0.17	.76	.84	.73	.83	−0.53	.71	.74	.12	.17	0.35	.22	.53	**.02**	.29	−0.07	.94	.97	.82	.94
−1, 1	−0.41	.44	.60	.15	.35	2.05	.56	.60	.53	.62	0.04	.89	.95	.58	.82	0.32	.80	.91	.53	.83
−1, 3	−0.84	.21	.38	**.03**	.14	1.48	.71	.74	.41	.51	−0.05	.98	.99	.89	.96	0.67	.47	.73	**.03**	.40
−1, 5	−0.8	.40	.56	.14	.35	−0.12	.93	.94	.79	.84	0.54	.42	.69	.06	.41	0.69	.39	.69	**.01**	.31
−3, 3	−0.67	.37	.54	**.02**	.10	2.2	.65	.68	.42	.52	−0.02	.99	.99	.94	.97	0.78	.40	.69	**.01**	.28
	Housing ($R^2 = 0.736$)					***Fossil*** ($R^2 = 0.715$)					***Clean*** ($R^2 = 0.722$)									
−3	−0.24	.82	.92	.56	.82	0.79	.08	.54	**<.01**	.24	0.64	.30	.66	.09	.59					
−2	−0.06	.92	.96	.80	.92	−0.21	.70	.90	.14	.77	1.16	.08	.45	**<.01**	.30					
−1	0.71	.36	.66	.05	.42	−1.09	**.03**	.42	**<.01**	.07	−0.5	.30	.67	**<.01**	.24					
0	−1.66	**.02**	.20	**<.01**	**.01**	−0.47	.25	.70	**<.01**	.53	−0.48	.36	.70	**.02**	.45					
1	1.34	.10	.40	**.01**	.21	−0.65	.15	.63	**<.01**	.32	0.47	.58	.82	.14	.65					
2	0.28	.82	.91	.57	.83	−0.75	.13	.60	**<.01**	.52	0.36	.65	.85	.17	.68					
3	−0.26	.63	.82	.26	.66	−0.8	.08	.53	**<.01**	.29	−0.35	.46	.76	.09	.60					
4	−1.03	.14	.47	**<.01**	**.02**	−0.52	.35	.75	**.01**	.57	−0.33	.56	.81	.27	.74					
5	−0.95	.14	.46	**<.01**	**<.01**	0.24	.39	.77	.05	.70	−0.35	.53	.80	**.04**	.51					
−1, 1	−0.56	.47	.73	**.04**	.39	−0.33	.65	.88	.21	.81	0.63	.69	.87	.32	.77					
−1, 3	−0.54	.50	.75	.16	.57	−1.88	.07	.53	**<.01**	.38	0.64	.86	.94	.69	.91					
−1, 5	−2.53	.10	.42	**<.01**	.08	−2.17	.12	.59	**<.01**	.36	−0.04	.76	.90	.51	.85					
−3, 3	0.11	.79	.90	.65	.86	−3.19	**.02**	.38	**<.01**	.24	1.31	.64	.85	.41	.81					

Note: The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (column *AR*), given in %. The abnormal returns were calculated based on the CAPM and tested by the parametric (Boehmer, Musumeci, and Poulsen 1991) test (column *BMP*) and Patell's test (1976; column *Patell*). Columns *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The *underlined p*-values are significant at the 10% level, and ones in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.

A highly significant abnormal return on the fourth day of the event even after correction for cross-correlation based on the adjusted BMP statistic (*aBMP*) is not likely connected to the event.

The energy-intensive and fossil fuel ETFs' results are controversial in terms of the BMP testing: while the fossil fuel sector experienced statistically significant negative abnormal returns, the energy-intensive sector received an additional 69 *bps* within five days. However, these results do not hold after the correction for the cross-sectional correlation. The energy-intensive ETFs' performance in late 2009 is likely related to the continuous rise of the oil prices since mid-2008. The clean energy ETFs' loss in returns is significant only for 48 *bps* on the event day and before the test statistics adjustment. Figure 2 shows that later the clean energy ETFs actually gained positive CAR as the Copenhagen meeting drew nearer.

3.2. Fukushima

As mentioned earlier, we expected a positive reaction of the energy stocks in connection with the Fukushima disaster. However, we also expected clean energy to be preferred as a source with a minimal negative environmental production effect. This type of reaction is exactly what is apparent for the clean energy and fossil fuel ETFs (Table 3). Their CAR reached 5.33% and 2.37%, respectively, within five days, with the greatest abnormal returns on the second and third days.

The Fukushima event is associated with a negative returns of 29–35 *bps* on the event day and the day after for the energy-intensive sector. The utilities sector also had negative returns of 43–73 *bps* on the first three days after the event. However, the statistical significance for both sectors disappeared after the adjustment for cross-sectional correlation.

Although market abnormal returns were negative, they were not statistically significant for most days for the BMP test, while the Patell test shows that $CAR_{[-1;3]} = -1.06\%$ is statistically different from 0. Transport ETFs' abnormal returns were not affected by the event. The housing sector's positive significant cumulative returns were found for three and five days after the event.

3.3. The Paris agreement

The PA was positive news for the clean energy ETFs, and a series of significant abnormal returns in the days following the announcement added up to 8.43% within five days (Table 4). This result remains highly significant irrespective of the test applied.

The market ETFs also had a positive and statistically significant reaction to the news, though of 10 times smaller magnitude (73 *bps*), which disappears for both adjusted and Patell's tests.

The energy-intensive sector also had a positive return of less than 1% on the days after the event, which cumulatively reached 1.2% on the fifth day. However, their statistical significance declines after the adjustment for cross-sectional correlation.

Unlike the clean energy ETFs, the fossil fuel ETFs lost up to 4.2% in returns in connection to the PA. However, a negative reaction to the event could also be seen five days before the event. This indicates that the fossil fuel sector anticipated negative news due to the Paris meeting long before the agreement took place.

Table 3. Stock market reaction to Fukushima.

Day (s)	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP
	Market ($R^2 = 0.876$)					***Transport*** ($R^2 = 0.755$)					***Utility*** ($R^2 = 0.695$)					***Energy Intensive*** ($R^2 = 0.718$)				
−3	−0.14	.50	.65	.07	.24	0.69	.37	.38	.35	.37	−0.02	.94	.97	.87	.95	0.62	**.01**	.12	<**.01**	.10
−2	0.1	.64	.75	.14	.34	0.09	.85	.85	.66	.68	0.57	<**.01**	.09	<**.01**	.14	0.22	**.02**	.20	**.04**	.38
−1	−0.28	.09	.23	.06	.21	0.56	.37	.38	.65	.67	0.27	.15	.46	.09	.44	0.28	.05	.29	**.01**	.21
0	−0.26	.23	.41	.12	.31	0.4	.59	.60	.27	.29	0.04	.93	.97	.87	.94	−0.29	.10	.39	<**.01**	.14
1	−0.07	.54	.68	.62	.76	−0.33	.54	.55	.65	.67	−0.63	<**.01**	.08	**.02**	.29	−0.35	**.02**	.19	<**.01**	.18
2	−0.4	.06	.17	**.04**	.17	−0.05	.87	.88	.94	.94	−0.73	<**.01**	**.04**	<**.01**	.10	−0.24	.23	.55	.09	.49
3	−0.19	.50	.65	.67	.79	0.61	.42	.43	.15	.16	−0.43	**.02**	.23	**.01**	.18	−0.12	.27	.58	.22	.63
4	0.63	**.02**	.07	.20	.42	−0.36	.67	.68	.68	.69	−0.09	.54	.76	.46	.75	0.13	.64	.82	.67	.87
5	0.33	.16	.33	.16	.37	0.37	.62	.62	.34	.36	0.23	.22	.53	.22	.59	0.36	**.04**	.26	**.02**	.29
−1, 1	−0.47	.17	.33	.16	.37	0.76	.57	.58	.34	.36	−0.62	**.04**	.27	**.02**	.29	−0.02	.48	.73	.26	.66
−1, 3	−1.06	**.04**	.13	.15	.36	1.32	.42	.43	.30	.32	−1.78	<**.01**	**.03**	<**.01**	.15	−0.38	.13	.44	.08	.47
−1, 5	−0.1	.73	.81	.51	.69	1.33	.46	.47	.39	.41	−1.64	<**.01**	.07	**.01**	.20	0.11	.53	.76	.42	.76
−3, 3	−1.25	**.03**	.11	.12	.32	1.98	.33	.34	.48	.50	−0.94	**.04**	.28	.06	.38	0.12	.59	.79	.48	.79
	Housing ($R^2 = 0.74$)					***Fossil*** ($R^2 = 0.717$)					***Clean*** ($R^2 = 0.738$)									
−3	0.6	**.03**	.33	<**.01**	.13	−1.22	<**.01**	.08	<**.01**	.10	−0.45	.25	.61	.06	.51					
−2	0.33	.23	.60	**.02**	.42	−0.49	.06	.48	<**.01**	.33	0.28	.30	.65	.20	.68					
−1	0.8	**.01**	.24	**.01**	.34	−2.08	<**.01**	**.01**	<**.01**	.05	−0.67	.05	.36	**.01**	.32					
0	0.04	.82	.93	.60	.87	0.68	**.01**	.28	**.01**	.47	−1.19	<**.01**	.12	<**.01**	.08					
1	−0.02	.99	.99	.98	.99	1.37	<**.01**	.08	<**.01**	.10	3.15	<**.01**	<**.01**	<**.01**	.16					
2	1.1	<**.01**	.11	<**.01**	.21	0.01	.65	.87	.58	.90	4.13	<**.01**	<**.01**	<**.01**	.09					
3	0.44	.10	.47	**.02**	.41	0.79	**.02**	.35	**.01**	.50	0.26	.10	.46	.14	.62					
4	−0.46	.11	.49	.08	.55	1.65	<**.01**	**.03**	<**.01**	.05	−0.02	.72	.88	.73	.91					
5	0.57	**.04**	.35	<**.01**	.24	−0.91	<**.01**	.21	<**.01**	.22	−0.55	.30	.65	.41	.79					
−1, 1	0.62	.15	.53	<**.01**	.28	0.83	.07	.50	**.01**	.52	1.51	**.02**	.27	**.03**	.46					
−1, 3	2.15	<**.01**	.13	<**.01**	**.04**	1.63	**.01**	.32	**.01**	.52	5.9	<**.01**	<**.01**	<**.01**	.08					
−1, 5	2.26	**.01**	.17	<**.01**	<**.01**	2.37	<**.01**	.22	<**.01**	.22	5.33	<**.01**	**.01**	<**.01**	.17					
−3, 3	3.28	<**.01**	.07	<**.01**	.08	−0.94	.13	.58	.08	.68	5.51	<**.01**	**.01**	<**.01**	.14					

Note: The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (column *AR*), given in %. The abnormal returns were calculated based on the CAPM and tested by the parametric (Boehmer, Musumeci, and Poulsen 1991) test (column *BMP*) and Patell's test (1976; column *Patell*). Columns *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The *underlined p*-values are significant at the 10% level, and those in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.

The transport ETFs did not have statistically significant returns in connection with the event. At the same time, utilities and housing ETFs experienced some positive movements in the returns, which cumulatively reached 1.59 and 1.86%, respectively.

3.4. The US election

The results of the USPE 2016 led to highly significant negative abnormal returns in all sectors in the study except for transport, which showed some negative returns at the 10% significance level. Since most sectors had significant negative CAR according to one test or both, we can conclude that the USPE was taken as news that increased uncertainty. However, the magnitude of the reaction differed across sectors. Within five days, market ETFs lost 3.09% in returns. If we consider this result to represent a general reaction pattern, energy-intensive and housing sectors were just in line with the negative market reaction. They had −3.11 and −2.91% in abnormal returns, respectively (Table 5).

However, the results for the energy sectors stand out. The comparison of the reaction based on $CAR_{[-1;\ 5]}$ shows that although fossil fuel ETFs had a negative abnormal return of −2.78%, this is 40 *bps* better than the average market ETFs loss. Moreover, after a period of some abnormal return fluctuations, fossil fuel cumulative returns rebounded after two weeks (Figure 2). In contrast, the clean energy sector cumulatively lost 5.55% in abnormal returns.

The magnitude and sign of the estimated abnormal returns from the CAPM and FF3 model (Table A2) are similar. The same applies to the test results based on the BMP and Patell tests for these models. However, the adjustment for cross-sectional correlation reveals that the significance of the reaction holds for fossil fuel (positive), clean energy (positive), and utilities (negative) ETFs for the Fukushima event; clean energy (positive) ETFs for the Paris Agreement; and all (negative) ETFs for the USPE. These results suggest that climate change-related events have a prominent effect on the energy sector.

4. Discussion

Based on the analysis results, accompanied by Figures 1 and 2, we can summarize the overall impact of the climate-related events on the stock market.

Climategate seems to have brought a negative news shock to all sectors in our study (Figure 1). However, it is associated with a temporary shock that was compensated for within a few days. The evidence is illustrated in Figure 2, which shows that cumulative returns were approximately zero (energy-intensive, transport, and clean energy sectors) or maintained the same level and dynamic as before the event (market, utilities, housing, and fossil fuel sectors). This reaction was concentrated within the first 10 days after the event. Later price development is likely to have been affected by the anticipation of the Copenhagen meeting. A negative reaction to Climategate suggests that the market accounts for the climate change discussion and prices its risks. Since climate change evidence was questioned, the market tried to adjust prices so as not to overcompensate for climate risks.

The stock market reaction to the Fukushima accident was similar. All sectors except fossil fuels had an initial negative reaction since abnormal returns on the event day (day 0 on Figure 1) were below zero on average. Even though negative returns were present a

Table 4. Stock market reaction to the Paris Agreement.

Day (s)	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP
	Market *($R^2 = 0.781$)*					***Transport*** *($R^2 = 0.582$)*					***Utility*** *($R^2 = 0.364$)*					***Energy Intensive*** *($R^2 = 0.706$)*				
−3	−0.02	.31	.52	.20	.46	−0.4	.51	.61	.29	.50	0.11	.56	.82	.45	.81	0.43	**.03**	.30	**.02**	.34
−2	−0.27	.12	.31	**.01**	.11	−0.12	.91	.93	.94	.97	−0.97	<**.01**	.09	<**.01**	.14	−0.44	**.02**	.26	<**.01**	.14
−1	0.19	.46	.64	.29	.55	1.08	.15	.23	.23	.43	0.47	**.01**	.26	**.01**	.34	−0.02	.35	.67	.19	.61
0	0.04	.38	.57	.54	.73	−0.96	.17	.26	.08	.20	0.09	.00	.00	.00	.00	0.22	.06	.38	.08	.49
1	−0.09	.59	.74	.48	.70	−0.35	.52	.62	.29	.49	0.19	.31	.69	**.04**	.48	−0.41	.14	.50	.06	.45
2	0.28	.36	.56	.18	.44	0.08	.81	.86	.73	.84	1.01	<**.01**	.07	<**.01**	.14	0.49	<**.01**	.11	<**.01**	.10
3	0.14	.80	.87	.63	.79	−2.38	**.04**	.07	.37	.57	0.68	**.01**	.26	<**.01**	.30	0.09	.66	.84	.55	.82
4	0.42	.13	.32	.08	.30	0	.86	.90	.94	.96	0.14	.68	.87	.63	.88	0.22	.24	.59	.46	.78
5	−0.03	.85	.91	.76	.86	0.49	.41	.53	.27	.48	−0.64	<**.01**	.20	**.01**	.34	0.15	.35	.67	.34	.72
−1, 1	−0.07	.43	.61	.46	.68	−1.71	.17	.26	.14	.30	0.39	.36	.72	.10	.58	0.24	.12	.48	.08	.48
−1, 3	0.35	.27	.47	**.04**	.22	−4.01	.07	.11	.33	.53	2.09	<**.01**	.11	<**.01**	.21	0.83	**.01**	.18	<**.01**	.16
−1, 5	0.73	.13	.32	**.02**	.13	−3.52	.11	.17	.17	.35	1.59	**.02**	.34	**.01**	.36	1.2	**.02**	.27	<**.01**	.20
−3, 3	0.27	.53	.69	.16	.41	−3.05	.15	.23	.46	.65	1.59	**.01**	.25	<**.01**	.18	0.37	.22	.57	.07	.47
	Housing *($R^2 = 0.441$)*					***Fossil*** *($R^2 = 0.427$)*					***Clean*** *($R^2 = 0.512$)*									
−3	0.85	<**.01**	.16	<**.01**	.28	−1.37	<**.01**	.27	<**.01**	.15	−0.27	.29	.64	.28	.71					
−2	−0.52	**.02**	.38	<**.01**	.35	0.36	.34	.76	.10	.80	−0.64	**.04**	.33	**.02**	.36					
−1	−0.22	.23	.68	.17	.73	1.94	<**.01**	.12	<**.01**	.33	1.02	**.01**	.17	<**.01**	.09					
0	−0.18	.18	.64	.30	.79	−0.59	.19	.68	.05	.75	1.49	**.01**	.15	.07	.52					
1	0.22	.24	.68	.09	.66	1.19	**.01**	.36	<**.01**	.49	0.87	**.04**	.33	**.02**	.37					
2	0.87	<**.01**	.14	<**.01**	.19	−2.33	<**.01**	.11	<**.01**	.45	3.09	<**.01**	<**.01**	<**.01**	.05					
3	0.58	**.01**	.33	<**.01**	.41	−0.95	**.04**	.48	<**.01**	.26	1.11	**.01**	.15	<**.01**	.07					
4	−0.07	.77	.92	.67	.91	0.5	.17	.66	**.03**	.71	1.77	<**.01**	.05	<**.01**	.08					
5	−0.41	.06	.50	**.02**	.54	−0.72	.09	.58	**.01**	.67	0.38	.57	.80	.43	.79					
−1, 1	0.89	**.03**	.43	**.04**	.57	−0.77	.27	.73	.15	.82	2.09	**.02**	.26	.09	.54					
−1, 3	2.34	<**.01**	.10	<**.01**	.20	−4.05	<**.01**	.19	<**.01**	.21	6.28	<**.01**	**.01**	<**.01**	.17					
−1, 5	1.86	<**.01**	.25	<**.01**	.36	−4.27	<**.01**	.25	<**.01**	.40	8.43	<**.01**	<**.01**	<**.01**	.16					
−3, 3	1.59	**.01**	.34	**.01**	.45	−1.76	.21	.69	**.03**	.71	6.67	<**.01**	**.01**	<**.01**	.13					

Note: The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (column *AR*), given in %. The abnormal returns were calculated based on the CAPM and tested by the parametric (Boehmer, Musumeci, and Poulsen 1991) test (column *BMP*) and Patell's test (1976; column *Patell*). Columns *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The *underlined p*-values are significant at the 10% level, and those in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.

Table 5. Stock market reaction to the American election.

Day (s)	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP
	Market ($R^2 = 0.814$)					***Transport*** ($R^2 = 0.685$)					***Utility*** ($R^2 = 0.251$)					***Energy Intensive*** ($R^2 = 0.476$)				
−3	−0.43	<u>.10</u>	.27	.16	.41	−0.19	.90	.93	.91	.96	0.23	.22	.65	.16	.68	0.26	.14	.49	**.03**	.37
−2	−0.27	.96	.98	.97	.98	0.24	.55	.66	.39	.63	−0.3	.16	.60	**.03**	.49	−0.66	<**.01**	<u>.06</u>	<**.01**	**.04**
−1	0.19	.78	.86	.66	.81	0.83	.21	.33	<u>.07</u>	.20	0.47	**.03**	.41	<**.01**	.36	−0.32	**.03**	.29	**.03**	.37
0	−0.07	.71	.81	.52	.71	−1.02	.22	.33	<u>.07</u>	.21	0.4	**.04**	.44	**.01**	.37	0.59	**.01**	.18	<**.01**	.14
1	−1.18	<**.01**	<**.01**	**.04**	.19	−1.05	.21	.32	<u>.10</u>	.27	−2.7	<**.01**	<**.01**	<**.01**	<u>.09</u>	−1.69	<**.01**	<**.01**	<**.01**	.12
2	−0.55	<u>.06</u>	.20	.31	.56	1.45	<u>.09</u>	.15	<u>.06</u>	.19	−2.08	<**.01**	<**.01**	<**.01**	.12	−1.78	<**.01**	<**.01**	<**.01**	.11
3	−0.46	**.01**	<u>.05</u>	.23	.49	−0.26	.88	.91	.87	.93	−0.77	<**.01**	.16	**.03**	.50	−0.32	.18	.54	.34	.72
4	−0.3	.64	.77	.77	.87	1.78	<u>.06</u>	.11	<u>.07</u>	.20	−0.37	<u>.07</u>	.49	**.01**	.42	−0.12	.40	.70	.42	.76
5	−0.11	.34	.54	.26	.51	−0.37	.54	.65	**.01**	**.02**	0.73	<**.01**	.18	<**.01**	.33	−0.05	.71	.87	.61	.84
−1, 1	−1.67	<**.01**	**.01**	**.01**	<u>.09</u>	−2.26	.18	.29	.25	.50	−2.06	<**.01**	**.04**	<**.01**	.13	−0.84	<**.01**	<u>.08</u>	**.02**	.34
−1, 3	−2.68	<**.01**	<**.01**	<u>.06</u>	.26	−1.08	.84	.89	.91	.95	−4.92	<**.01**	<**.01**	<**.01**	.13	−2.94	<**.01**	<**.01**	<**.01**	.17
−1, 5	−3.09	<**.01**	**.01**	<u>.07</u>	.26	0.33	.42	.55	.64	.81	−4.56	<**.01**	<**.01**	<**.01**	.16	−3.11	<**.01**	<**.01**	<**.01**	.17
−3, 3	−2.77	<**.01**	**.01**	<u>.10</u>	.32	−0.01	.52	.64	.73	.86	−4.74	<**.01**	<**.01**	<**.01**	.20	−3.91	<**.01**	<**.01**	<**.01**	.13
	Housing ($R^2 = 0.384$)					***Fossil*** ($R^2 = 0.481$)					***Clean*** ($R^2 = 0.615$)									
−3	−0.36	**.03**	.50	**.01**	.54	−1.46	**.01**	.32	<**.01**	.23	−0.73	**.04**	.32	<**.01**	.19					
−2	0.7	<**.01**	.20	<**.01**	.26	−0.65	.16	.65	<**.01**	<u>.08</u>	−0.06	.89	.95	.84	.94					
−1	−0.15	.34	.77	<u>.07</u>	.68	0.88	<u>.05</u>	.51	<**.01**	.52	−0.38	.43	.72	.42	.77					
0	0.06	.72	.91	.53	.89	−0.81	<u>.10</u>	.59	<**.01**	.23	0.04	.76	.89	.70	.89					
1	−1.79	<**.01**	**.01**	<**.01**	.36	0.12	.94	.98	.91	.99	−3.83	<**.01**	<**.01**	<**.01**	.13					
2	−1.47	<**.01**	**.04**	<**.01**	.46	−0.62	.18	.67	**.02**	.71	−0.82	**.02**	.23	.12	.56					
3	0.18	.19	.68	.27	.80	−1.95	<**.01**	.16	<**.01**	.19	−0.2	.89	.95	.92	.97					
4	1.4	<**.01**	**.02**	<**.01**	.13	0.43	.48	.83	.20	.85	0.08	.94	.97	.93	.97					
5	−0.93	<**.01**	.11	<**.01**	.19	1.51	<**.01**	.29	**.01**	.63	−0.08	.92	.96	.88	.96					
−1, 1	−2.09	<**.01**	<u>.05</u>	<**.01**	.20	−2.15	**.01**	.37	<**.01**	.19	−4.51	<**.01**	<**.01**	<**.01**	<u>.10</u>					
−1, 3	−3.38	<**.01**	**.03**	<**.01**	.33	−4.72	<**.01**	.14	<**.01**	.18	−5.54	<**.01**	<**.01**	**.01**	.24					
−1, 5	−2.91	<**.01**	<u>.10</u>	<**.01**	.43	−2.78	**.02**	.42	<**.01**	.61	−5.55	<**.01**	**.01**	**.02**	.33					
−3, 3	−2.83	<**.01**	.12	<**.01**	.46	−4.49	<**.01**	.23	<**.01**	.31	−5.98	<**.01**	**.01**	**.01**	.27					

Note: The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (column *AR*), given in %. The abnormal returns were calculated based on the CAPM and tested by the parametric (Boehmer, Musumeci, and Poulsen 1991) test (column *BMP*) and Patell's test (1976; column *Patell*). Columns *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The *underlined p*-values are significant at the 10% level, and those in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.

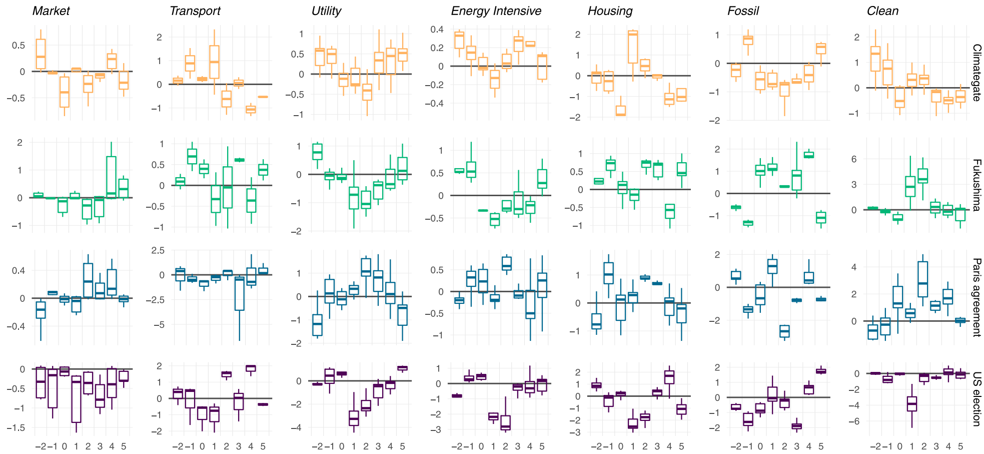

Figure 1. Distribution of the abnormal returns from the capital asset pricing model calculated from two days before the event until five days after event. *Y*-axis – estimated abnormal returns (in percentages), *x*-axis – days.

few days afterward in the history of the energy-intensive and utilities sectors and the market in general, prices reverted later. This means that Fukushima caused some uncertainty in the market, but as more information about the event and its scope and handling became available, prices stabilized. However, the clean energy, fossil fuel, and transport sectors experienced a qualitative shift in the price level since after the initial drop they recovered and began to perform better than before the event. Our results for the ETFs are similar to those obtained by Lei and Shcherbakova (2015) for stocks: they capture an expected behavior on the market because other energy sources would benefit from nuclear energy being compromised. These benefits could be associated with greater future growth in other sectors of the energy industry. However, contrary to Ferstl, Utz, and Wimmer (2012), who used bootstrapping for the inference, our analysis shows a significant positive impact on the clean energy ETFs with the FF3 specification.

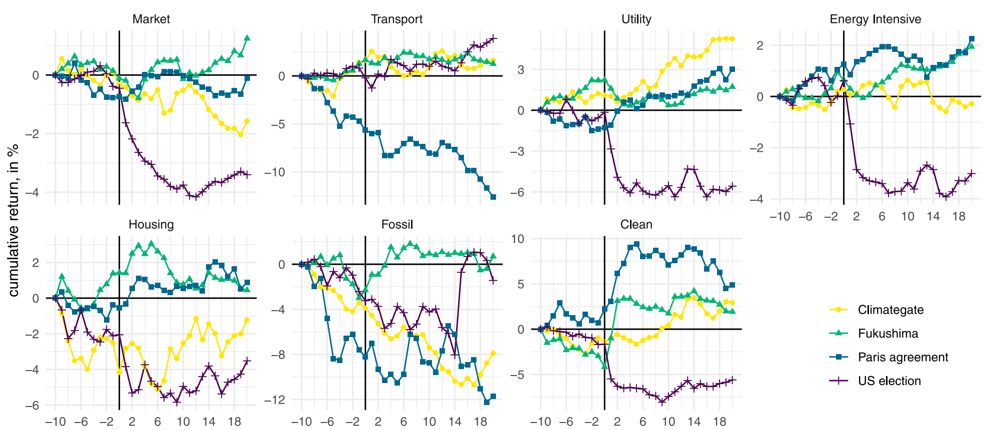

Figure 2. Cumulative abnormal returns from the capital asset pricing model calculated from 10 days before the event until 20 days after the event.

The PA caused a positive price development in the market. The market in general and the utilities, energy-intensive, and housing sectors in particular also remained optimistic after the event. The PA created a positive long-term change for the clean energy sector since its CAR increased dramatically. However, this sector likely overreacted since CAR declined after 11 trading days. Such results suggest that better market conditions for clean energy development are anticipated.

Because the PA was not a one-day event, it appears that the sectors analyzed here anticipated some changes in climate change policy since the CAR of the fossil fuel and transport sectors also decreased before the agreement announcement, corroborating the results of Pham et al. (2019) for Germany and Diaz-Rainey et al. (2021) for the US oil and gas companies. However, new information about the agreement reached further reduced asset values in the U.S.A. as was the case for the EU (Birindelli and Chiappini 2021).

The expectation about different restrictive measures against fossil fuels (i.e. extraction limits, required carbon compensation) and transport (i.e. emission control) affected these sectors' growth estimation.

The results show that the USPE was a major surprise for the stock market in general. Increased uncertainty about the future of the economy and policies of the new president reduced all returns. Only transport recovered shortly after the price drop, meaning its negative overreaction to USPE results had a temporary effect; later, CAR became positive and stable, which is likely due to the agenda featuring policies favorable for this sector. If we increase the period after the event to 20 days, the USPE had a similar effect for fossil fuel ETFs since CAR reverted to 0 (see Figure 1 for a graphical illustration). This finding is similar to the results of Diaz-Rainey et al. (2021) for stocks. A dramatic CAR recovery occurred when Trump announced his new team on 29 November (day 15). For other sectors, the USPE had a significant permanent effect: their CAR dropped with no subsequent recovery. One could argue that such a reaction could simply be a response to the election itself and not connected to climate change risks. However, our results contrast with those of Blau, Griffith, and Whitby (2019), who found a positive reaction of pharmaceutical and healthcare companies to the USPE. This means that the reaction is indeed sector-specific and can be connected to the candidate's political program concerning climate-related issues.

Considering sector-specific responses, the ETFs' reaction to the events has a systematic character. In terms of the climate change risks for each type of ETF, clean energy ETFs have lower transition risks since the firms in such ETFs have smaller carbon footprints. We argue that expectations about clean energy development are among the major factors that drive stock prices in this sector and others. Renewable energy prices has the potential to be lower than those of fossil fuels. If climate change policy supports the transition to a low-carbon economy and thus creates favorable conditions for clean energy, its prices are likely to decrease in the future. The utilities, energy-intensive, and housing sectors will benefit from lower energy prices. The International Renewable Energy Agency (IRENA) statistics also show that solar energy costs became comparable to those generated by fossil fuels in 2016 and that renewable energy costs decreased later.[1]

In contrast, transportation is strongly dependent on fossil fuels and is among the most significantly emitting sectors, accounting for 28% of total greenhouse gas emissions in the U.S.A. and 14% worldwide (see US EPA 2019a, 2019b). Thus, this sector will be negatively affected by a transition to a low-carbon economy. This might imply an increase in fossil energy costs and a challenging change for most of the current vehicles in this sector.

Our findings suggest that sector-specific climate sensitivity, discussed in Battiston et al. (2017) via climate stress testing of the financial system in five-year intervals up to 2050, is also present in the stock market for a shorter horizon. The stock market and ETF stocks in particular experience price adjustments in connection to climate change-related events. Namely, these events are associated with lowering of transition political risks (PA) and transition market risks (Climategate, Fukushima) since they motivate the shift to and development of cleaner energy sources based on current climatic issues. One possible explanation of changes in the non-energy ETFs' return could be the transition climate risk premium. Since climate transition risks become better recognized after climate-related events, investors adjust prices to account for the potential risk premium. Climate change policy addresses the reduction of carbon emissions. It makes sectors dependent on energy, especially fossil fuel energy, sensitive to the policy-related decisions. The more restrictive the climate policy expected, the higher the transition climate risks implied and the higher the compensation for the accompanying risks and vice versa. This is exactly what happened in case of the PA, for instance, since the utilities, energy-intensive, and housing sectors' returns increased. In contrast, these sectors' returns decreased when less focus on climate change was expected after the USPE.

In summary, we investigated how investors in financial markets account for climate change risk by performing an event study of 118 ETFs from six different industry sectors. In most cases, the effects of the selected events were significant for the sectors we studied. Not surprisingly, we found that the energy industry has the highest magnitude of abnormal returns related to the events for both the fossil fuel and clean or renewable energy sectors. Other sectors' dependence on energy shaped their reaction to the events. The sectors' responses to the events have a systematic character that is reflected in the directions of the abnormal price changes around similar events: the response pattern is the same for events that similarly contribute to the discussion of climate change consequences and policies. We argue that the stock market recognizes events that carry new information about transition climate risks, and investors in the market are quick to adjust prices accordingly. This implies that policymakers should be aware of the market reactions to climate change policy since investors price the accompanying changes in terms of both risk and growth expectations.

Note

1. IRENA. 2020. How Falling Costs Make Renewables a Cost-effective Investment (webpage).

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Yevheniia Antoniuk http://orcid.org/0000-0003-0727-3047
Thomas Leirvik http://orcid.org/0000-0002-8174-601X

References

Alley, R. B. 2003. “Abrupt Climate Change.” *Science* 299 (5615): 2005–2010. https://doi.org/10.1126/science.1081056

Alsaifi, Khaled, Marwa Elnahass, and Aly Salama. 2020. “Market Responses to Firms’ Voluntary Carbon Disclosure: Empirical Evidence From the United Kingdom.”*Journal of Cleaner Production* 262: 121377. https://doi.org/10.1016/j.jclepro.2020.121377.

Andreae, Meinrat O., Chris D. Jones, and Peter M. Cox. 2005. “Strong Present-day Aerosol Cooling Implies a Hot Future.” *Nature* 435 (7046): 1187–1190. https://doi.org/10.1038/nature03671

Battiston, Stefano, Antoine Mandel, Irene Monasterolo, Franziska Schütze, and Gabriele Visentin. 2017. “A Climate Stress-test of the Financial System.” *Nature Climate Change* 7 (4): 283–288. https://doi.org/10.1038/nclimate3255

Betzer, André, Markus Doumet, and Ulf Rinne. 2013. “How Policy Changes Affect Shareholder Wealth: The Case of the Fukushima Dai-ichi Nuclear Disaster.” *Applied Economics Letters* 20 (8): 799–803. https://doi.org/10.1080/13504851.2012.748172

Birindelli, Giuliana, and Helen Chiappini. 2021. “Climate Change Policies: Good News Or Bad News for Firms in the European Union?.” *Corporate Social Responsibility and Environmental Management* 28 (2): 831–848. https://doi.org/10.1002/csr.2093

Blau, Benjamin M., Todd G. Griffith, and Ryan J. Whitby. 2019. “Information in Stock Prices: the Case of the 2016 U.S. Presidential Election.” *Applied Economics* 51 (40): 4385–4396. https://doi.org/10.1080/00036846.2019.1591608

Boehmer, Ekkehart, Jim Musumeci, and Annette B. Poulsen. 1991. “Event-study Methodology Under Conditions of Event-induced Variance.” *Journal of Financial Economics* 30 (2): 253–272. https://doi.org/10.1016/0304-405X(91)90032-F

Bolton, Patrick, and Marcin T. Kacperczyk. 2021. “Do Investors Care About Carbon Risk?.” *Journal of Financial Econometrics*. (In press). https://doi.org/10.1016/j.jfineco.2021.05.008.

Christoff, Peter. 2016. “The Promissory Note: COP 21 and the Paris Climate Agreement.” *Environmental Politics* 25 (5): 765–787. https://doi.org/10.1080/09644016.2016.1191818

Clapp, Christa, Harald Francke Lund, Aamaas Borgar, and Elisabeth Lannoo. 2017. *Shades of Climate Risk: Categorizing climate risk for investors*. Technical Report. Oslo: CICERO.

Corrado, Charles J. 2011. “Event Studies: A Methodology Review.” *Accounting and Finance* 51 (1): 207–234. https://doi.org/10.1111/j.1467-629X.2010.00375.x

Diaz-Rainey, Ivan, Sebastian A. Gehricke, Helen Roberts, and Renzhu Zhang. 2021. “Trump Vs. Paris: The Impact of Climate Policy on U.S. Listed Oil and Gas Firm Returns and Volatility.” *International Review of Financial Analysis* 76: 101746. https://doi.org/10.1016/j.irfa.2021.101746

Easterling, David, Gerald Meehl, Camille Parmesan, Stanley Changnon, Thomas Karl, and Linda Mearns. 2000. “Climate Extremes: Observations, Modeling, and Impacts.” *Science* 289 (5487): 2068–2074. https://doi.org/10.1126/science.289.5487.2068

Fama, Eugene, and Kenneth French. 1993. “Common Risk Factors in the Returns on Stocks and Bonds.” *Journal of Financial Economics* 33: 3–56. https://doi.org/10.1016/0304-405X(93)90023-5

Ferstl, Robert, Sebastian Utz, and Maximilian Wimmer. 2012. “The Effect of the Japan 2011 Disaster on Nuclear and Alternative Energy Stocks Worldwide: An Event Study.” *Business Research* 5 (1): 25–41. https://doi.org/10.1007/BF03342730

Hansen, James, Larissa Nazarenko, Reto Ruedy, Makiko Sato, Josh Willis, Anthony Del Genio, and Dorothy Koch, et al.. 2005. “Earth’s Energy Imbalance: Confirmation and Implications.” *Science* 308 (November): 1431–1435. https://doi.org/10.1126/science.1110252

Hayhoe, Katharine, Daniel Cayan, Christopher Field, Peter Frumhoff, Edwin Maurer, Norman L Miller, Susanne Moser, and et al. 2004. “Emissions Pathways, Climate Change, and Impacts on California.” *Proceedings of the National Academy of Sciences* 101 (34): 12422–12427. https://doi.org/10.1073/pnas.0404500101

He, Xubiao, and Yi Liu. 2018. “The Public Environmental Awareness and the Air Pollution Effect in Chinese Stock Market.” *Journal of Cleaner Production* 185: 446–454. https://doi.org/10.1016/j.jclepro.2018.02.294

Jung, Juhyun, Kathleen Herbohn, and Peter Clarkson. 2018. “Carbon Risk, Carbon Risk Awareness and the Cost of Debt Financing.” *Journal of Business Ethics* 150 (4): 1151–1171. https://doi.org/10.1007/s10551-016-3207-6

Kolari, James W., and Seppo Pynnönen. 2010. “Event Study Testing with Cross-sectional Correlation of Abnormal Returns.” *Review of Financial Studies* 23 (11): 3996–4025. https://doi.org/10.1093/rfs/hhq072

Kothari, S. P, and Jerold Warner. 2007. “Econometrics of Event Studies.” In Handbook of Empirical Corporate Finance. Vol. 1, edited by B. Espen Eckbo, 3–36. Amsterdam: Elsevier.

Krueger, Philipp, Zacharias Sautner, and Laura T. Starks. 2020. “The Importance of Climate Risks for Institutional Investors.” *Review of Financial Studies* 33 (3): 1067–1111. https://doi.org/10.1093/rfs/hhz137

Lei, Zhen, and Anastasia V. Shcherbakova. 2015. “Revealing Climate Change Opinions Through Investment Behavior: Evidence From Fukushima.” *Journal of Environmental Economics and Management* 70: 92–108. https://doi.org/10.1016/j.jeem.2015.01.004

Leiserowitz, Anthony A., Edward W. Maibach, Connie Roser-Renouf, Nicholas Smith, and Erica Dawson. 2013. “Climategate, Public Opinion, and the Loss of Trust.” *American Behavioral Scientist* 57 (6): 818–837. https://doi.org/10.1177/0002764212458272

Li, Meng, Liye Dong, Jing Luan, and Pengfei Wang. 2020. “Do Environmental Regulations Affect Investors? Evidence From China’s Action Plan for Air Pollution Prevention.” *Journal of Cleaner Production* 244: 118817. https://doi.org/10.1016/j.jclepro.2019.118817

Lintner, John. 1965. “The Valuation of Risky Assets and the Selection of Risky Investments in Stock Portfolio and Capital Budgets.” *Review of Economics and Statistics* 47 (1): 13–27. https://doi.org/10.2307/1924119

Matthews, Damon, Nathan Gillett, Peter Stott, and Kirsten Zickfeld. 2009. “The Proportionality of Global Warming to Cumulative Carbon Emissions.” *Nature* 459 (7248): 829–832. https://doi.org/10.1038/nature08047

Matthews, Tom K. R., Robert L. Wilby, and Conor Murphy. 2017. “Communicating the Deadly Consequences of Global Warming for Human Heat Stress.” *Proceedings of the National Academy of Sciences* 114 (15): 3861–3866. https://doi.org/10.1073/pnas.1617526114

Mukanjari, Samson, and Thomas Sterner. 2018. *Do Markets Trump Politics? Evidence from Fossil Market Reactions to the Paris Agreement and the US Election*. Technical Report. Resources for the Future.

Nordhaus, William. 2019. “Climate Change: The Ultimate Challenge for Economics.” *American Economic Review* 109 (6): 1991–2014. https://doi.org/10.1257/aer.109.6.1991

Nordhaus, William, and Zili Yang. 1996. “A Regional Dynamic General-Equilibrium Model of Alternative Climate-Change Strategies.” *American Economic Review* 86 (17): 741–765.

Oberndorfer, Ulrich, Peter Schmidt, Marcus Wagner, and Andreas Ziegler. 2013. “Does the Stock Market Value the Inclusion in a Sustainability Stock Index? An Event Study Analysis for German Firms.” *Journal of Environmental Economics and Management* 66 (3): 497–509. https://doi.org/10.1016/j.jeem.2013.04.005

Patell, James M. 1976. “Corporate Forecasts of Earnings Per Share and Stock Price Behavior: Empirical Test.” *Journal of Accounting Research* 14 (2): 246–276. https://doi.org/10.2307/2490543

Pham, Huy, Van Nguyen, Vikash Ramiah, Kashif Saleem, and Nisreen Moosa. 2019. “The Effects of the Paris Climate Agreement on Stock Markets: Evidence From the German Stock Market.” *Applied Economics* 51 (57): 6068–6075. https://doi.org/10.1080/00036846.2019.1645284

Phillips, Peter C. B., Thomas Leirvik, and Trude Storelvmo. 2020. “Econometric Estimates of Earth’s Transient Climate Sensitivity.” *Journal of Econometrics* 214 (1): 6–32. https://doi.org/10.1016/j.jeconom.2019.05.002

Qian, Wei, Ani Wilujeng Suryani, and Ke Xing. 2020. “Does Carbon Performance Matter to Market Returns During Climate Policy Changes? Evidence From Australia.” *Journal of Cleaner Production* 259: 121040. https://doi.org/10.1016/j.jclepro.2020.121040.

Sarkodie, Samuel Asumadu, Samuel Adams, Phebe Asantewaa Owusu, Thomas Leirvik, and Ilhan Ozturk. 2020. “Mitigating Degradation and Emissions in China: The Role of Environmental

Sustainability, Human Capital and Renewable Energy." *Science of the Total Environment* 719: 137530. https://doi.org/10.1016/j.scitotenv.2020.137530
Sarkodie, Samuel Asumadu, Samuel Adams, and Thomas Leirvik. 2020. "Foreign Direct Investment and Renewable Energy in Climate Change Mitigation: Does Governance Matter?." *Journal of Cleaner Production* 263: 121262. https://doi.org/10.1016/j.jclepro.2020.121262.
Sen, Suphi, and Marie Theres von Schickfus. 2020. "Climate Policy, Stranded Assets, and Investors' Expectations." *Journal of Environmental Economics and Management* 100. https://doi.org/10.1016/j.jeem.2019.102277
Sharpe, William F. 1964. "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk." *The Journal of Finance* 19 (3): 425–442. https://doi.org/10.1111/j.1540-6261.1964.tb02865.x
Sorokina, Nonna, David E. Booth, and John H. Thornton. 2013. "Robust Methods in Event Studies: Empirical Evidence and Theoretical Implications." *Journal of Data Science* 11 (3): 575–606.
Storelvmo, Trude, Thomas Leirvik, Ulrike Lohmann, Peter C. B. Phillips, and Martin Wild. 2016. "Disentangling Greenhouse Warming and Aerosol Cooling to Reveal Earth's Climate Sensitivity." *Nature Geoscience* 9 (4): 286–289. https://doi.org/10.1038/ngeo2670
Teng, Min, and Xubiao He. 2020. "Air Quality Levels, Environmental Awareness and Investor Trading Behavior: Evidence From Stock Market in China." *Journal of Cleaner Production* 244: 118663. https://doi.org/10.1016/j.jclepro.2019.118663
US EPA. 2019a. "Global Greenhouse Gas Emissions Data — Greenhouse Gas (GHG) Emissions." Accessed 2020-06-05. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.
US EPA. 2019b. "Sources of Greenhouse Gas Emissions — Greenhouse Gas (GHG) Emissions." Accessed 2020-06-05. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

Appendices

Appendix 1. Data

Table A1. List of the selected ETFs used in this study.

Ticker	ETF Name	Ticker	ETF Name
	Market		**Fossil fuels**
EEM	iShares MSCI Emerging Markets	FXN	First Trust Energy AlphaDEX ETF
EFA	iShares MSCI EAFE	IEO	iShares US Oil & Gas Explor&Prodtn
IWM	iShares Russell 2000	IPW	SPDR S&P International Energy Sect ETF
IWV	iShares Russell 3000	IXC	iShares Global Energy
SPY	SPDR S&P 500 ETF	IYE	VanEck Vectors Environmental Svcs ETF
VEA	Vanguard FTSE Developed Markets ETF	KOL	VanEck Vectors Coal ETF
VGK	Vanguard FTSE Europe ETF	OIH	VanEck Vectors Oil Services ETF
VTI	Vanguard Total Stock Market ETF	RYE	Guggenheim S&P 500 Equal Wt Energy ETF
	Utilities	USO	United States Oil
EMIF	iShares Emerging Markets Infrastructure ETF	VDE	Vanguard Energy ETF
FUTY	Fidelity MSCI Utilities Index ETF	XES	SPDR S&P Oil & Gas Equipment & Svcs ETF
FXU	First Trust Utilities AlphaDEX Fund	XLE	Energy Select Sector SPDR ETF
GHII	Guggenheim S&P High Income Infrastructure ETF	XOP	SPDR S&P Oil & Gas Explor & Prodtn ETF
GII	SPDR S&P Global Infrastructure ETF		**Clean energy**
IDU	iShares U.S. Utilities ETF	EVX	VanEck Vectors Environmental Svcs ETF
IGF	iShares Global Infrastructure ETF	FAN	First Trust ISE Global Wind Energy Index Fund
INXX	Columbia India Infrastructure Index Fund	GEX	VanEck Vectors Global Alternative Energy ETF
JHMU	John Hancock Multi-Factor Utilities ETF	ICLN	iShares Global Clean Energy ETF
JXI	iShares Global Utilities ETF	KWT	VanEck Vectors Solar Energy ETF
PSCU	PowerShares S&P SmallCap Utilities Portfolio	PBD	PowerShares Global Clean Energy Portfolio ETF
PUI	PowerShares DWA Utilities Momentum Portfolio	PBW	PowerShares WilderHill Clean Energy Portfolio ETF
PXR	PowerShares Emerging Markets Infrastructure ETF	PUW	PowerShares WilderHill Progressive Energy Portfolio ETF
RYU	Guggenheim S&P Equal Weight Utilities	PZD	PowerShares Cleantech Portfolio ETF
SDP	ProShares Ultra Short Utilities	QCLN	First Trust NASDAQ Clean Edge Green Energy Index Fund
TOLZ	ProShares DJ Brookfield Global Infrastructure ETF	TAN	Guggenheim Solar ETF
UPW	ProShares Ultra Utilities		**Housing**
UTES	Reaves Utilities ETF	DXJR	WisdomTree Japan Hedged Real Estate Fund
UTLF	iShares Edge MSCI Multifactor Utilities ETF	EWRE	Guggenheim S&P 500 Equal Weight Real Estate ETF
VPU	Vanguard Utilities ETF	FLM	First Trust ISE Global Engineering and Construction ETF
XLU	Utilities Select Sector SPDR Fund	FREL	Fidelity MSCI Real Estate Index ETF
	Energy intensive	FRI	First Trust S&P REIT Index Fund
BFIT	Global X Health & Wellness Thematic ETF	ICF	iShares Cohen & Steers REIT ETF
CARZ	First Trust NASDAQ Global Auto Index Fund	ITB	iShares U.S. Home Construction ETF
CNSF	iShares Edge MSCI Multifactor Consumer Staples ETF	IYR	iShares U.S. Real Estate ETF
CPER	United States Copper Index Fund	KBWY	PowerShares KBW Premium Yield Equity REIT Portfolio
CUPM	iPath Pure Beta Copper ETN	LARE	Tierra XP Latin America Real Estate ETF
DBB	PowerShares DB Base Metals Fund	MORT	VanEck Vectors Mortgage REIT Income ETF
ECON	Columbia Emerging Markets Consumer ETF	MRRL	ETRACS Monthly Pay 2xLeveraged Mortgage REIT ETN
FOIL	iPath Pure Beta Aluminum ETN	NURE	NuShares Short-Term REIT ETF
FSTA	Fidelity MSCI Consumer Staples Index ETF	OLD	Long-Term Care ETF
FTXG	First Trust Nasdaq Food & Beverage ETF	PAVE	US Infrastructure Development ETF
FXG	First Trust Consumer Staples AlphaDEX Fund	PKB	PowerShares Dynamic Building & Construction
HEVY	iPath Pure Beta Industrial Metals ETN	PRME	First Trust Heitman Global Prime Real Estate ETF
IYK	iShares U.S. Consumer Goods ETF	PSR	PowerShares Active U.S. Real Estate Fund
JHMS	John Hancock Multifactor Consumer Staples ETF	REM	iShares Mortgage Real Estate Capped ETF
JJC	iPath Dow Jones-UBS Copper ETN	REZ	iShares Residential Real Estate Capped ETF

(*Continued*)

Table A1. Continued.

Ticker	ETF Name	Ticker	ETF Name
JJM	iPath Dow Jones-UBS Industrial Metals ETN	ROOF	IQ US Real Estate Small Cap ETF
JJN	iPath Dow Jones-UBS Nickel ETN	RORE	Hartford Multifactor REIT ETF
JJT	iPath Dow Jones-UBS Tin ETN	RWR	SPDR Dow Jones REIT ETF
JJU	iPath Dow Jones-UBS Aluminum ETN	SCHH	Schwab US REIT ETF
KXI	iShares Global Consumer Staples ETF	SRET	Global X SuperDividend REIT ETF
LD	iPath Dow Jones-UBS Lead ETN	USRT	iShares Core U.S. REIT ETF
LEDD	iPath Pure Beta Lead ETN	VNQ	Vanguard REIT ETF
NINI	iPath Pure Beta Nickel ETN	WREI	Wilshire US REIT ETF
PBJ	PowerShares Dynamic Food and Beverage	XHB	SPDR S&P Homebuilders ETF
PSCC	PowerShares S&P SmallCap Consumer Staples Portfolio	XLRE	Real Estate Select Sector SPDR Fund
PSL	PowerShares DWA Consumer Staples Momentum Portfolio		**Transport**
RHS	Guggenheim S&P Equal Weight Consumer Staples	IYT	iShares Transportation Average ETF
RJZ	RICI-Metals ETN	SEA	Guggenheim Shipping ETF
SOIL	Global X Fertilizers/Potash ETF	XTN	SPDR S&P Transportation ETF
UBM	E-TRACS UBS Bloomberg CMCI Industrial Metals ETN		
VDC	Vanguard Consumer Staples ETF		
XLP	Consumer Staples Select Sector SPDR Fund		

Appendix 2. Analysis results

This section presents the regression results for the ETFs' returns for the FF3 (for details, see Subsection 2.1). Figure A1 shows the dynamic of CAR beginning 10 days before each event.

In Table A2, each event was tested separately (i.e. for each event, abnormal returns for the event window were estimated and tested in addition to CAR).

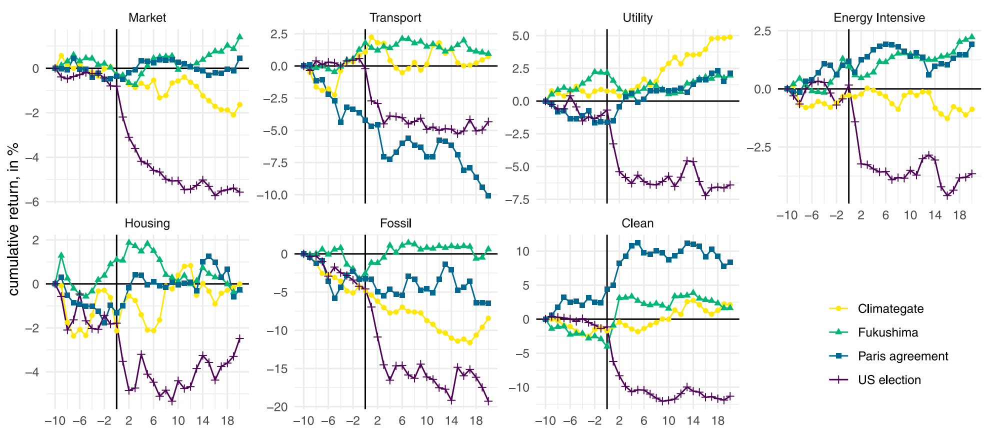

Figure A1. Cumulative abnormal returns from Fama-French three-factor model calculated from 10 days before the event to 20 days after event.

Table A2. Stock market reaction to the selected events.

Day (s)	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP
	Market					***Transport***					***Utility***					***Energy Intensive***				
Climategate																				
	$R^2 = 0.931$					$R^2 = 0.729$					$R^2 = 0.609$					$R^2 = 0.717$				
−3	0.09	.77	.85	.27	.51	0.52	.83	.85	.78	.83	0.14	.60	.80	.18	.56	0.27	.78	.89	.62	.86
−2	0.34	.33	.52	.08	.28	0.01	.96	.97	.86	.90	0.36	.21	.53	**.01**	.24	0.19	.39	.68	.07	.47
−1	−0.17	.70	.80	.48	.68	0.68	.66	.70	.07	.10	−0.38	.19	.50	**.02**	.25	−0.16	.60	.80	.22	.64
0	−0.42	.12	.29	**.01**	.07	0.24	.87	.89	**.03**	**.04**	−0.13	.68	.84	.18	.56	0.06	.90	.95	.56	.83
1	−0.09	.85	.90	.68	.81	1.16	.57	.61	.56	.65	0	.97	.99	.92	.97	−0.06	.84	.92	.56	.83
2	−0.28	.24	.43	**.01**	.07	−0.44	.86	.88	.81	.86	−0.37	.25	.56	**.01**	.24	0.11	.59	.80	.05	.44
3	−0.15	.66	.78	.32	.56	−0.04	.99	.00	.97	.98	0.29	.37	.65	.08	.43	0.26	.43	.70	**.02**	.33
4	0.2	.69	.79	.44	.65	−1.33	.44	.48	.05	.07	0.13	.59	.79	.22	.60	−0.09	.98	.99	.95	.98
5	−0.17	.81	.88	.79	.88	−0.6	.68	.71	.10	.14	0.31	.27	.58	**.03**	.32	−0.14	.72	.86	.28	.69
(−1; 1)	−0.42	.49	.65	.17	.41	1.92	.59	.63	.59	.68	0.01	.94	.97	.74	.89	0.27	.91	.96	.79	.92
(−1; 3)	−0.84	.22	.41	**.04**	.19	1.44	.71	.75	.42	.52	−0.07	.95	.98	.79	.91	0.63	.49	.74	**.04**	.42
(−1; 5)	−0.82	.40	.58	.18	.42	−0.49	.84	.86	.62	.71	0.37	.56	.77	.12	.49	0.41	.65	.83	.15	.59
(−3; 3)	−0.68	.40	.58	.08	.27	2.13	.65	.69	.40	.50	−0.09	.94	.97	.70	.87	0.67	.48	.73	**.03**	.36
Fukushima																				
	$R^2 = 0.928$					$R^2 = 0.764$					$R^2 = 0.697$					$R^2 = 0.757$				
−3	−0.17	.38	.57	.07	.28	0.71	.35	.36	.38	.40	−0.03	.88	.94	.76	.90	0.69	**<.01**	.07	**<.01**	.07
−2	0.05	.99	.99	.95	.97	0.11	.81	.81	.68	.70	0.56	**<.01**	.09	**<.01**	.14	0.33	**<.01**	.09	**.02**	.27
−1	−0.29	.11	.28	.08	.30	0.48	.39	.40	.68	.70	0.32	.09	.38	.06	.39	0.44	**.01**	.11	**<.01**	.10
0	−0.32	.06	.20	**.02**	.13	0.52	.49	.50	.10	.11	−0.04	.57	.78	.39	.71	−0.33	.06	.30	**<.01**	.08
1	−0.03	.75	.84	.80	.89	−0.38	.49	.50	.63	.66	−0.6	**<.01**	.09	**.03**	.30	−0.37	**.01**	.14	**<.01**	.15
2	−0.34	.07	.23	**<.01**	**.04**	−0.2	.95	.95	.97	.97	−0.64	**<.01**	.06	**<.01**	.10	−0.12	.57	.78	.34	.71
3	−0.09	.56	.71	.57	.75	0.31	.64	.65	.05	.06	−0.25	.17	.48	**.02**	.27	0.11	.74	.87	.64	.86
4	0.49	.13	.32	.40	.64	−0.12	.00	.00	.00	.00	−0.23	.14	.44	.08	.43	0.13	.66	.83	.65	.86
5	0.37	**.04**	.16	.06	.25	0.26	.73	.74	.55	.58	0.3	.10	.39	.12	.48	0.45	**.01**	.15	**<.01**	.16
(−1; 1)	−0.52	.08	.24	.10	.32	0.85	.52	.53	.25	.27	−0.67	**.02**	.22	**.02**	.27	−0.02	.46	.71	.25	.64
(−1; 3)	−0.96	.06	.20	.14	.38	0.96	.51	.52	.34	.37	−1.57	**<.01**	**.04**	**<.01**	.15	−0.03	.49	.73	.35	.71
(−1; 5)	−0.1	.76	.85	.48	.69	1.1	.50	.52	.45	.48	−1.5	**<.01**	.09	**.01**	.20	0.56	.66	.83	.49	.79
(−3; 3)	−1.19	**.04**	.15	.10	.32	1.55	.38	.39	.54	.57	−0.69	.11	.41	.10	.46	0.74	.06	.31	**.02**	.29
Paris agreement																				
	$R^2 = 0.86$					$R^2 = 0.61$					$R^2 = 0.373$					$R^2 = 0.727$				
−3	0.01	.27	.51	.09	.37	−0.29	.62	.71	.36	.56	0.08	.67	.87	.54	.84	0.42	.05	.35	**.02**	.37
−2	−0.27	.10	.32	**<.01**	.08	−0.15	.84	.88	.90	.94	−0.94	**<.01**	.10	**<.01**	.15	−0.42	**.02**	.28	**<.01**	.17

(*Continued*)

Table A2. Continued.

Day (s)	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP
−1	0.2	.54	.73	.30	.61	1.18	.12	.19	.20	.38	0.39	**.02**	.32	**.01**	.38	−0.07	.19	.55	.09	.52
0	0.12	.54	.73	.50	.74	−0.59	.31	.42	.14	.29	−0.04	.46	.77	.31	.74	0.16	.24	.60	.17	.60
1	−0.15	.87	.92	.88	.94	−0.44	.43	.54	.34	.54	0.14	.44	.76	.16	.64	−0.46	.13	.50	.08	.50
2	0.3	.30	.55	.17	.48	0.09	.80	.85	.68	.81	1.06	**<.01**	.05	**<.01**	.12	0.53	**<.01**	.10	**<.01**	.11
3	0.14	.60	.77	.30	.61	−2.46	**.03**	.06	.36	.55	0.75	**<.01**	.21	**<.01**	.27	0.14	.47	.75	.31	.71
4	0.4	.30	.54	.51	.75	−0.2	.61	.70	.82	.89	0.27	.28	.67	.19	.67	0.3	.48	.75	.64	.87
5	−0.03	.56	.74	.44	.71	0.54	.37	.47	.26	.45	−0.66	**<.01**	.18	**.01**	.33	0.14	.39	.70	.39	.75
(−1; 1)	−0.01	.37	.60	.26	.57	−1.32	.24	.34	.20	.38	0.17	.79	.92	.55	.85	0.12	.31	.65	.15	.58
(−1; 3)	0.43	.18	.42	**.01**	.14	−3.69	.07	.12	.35	.55	1.98	**<.01**	.13	**<.01**	.18	0.79	**.01**	.22	**<.01**	.14
(−1; 5)	0.8	.10	.31	**.01**	.10	−3.34	.11	.17	.17	.34	1.59	**.02**	.34	**.01**	.33	1.23	**.02**	.28	**<.01**	.20
(−3; 3)	0.35	.46	.67	**.04**	.26	−2.66	.17	.26	.50	.67	1.44	**.01**	.30	**<.01**	.15	0.31	.34	.67	.08	.51
US election																				
			$R^2 = 0.884$					$R^2 = 0.738$					$R^2 = 0.27$					$R^2 = 0.55$		
−3	−0.36	.10	.31	.17	.48	0.13	.52	.62	.60	.75	0.24	.21	.64	.13	.65	0.27	.18	.55	**.04**	.43
−2	−0.2	.38	.61	.48	.72	0.05	.79	.84	.63	.77	−0.13	.54	.82	.27	.75	−0.52	**<.01**	.13	**<.01**	.09
−1	0	.78	.87	.80	.90	0.4	.38	.48	.28	.47	0.31	.13	.58	.08	.61	−0.45	**.01**	.22	**<.01**	.24
0	−0.01	.68	.81	.42	.69	−0.78	.28	.38	.11	.25	0.41	**.04**	.44	**<.01**	.34	0.59	**.01**	.20	**<.01**	.15
1	−1.39	**<.01**	**<.01**	**.01**	.12	−2.5	**.04**	.06	**.02**	.05	−2.58	**<.01**	**<.01**	**<.01**	.07	−1.58	**<.01**	**<.01**	**<.01**	.11
2	−0.91	.05	.20	.39	.67	−0.21	.00	.00	.00	.00	−2.13	**<.01**	**<.01**	**<.01**	.11	−1.81	**<.01**	**<.01**	**<.01**	.06
3	−0.5	**.02**	.12	**.01**	.16	−1.57	.09	.15	.06	.15	−0.44	**.03**	.42	.22	.72	−0.03	.18	.55	.47	.79
4	−0.58	.84	.90	.93	.97	0.61	.21	.30	.31	.51	−0.45	**.04**	.44	**.02**	.46	−0.18	.83	.92	.86	.95
5	−0.11	.13	.36	.08	.34	−0.05	.93	.95	.28	.47	0.63	**<.01**	.24	**<.01**	.37	−0.13	.68	.86	.50	.81
(−1; 1)	−1.76	**<.01**	**.02**	**<.01**	.08	−3.15	.08	.14	.14	.30	−1.93	**<.01**	.06	**<.01**	.14	−0.72	**.01**	.18	**.04**	.42
(−1; 3)	−3.17	**<.01**	**.01**	**.03**	.22	−4.94	.06	.10	.18	.36	−4.5	**<.01**	**<.01**	**<.01**	.17	−2.57	**<.01**	**.01**	**<.01**	.21
(−1; 5)	−3.86	**<.01**	**.01**	**.04**	.26	−4.38	.12	.19	.34	.54	−4.32	**<.01**	**.01**	**<.01**	.23	−2.88	**<.01**	**.01**	**<.01**	.22
(−3; 3)	−3.37	**<.01**	**.02**	.06	.31	−4.49	.12	.18	.32	.52	−4.32	**<.01**	**.01**	**<.01**	.25	−3.54	**<.01**	**<.01**	**<.01**	.13
	Housing		***Fossil***					***Clean***												
Climategate																				
			$R^2 = 0.774$					$R^2 = 0.722$					$R^2 = 0.743$							
−3	−0.34	.53	.75	.10	.48	0.84	.06	.50	**<.01**	.28	0.21	.89	.96	.81	.94					
−2	0.04	.99	.00	.98	.99	−0.26	.64	.87	.09	.74	1.01	.14	.52	**.01**	.38					
−1	1.11	.11	.41	**<.01**	**.04**	−1.28	**.01**	.34	**<.01**	.06	−0.3	.54	.80	**.02**	.44					
0	−1.51	**.02**	.20	**<.01**	**.02**	−0.54	.19	.65	**<.01**	.47	−0.43	.41	.73	**.04**	.50					
1	1.18	.11	.41	**<.01**	.10	−0.58	.19	.66	**<.01**	.37	0.69	.32	.67	**.01**	.36					
2	0.41	.56	.77	.11	.49	−0.81	.09	.55	**<.01**	.45	0.6	.35	.69	**<.01**	.25					
3	−0.21	.63	.81	.33	.69	−0.82	.07	.52	**<.01**	.27	−0.45	.34	.69	**.04**	.50					
4	−0.64	.28	.59	**<.01**	**.01**	−0.7	.19	.65	**<.01**	.44	−0.57	.30	.66	.06	.54					

5	−0.7	.23	.54	**<.01**	**.01**	0.12	.54	.84	.15	.78	−0.39	.48	.77	**.03**	.45
(−1; 1)	−0.67	.35	.64	.05	.38	−0.28	.71	.90	.33	.85	0.46	.85	.94	.64	.89
(−1; 3)	−0.47	.50	.74	.19	.58	−1.92	.07	.52	**<.01**	.36	0.61	.89	.95	.76	.93
(−1; 5)	−1.81	.16	.47	**.01**	.21	−2.49	.07	.52	**<.01**	.25	−0.35	.58	.82	.27	.74
(−3; 3)	0.68	.94	.97	.89	.96	−3.45	**.01**	.33	**<.01**	.18	1.32	.63	.84	.40	.80
Fukushima															
			$R^2 = 0.762$					$R^2 = 0.718$					$R^2 = 0.762$		
−3	0.52	.05	.36	**<.01**	.12	−1.28	**<.01**	.07	**<.01**	.10	−0.43	.30	.65	.09	.57
−2	0.19	.43	.73	.19	.65	−0.58	**.03**	.41	**<.01**	.30	0.31	.24	.61	.12	.61
−1	0.52	.07	.41	.06	.50	−2.17	**<.01**	**.01**	**<.01**	**.04**	−0.71	**.03**	.32	**.01**	.31
0	0.2	.39	.71	**.03**	.43	0.67	**.01**	.30	**.01**	.49	−1.1	**<.01**	.16	**<.01**	.13
1	−0.04	.97	.99	.95	.98	1.4	**<.01**	.07	**<.01**	.10	3.11	**<.01**	**<.01**	**<.01**	.19
2	0.81	**.01**	.19	**.01**	.28	−0.03	.66	.88	.62	.91	4.03	**<.01**	**<.01**	**<.01**	.11
3	−0.15	.59	.81	.36	.75	0.72	**.02**	.37	**.01**	.47	0.05	.38	.71	.32	.75
4	−0.24	.37	.69	.26	.70	1.57	**<.01**	**.04**	**<.01**	**.03**	0.18	.22	.59	.16	.64
5	0.35	.17	.54	.05	.46	−0.94	**<.01**	.20	**<.01**	.22	−0.63	.17	.54	.29	.73
(−1; 1)	0.69	.10	.46	**<.01**	.20	0.8	.08	.52	**.02**	.56	1.58	**.02**	.24	**.02**	.41
(−1; 3)	1.35	**.03**	.29	**<.01**	.05	1.49	**.01**	.34	**.01**	.54	5.66	**<.01**	**<.01**	**<.01**	.13
(−1; 5)	1.45	**.04**	.32	**<.01**	**.03**	2.13	**.01**	.26	**<.01**	.26	5.21	**<.01**	**.01**	**<.01**	.20
(−3; 3)	2.06	**.01**	.19	**<.01**	.13	−1.25	.07	.50	**.03**	.59	5.26	**<.01**	**.02**	**<.01**	.20
Paris agreement															
			$R^2 = 0.475$					$R^2 = 0.54$					$R^2 = 0.572$		
−3	0.79	**<.01**	.18	**<.01**	.29	−1.04	**.01**	.31	**<.01**	.21	−0.1	.61	.82	.62	.86
−2	−0.53	**.01**	.37	**<.01**	.36	0.54	.11	.59	**.02**	.66	−0.66	**.04**	.31	**.02**	.34
−1	−0.23	.20	.66	.13	.71	1.59	**<.01**	.12	**<.01**	.33	1.11	**<.01**	.12	**<.01**	.09
0	−0.33	.05	.49	.06	.63	0.07	.84	.95	.74	.96	1.98	**<.01**	**.04**	**.01**	.33
1	0.32	.10	.57	.05	.62	−0.07	.00	.00	.00	.00	0.64	.16	.52	.11	.56
2	0.82	**<.01**	.16	**<.01**	.21	−1.64	**<.01**	.17	**<.01**	.50	3.17	**<.01**	**<.01**	**<.01**	**.04**
3	0.59	**.01**	.34	**.01**	.46	−0.56	.14	.62	**<.01**	.41	1.05	**.01**	.15	**<.01**	.06
4	−0.03	.88	.96	.83	.96	0.87	**.02**	.40	**<.01**	.46	1.57	**<.01**	.06	**<.01**	.08
5	−0.43	.05	.48	**.02**	.54	−0.69	.06	.52	**.01**	.63	0.44	.42	.72	.29	.71
(−1; 1)	0.77	**.04**	.48	**.02**	.55	−1.04	.11	.58	**.04**	.70	2.52	**.01**	.14	**.04**	.44
(−1; 3)	2.18	**<.01**	.12	**<.01**	.16	−3.24	**<.01**	.22	**<.01**	.24	6.74	**<.01**	**<.01**	**<.01**	.13
(−1; 5)	1.73	**<.01**	.28	**<.01**	.37	−3.05	**.01**	.32	**<.01**	.47	8.75	**<.01**	**<.01**	**<.01**	.14
(−3; 3)	1.42	**.02**	.39	**.01**	.45	−1.11	.42	.79	.16	.81	7.19	**<.01**	**.01**	**<.01**	.11
US election															
			$R^2 = 0.41$					$R^2 = 0.641$					$R^2 = 0.67$		
−3	−0.39	**.02**	.46	**<.01**	.48	−0.82	**.04**	.48	**<.01**	.37	−0.49	.14	.46	**.02**	.32
−2	0.63	**<.01**	.25	**<.01**	.23	−0.59	.16	.64	**<.01**	.25	−0.38	.31	.62	.15	.56
−1	−0.04	.82	.95	.51	.89	−0.36	.44	.80	.13	.78	−0.57	.18	.51	.22	.62

(*Continued*)

Table A2. Continued.

Day (s)	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP	AR	Patell	aPatell	BMP	aBMP
0	0.04	.80	.94	.64	.92	−0.34	.43	.80	<**.01**	.54	0.22	.71	.86	.65	.86					
1	−1.74	<**.01**	**.01**	<**.01**	.30	−2.37	<**.01**	.06	<**.01**	**.01**	−5.09	<**.01**	<**.01**	<**.01**	**.02**					
2	−1.33	<**.01**	.06	<**.01**	.49	−3.93	<**.01**	**.01**	<**.01**	<**.01**	−2.1	<**.01**	<**.01**	<**.01**	.10					
3	0.11	.51	.84	.66	.92	−3.65	<**.01**	**.01**	<**.01**	<**.01**	−1.56	<**.01**	**.03**	<**.01**	.09					
4	1.53	<**.01**	**.01**	<**.01**	.23	−2.01	<**.01**	.09	<**.01**	**.04**	−0.78	**.01**	.18	**.01**	.20					
5	−0.9	<**.01**	.12	<**.01**	.26	1.88	<**.01**	.12	<**.01**	.45	0.27	.21	.54	.16	.56					
(−1; 1)	−2.09	<**.01**	.06	<**.01**	.18	−3.52	<**.01**	.11	<**.01**	**.01**	−5.35	<**.01**	<**.01**	<**.01**	**.03**					
(−1; 3)	−3.3	<**.01**	**.03**	<**.01**	.30	−11.1	<**.01**	<**.01**	<**.01**	<**.01**	−9.01	<**.01**	<**.01**	<**.01**	**.02**					
(−1; 5)	−2.67	<**.01**	.14	<**.01**	.46	−11.23	<**.01**	<**.01**	<**.01**	<**.01**	−9.52	<**.01**	<**.01**	<**.01**	**.04**					
(−3; 3)	−2.7	<**.01**	.14	<**.01**	.42	−12.06	<**.01**	<**.01**	<**.01**	<**.01**	−9.96	<**.01**	<**.01**	<**.01**	**.02**					

Note: The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (column *AR*), given in %. The abnormal returns were calculated based on the Fama-French three-factor model (Fama and French 1993), and tested by the parametric (Boehmer, Musumeci, and Poulsen 1991) test (column *BMP*) and Patell's test (1976; column *Patell*). Columns *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The *underlined p*-values are significant at the 10% level, and those in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.