Do financial markets respond to green opportunities?

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Abstract

This paper investigates whether financial markets respond to firms' climate actions. We exploit the signing of the Paris Agreement, which required governments to commit to ambitious climate action, as a quasi-natural experiment. Using a proprietary green revenue database, we find that firms deriving a significant fraction of their revenues from green goods and services experience on average a 10% increase in cumulative abnormal returns following the Agreement. The empirical evidence indicates that financial markets are responding to opportunities associated with new green markets, and strengthening climate policies can reallocate capital to support green private sector investment.

1 Introduction

Climate change and the decisions by many states to push for carbon neutrality by 2050 bring both risks and opportunities to market participants. So far, the literature has revolved around the risks associated with the low-carbon transition. Investors are reportedly increasingly aware of sustainability and climate-related risks (Ardia et al., 2022; Bolton and Kacperczyk, 2021a). These are typically managed by incorporating analyses of carbon footprints and stranded asset risks (Krueger et al., 2020). Firms are valued more when they adopt cleaner technologies and use resources more efficiently to reduce risks around volatile commodity prices and tightened environmental regulations (Bolton and Kacperczyk, 2021a). This paper focuses on the emerging opportunities associated with the transition to climate neutrality, which requires firms to change the goods and services they produce (Dugoua and Dumas, 2021). We provide the first across-sector empirical study on capital market responses to opportunities associated with the low-carbon transition.

Shifting the global economy towards a sustainable path - to limit the global temperature increase well below 2 degrees Celsius - requires public and private investments. The OECD estimates that

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USD 6.9 trillion a year is required up to 2030 to meet climate and development goals (OECD, 2017). Businesses are expected to play a key role in developing low-carbon technologies and producing goods and services that prevent, minimize or remediate environmental damage, by seizing the green opportunities associated with the low-carbon transition. Firms across sectors are indeed seeking revenue gains by expanding into new green markets. According to Clements et al. (2020) the green economy, at 6% of the globally listed equity market, was worth as much as the fossil fuel sector in 2020.

In this paper, we evaluate the stock market response to firms engaged in green activities. Measuring firms' environmental efforts on the commercial side to develop new cleaner goods and services has been a key challenge. We overcome this by using proprietary data on firms' annual revenues generated from green goods and services available from the financial services company *FTSE Russell*. To the best of our knowledge, this is the first database to provide comprehensive and detailed information on the sustainability of commercial activities across a wide cross-section of publicly listed firms. For example, General Electric is a key technology provider in several green sectors, including wind electricity generation equipment, LED lighting, and railway equipment. According to the FTSE Russell data, its green revenues represented around 16% of total revenue in 2013. We combine firm-level green revenue data with daily stock prices from the Center for Research in Security Prices (CRSP). The resulting new dataset includes over 5,000 publicly listed firms headquartered in the US, representing 98% of US market capitalization. Around 15% of these firms derive some revenues from the production and sale of green goods and services, operating across a wide range of sectors.

To identify a causal relation between green revenues and stock market prices, we exploit the signing of the Paris Agreement as a quasi-natural experiment (Pham et al., 2019; Monasterolo and de Angelis, 2020; Seltzer et al., 2020). After an extensive negotiation period, the Paris Agreement was signed on December 12, 2015. It marked a landmark global commitment in the fight against climate change. Under the Agreement, countries collectively pledged to pursue efforts to limit the increase in global average temperature to 1.5 degrees above pre-industrial levels. The Paris Agreement was arguably an unexpected success, thus providing an exogenous global shock to firms, affecting their global operations. By endorsing the transition to a low-carbon economy, the Paris Agreement created new green opportunities and reduced policy uncertainty. Since the future income stream of inventors became more attractive, we expect the stock market price of green firms to increase.

We document a large causal response to opportunities associated with new green markets. Through an event study, we find evidence that the stock market repriced firms that are engaged in the commercialization of green goods and services. Firms whose green revenue share was among the top 30% of firms in 2013 significantly outperformed the market following the Paris Agreement. These green firms experienced, on average, a 10% higher returns in the post-event period (up to five days following the Agreement) compared to the overall market. This is equivalent to a relative increase of approximately USD 149 million in market capitalization per firm, or a total relative increase of USD 7.6 billion in market capitalization. The level-shift in market capitalization persisted for the entire post-event period. The magnitude of the effect is therefore economically significant. Moreover, we show that additional green effort was rewarded more. Unlike binary indicators of firms' green activities (e.g. the inclusion in a sustainability index or adoption of an environmental management system), our continuous green revenue data can reveal intensive margin effects. We find significant differences between the greenest and less green firms. Our results are robust to alternative event windows and specifications. We also show that there were no confounding events. We show that our results can be interpreted in the context of the wider economy and not only in renewable energy investments, as our results continue to hold when excluding firms in electricity generation.

Our findings are consistent with green opportunities. Similar to our results based on green revenues, firms with clean patents also outperform the overall market after the Paris Agreement. Using a firm-level measure of exposure to climate change opportunities based on discussions between analysts and management Sautner et al. (2022), we find that firms with high exposure to climate change opportunities experienced a significantly higher returns following the Paris Agreement. This is not the case for firms with low exposures to climate change opportunities. Moreover, our results remain even when taking into account climate risks and climate awareness associated with the Paris Agreement. Green firms experienced a level shift following the Paris Agreement, even after controlling for physical risk. The Paris Agreement did not differentially impact firms with high and low exposure to physical shocks related to climate change.

Taken together, our findings show that financial markets are responding to opportunities related to new green markets. The positive repricing of green firms following the Paris Agreement indicates that inventors are now willing to pay a higher price for green stocks given the lower policy risk and the better prospects for these firms. This demonstrates the importance of robust policy signals in the form of international climate change treaties in signaling commitment to future climate action. Our results also indicate that financial markets can differentiate firms by their level of green revenue. This is reassuring because the lion share of green revenue is generated by firms that operate in both green and non-green markets to varying degrees (Kooroshy et al., 2020). Our results give support to numerous recent public and private sector initiatives that push for changes in financial markets to ensure capital flows towards low-carbon investments, including efforts to improve climate-related information and disclosure. For example, the European Union Taxonomy Regulation designed to aid the identification of green products, services, and economic activities entered into force in July 2020 (The European Parliament and The Council of the Eurpean Union, 2020).[1] By helping investors identify, measure and assess risks and opportunities, such policies can ensure capital reallocation towards low-carbon investments. This is paramount given the role of the financial sector in filling the investment gap and bolstering capital flows to green firms whose activities are key to tackle climate change.

This paper contributes to the rapidly growing literature that evaluates whether, and to what extent, climate change affects financial markets. So far, most studies have focused on the

[1] Global private sector initiatives have also been launched, such as the Task Force on Climate-related Financial Disclosures, which promotes consistent climate-related financial risk disclosures to meet investors' information needs. Other examples include the Chinese Green Bond Endorsed Project Catalogue in 2015 and updated in 2020 that defines green financial bonds. Countries such as Canada, Japan and France are also following suit (OECD, 2020). Countries such as the United Kingdom and New Zealand mandate disclosure of climate risk.

risks associated with climate change, particularly for carbon-intensive firms. It has been shown that strengthening national and international climate policies adversely affects carbon-intensive emitters by decreasing financial leverage (Nguyen and Phan, 2020), increasing credit costs (Delis et al., 2020) and decreasing bond credit ratings (Seltzer et al., 2020). Results on how stock markets value carbon intensive firms are mixed. Some studies find that the stock prices of high carbon firms fall following climate policy announcements (e.g. Sen and von Schickfus, 2020; Nguyen and Phan, 2020) while others report limited (e.g. Monasterolo and de Angelis, 2020) or positive response (e.g. Bolton and Kacperczyk, 2021b; Hsu et al., 2020). There is consensus, however, that investors view reporting and disclosure of carbon emissions and targets to be important (e.g. Matsumura et al., 2014; Ilhan et al., 2019; Krueger et al., 2020). In addition to climate related "transitional risks", interest in financial market responses to "physical risks" such as drought and temperature anomalies is growing (e.g. Choi et al., 2020; Pástor et al., 2020; Alok et al., 2020; Hong et al., 2019; Bansal et al., 2019). The overall evidence suggests that financial markets are under-reacting and not yet systematically pricing in the full costs of climate change risks, both transitional and physical, into asset prices (Krueger et al., 2020; Kumar et al., 2019; Litterman, 2020).

Our study compliments this literature by examining the opportunities associated with climate change. Studies on low-carbon investment opportunities have been limited to investments in renewable energy (e.g. Mukanjari and Sterner, 2018; Aklin, 2018; Ramelli et al., 2018) and green bonds (Baker et al., 2018; Flammer, 2020; Tang and Zhang, 2018; Zerbib, 2019).[2] Monasterolo and de Angelis (2020) find that stock market participants respond positively to the Paris Agreement on low-carbon assets, as defined primarily by clean energy indices. However, firms are expanding into markets in green goods and services across a broad range of sectors including industry, transport, agriculture, construction, engineering, finance and consulting. Related literature examines the impact of composite indicators of environmental or social performance, including the ESG (environmental, social, and governance), CSR (corporate social responsibility), and CSP (content security policy) indices, on shareholder wealth (Friede et al., 2015). The mixed results found so far may be due to the low convergence of these indicators (Gillan et al., 2021; Chatterji et al., 2015). While some of these indicators consider whether firms derive revenue from environmentally beneficial products and services, to the best of our knowledge, we are the first to directly examine how the stock market responds to firms pursuing commercial opportunities in new markets for low-carbon goods and services.

The remainder of this paper is structured as follows. We begin with some background on the Paris Agreement in Section 2. We explain the financial market event study methodology and present our main datasets in Sections 3 and 4, respectively. Section 5 presents our main results by estimating the impact of engaging in green commercial activities on stock prices. Section 6 presents evidence that our results are consistent with green opportunities, while Section 7 explores alternative explanations. The validity of our study design and the robustness of our results are discussed in Section 8, before we conclude in Section 9.

[2] Green bonds are an adaptation of project bonds issued to fund green projects in areas such as renewable energy, energy efficiency, clean transportation and responsible waste management. These projects range from the adaptation of the Great Barrier Reef to sea temperature rise to building Nile Delta flood defenses.

2 The Paris Agreement

The Paris Agreement was signed on December 12, 2015 by the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) at the 21st Conference of the Parties (COP 21). It marked a landmark global commitment to combat climate change. Its aim was to accelerate and intensify the actions and investments needed for a sustainable low-carbon future. The Agreement was generally considered as a success. Compared to previous climate summits where agreeing mandatory emission reductions from countries had been a major barrier, the Paris Agreement adopted a new strategy allowing countries to set their own targets, along with an international review process that scrutinized the ambitions of each pledge. This new "pledge and review" approach based on voluntary pledges provided a breakthrough in the negotiation process (Falkner, 2016).[3] In addition, the Paris Agreement also set out aims to make international "finance flows consistent with a pathway towards low greenhouse gas emissions and climate resilient development" (UNFCCC, 2016, p.22).

The success of the Paris Agreement came as a surprise and was not fully anticipated by the markets. The Paris Agreement was preceded by a two-week negotiation period. Until the final signing, there was a high degree of uncertainty around whether an agreement would actually be reached. Indeed, the Agreement was scheduled to pass on Friday December 11, but negotiations continued until Saturday December 12. On Friday (last trading day before the signing), there was still considerable uncertainty around ambition, unanimity, and final wording. For example, it was unclear if the long-term temperature goal of 1.5°C would be included instead of the more lenient 2°C. Moreover, the positions of large oil producing states such as Saudi Arabia were uncertain. During overnight negotiation sessions between Thursday December 10 and Friday December 11, Saudi Arabia opposed the 1.5°C target, arguing that the science is not entirely conclusive. The positions of large emerging economies also remained unclear. The Indian Environment Minister gave a press conference on Friday December 11 at around 4 pm (CET) saying that there would still be a "long road ahead" if there was not more effort from the developed nations and that the likelihood of passing an agreement hung in balance (ClimateHome, 2015). Brazil joined the "coalition of high ambition" (also known as the "progressive alliance") only at around 4:30 pm (CET) on Friday December 11. This was considered a potential game changer, as it was the first large emerging country to join this coalition. This raised expectations that it would bring other large emerging economies to raise their ambition.[4]

Information on the negotiation process was regularly made public and was covered in liveblogs and newsfeeds. Figure 1 shows the trading volume of the S&P 500 Futures. We observed an increase in trading leading to Monday December 14, confirming that a lot of information was provided and that investors updated their portfolios. This is also reflected in Google Trends that shows a spike in searches for the term "Paris Agreement" in the US from December 13 to 19, 2015 (See Figure B.1 in the Appendix B).

[3] Large parts of the Agreement are either non-mandatory or non-enforceable. Bodansky (2016a,b) for instance discuss whether the Agreement, or parts of it, are "legally-binding" based on environmental law.

[4] See for example the Guardian liveblog on 11 December 4:30pm (CET) from the Paris negotiations (Guardian, 2015).

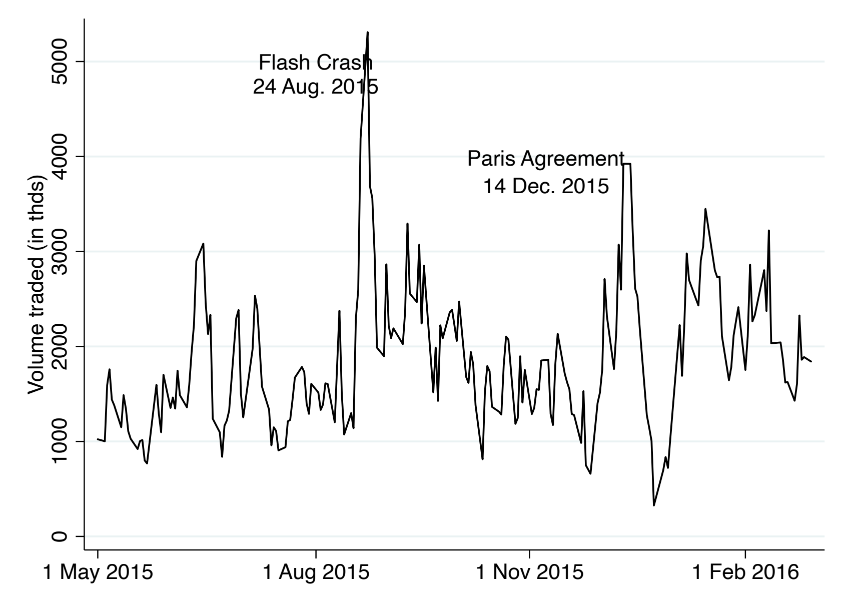


Figure 1: S&P 500 Futures Trading Volume
Note: This figure shows the trading volume (in thousands) of S&P500 Futures (CME-Mini S&P500) for a 10 month period between May 2015 and February 2016 including the passing of the Paris Agreement.

3 Event Study Design

We exploit the Paris Agreement as a significant, discrete and exogenous shock that shifted the public perception about the global commitment to fight climate change. Using a financial market event study setup, we test whether the market reacted to the Paris Agreement by repricing firms with high and low stakes in the green economy. We assess the effect of the Paris Agreement on daily stock market returns by comparing realized (actual) returns with the predicted returns in the absence of the Agreement.

Figure 2 illustrates the stylized timeline of the Paris Agreement. The event day t_0 is defined as the first trading day at which the event becomes effective (MacKinlay, 1997). Monday December 14, 2015 (day 0 in the event analysis) was the first trading day following the Agreement. Our "post event" includes the next 10 days. The "event window" consists of the pre-negotiation and negotiation periods, both of which have a ten day length. The pre-negotiation period is included in order to take into account any anticipation during the negotiation. The pre-event "estimation period" is used to generate predictions of returns for the event period. These predictions capture the counterfactual (i.e. the potential returns had the event not taken place). In line with the existing literature (Fisher-Vanden and Thorburn, 2011; Oberndorfer et al., 2013; Griffin et al., 2015) we define the estimation window to be the one hundred days before the event window ($t_{-121,-21}$).

Following a long tradition in finance literature, we use the Fama-French three-factor model (Fama and French, 1993) to obtain predicted returns in the absence of the Agreement. Specifically, the predicted returns are measured as "excess returns" with respect to the risk-free interest rate and represented by a linear combination of three aggregate and observable risk factors: size

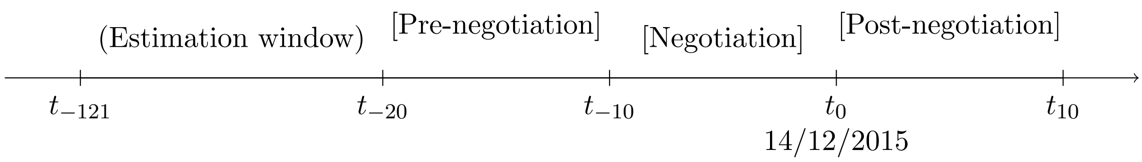


Figure 2: Timeline for the Paris Agreement

risk, value risk, and market risk. The excess returns thus are defined following (Engle, 2001):

$$r^e_{it} = \alpha_i + \beta_{i1} r^e_{mt} + \beta_{i2} SMB_t + \beta_{i3} HML_t + \sqrt{h_{it}}\epsilon_{it} \qquad \epsilon_{it} \sim N(0,1) \tag{1}$$

where r^e_{it} and r^e_{mt} are the excess returns for firm i and the market portfolio (with respect to the risk-free rate) respectively. SMB_t and HML_t refer to small-minus-big market capitalization and high-minus-low book-equity/market-equity factor returns.

Given the time-varying volatility observed in stock returns (i.e. the tendency for current volatility to be positively correlated with its past value) (Ding and Granger, 1996), we model the variance of error terms as generalized autoregressive conditional heteroskedasticity (GARCH). It addresses the so-called volatility clustering by incorporating both an autoregressive component to capture the persistence of volatility and a moving average component to capture the effect of recent shocks on current volatility (Kolari and Pynnonen, 2010, 2011). GARCH models have become widely used to deal with volatility clustering (Engle, 2001).[5] We use GARCH(1,1) models throughout the analysis as follows:

$$h_{it} = a_i + b_i h_{it-1} + c_i h_{it-1}\epsilon^2_{it-1} \tag{2}$$

The parameters $\alpha_i, \beta_{i1}, \beta_{i2}, \beta_{i3}, a_i, b_i, c_i$ are estimated within the estimation window and are used to determine the predicted returns. The difference between realized (actual) and predicted returns is the abnormal (excess) returns. For the event window period, abnormal returns for firm i on day t are then given by the following equation:

$$\widehat{AR}_{it} = r^e_{it} - \left(\hat{\alpha}_i + \hat{\beta}_{i1} r^e_{mt} + \hat{\beta}_{i2} SMB_t + \hat{\beta}_{i3} HML_t\right) \tag{3}$$

We aggregated the estimated abnormal returns across portfolios of green firms and over event days. Following Kothari and Warner (2006), our estimated average abnormal returns (AAR) over the cross-section of N firms are defined as:

[5]Given that the signing of the Paris Agreement is a single event date for our sample of firms, our event study is prone to cross-sectional correlation among abnormal returns. The GARCH model adjusts the standard errors for event-day clustering. We use GARCH(1,1), which has been found to sufficiently explain the systematic variation of stock return volatility in most cases (e.g. Akgiray (1989); Engle (2001)). Results are however robust to non-GARCH modelling of the error term.

$$\widehat{AAR}_t = \frac{1}{N}\sum_{i=1}^{N}\widehat{AR}_{it} \tag{4}$$

Aggregating these estimated average abnormal returns over multiple event days (starting at time t_1 through time t_2) results in our estimated cumulative average abnormal returns (CAAR) (Cowan, 1992; Oberndorfer et al., 2013):

$$\widehat{CAAR}_{t_1,t_2} = \sum_{t=t_1}^{t_2}\widehat{AAR}_t \tag{5}$$

We report our main results in three-day "rolling" cumulative average abnormal returns (CAARs), which covers the three-day window centered around the respective median day and show the gradual change (Sen and von Schickfus, 2020; Kogan et al., 2017).[6] We also report results on five-day CAARs (Oberndorfer et al., 2013) to quantify the magnitude of the effects over the entire post-event period (Figures in Appendix E.1). In general, inference based on CAARs reduces the possibility of incorrect rejection of a true null hypothesis (type I error) but increases the possibility of failing to reject a false null hypothesis (type II error).[7]

To test the hypothesis that the event had in fact an effect on excess returns, we use the non-parametric rank test (Corrado, 1989) which accounts for event-induced volatility (i.e. the fact that the cross-sectional variation in the true abnormal returns in variance increases around the event). Event-induced volatility may bias commonly used parametric tests towards rejecting the null hypothesis. As a robustness check, we also use the BMP (Boehmer et al., 1991) and KP (Kolari and Pynnonen, 2010) parametric tests.[8] Results are robust to using the BMP and KP test statistics (see E.3 and E.4).

4 Data

This paper brings together data from various sources to create a new and comprehensive panel of US listed firms with information on their financial and environmental activities. This section describes the main data sources and how the samples are constructed. Descriptive statistics are reported in Table C.1 of Appendix C.

[6]For instance, the calculation of the rolling 3-day CAAR on day one employs the abnormal returns from the days zero, one and two. Using the Cowan (1992) adjustment for CAARs is important because the nonparametric tests we will use were developed to examine single-day returns (Kolari and Pynnonen, 2011). The Cowan (1992) approach overcomes the potential problems with the Corrado (1989) test by cumulating daily ranks of abnormal returns within the CAAR-period.

[7]Our analysis examines the effect of a single treatment (i.e. the Paris Agreement), in contrast to Marcus and Sant'Anna (2021)'s recently published work on non-financial market event studies. The authors study difference-in-difference methods with staggered treatment timings, which are heterogeneous across units and time. We have also estimated a difference-in-difference, comparing the returns of green, less green and emission intensive firms around the Paris Agreement (see Section 8 on robustness) and our main results remain.

[8]Harrington and Shrider (2007) show that among the parametric tests, the BMP test is robust to event-induced increase in volatility. The KP parametric test further modified the BMP-test statistic to account for cross-correlation in abnormal returns.

Financial Data

Daily stock prices are obtained from the Center for Research in Security Prices (CRSP), which includes more than 32,000 securities with primary listings in any of the main US stock indices (NYSE, AMEX, or NASDAQ).[9] The information used to create our three-factor model (i.e. the excess market return (r^e_{mt}), the small-minus-big market capitalization, and the high-minus low book-equity/market-equity) is available from Kenneth French's website.[10] The market excess returns capture the value-weighted return of all CRSP firms in the US (Fama and French, 2004; Kolari and Pynnonen, 2011).

Green Revenue Data

To identify "green" firms, we use a novel dataset from the financial service company *FTSE Russell* which contains detailed information on listed firms' annual revenues attributable to "green" goods and services. The dataset covers approximately 16,500 global publicly listed firms, representing approximately 98% of global market capitalization between 2009 and 2017. To determine each firm's contribution to the green economy, FTSE Russell (2010) first defines the green economy using a "Green Revenues" classification model. The FTSE definition is similar in structure and highly aligned on core activities to the EU taxonomy. However, in contrast to the EU taxonomy, the FTSE definition encompasses a broader range of activities, such as waste management and pollution control (Kooroshy et al., 2020), and covers goods and services. Specifically, it contains ten broad green sectors and 60 green sub-sectors (see Table A.1 in Appendix A). The data includes sectors traditionally regarded as green, such as renewable energy generation, energy efficiency equipment, and waste and natural resource management. It also includes sectors more recently regarded as green, such as electric vehicles, railway operation, and smart cities design. FTSE analysts then go through firms' annual reports to assess whether there is any evidence of engagement in green subsectors. This analysis is conducted in a centralized way to reduce potential bias from self-reported non-quantifiable environmental performance metrics provided by the firms themselves. For each firm and year, the total green revenues from subsectors is divided by total revenues to express the share of green revenue. There are cases where a firm's annual report indicates that the firm is active in a green sub-sector but the exact revenue attributed to that activity is not disclosed. In such cases, a possible range of values is reported (a minimum and maximum value of the green revenues by sub-sector, where the minimum green revenue is typically set at zero).[11]

Indicators capturing the intensity of firms' environmental efforts are hard to come by, particularly for a large sample of firms across a wide range of sectors. Our measure is based on green revenue share, which captures within-firm strategic shifts away from the non-green and into the green economy. Green revenue share thus captures firms' commercial interest in environmental goods and services related to climate-related opportunities, rather than internally

[9] The data was downloaded in March 2019 through Thomson Reuters Datastream.

[10] We downloaded the data on 18 March 2019 from `https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html`

[11] We therefore face a distribution of minimum green revenue share highly skewed towards zero. Approximately 70% of the minimum green revenue share at the firm level is less than 1%.

driven environmental efforts related to transitional or physical risks. It is an objective and continuous measure that covers a broad range of sectors, with clear advantages over previously used measures based on surveys on green product development (e.g. González-Benito and González-Benito, 2005; Jabbour et al., 2015) or media announcements about new green product introductions (Palmer and Truong, 2017; Gilley et al., 2000).[12]

Among the 16,500 firms in *FTSE Russell*, 5,000 firms are in the US. Among American firms, around 15% (729 firms) are reportedly active in green sectors, 249 of which have a minimum green revenue with a positive value between 2009 and 2013 (see Figure C.1 in the Appendix for the distribution of green revenue share). We focus on this sample of firms with positive green revenue as the most conservative estimate. Firms generating green revenues tend to specialize in green activities, with the median firm generating more than 40% of their turnover from green goods and services. We classify green firms into the percentile of firms' green revenue share in 2013, prior to the Paris Agreement to avoid any anticipation effect. In our baseline specification, we focus on firms with a green revenue share within the top 30%. These firms have a green revenue share between 97 and 100%.[13] We also look at fully green firms (i.e. generating all their revenue from green activities). To assess robustness and establish intensive margin effects, we also examine firms in the top 40% and the median in the distribution of green revenue share. Table 1 below summarizes our various samples.

Definition	Green Revenue Share	N
Fully green	GR 100%	51
Top 30%	GR 97-100%	63
Top 40%	GR 70-100%	83
50-70% percentile	GR 25-96%	63
Median	GR 25-42%	22
Some green revenue	GR > 0	249

Table 1: Samples Definition

5 Abnormal Returns around the Paris Agreement

We present our results in figures showing the event path over three time windows: (1) the ten days prior to the beginning of the negotiations of the Paris Agreement (pre-negotiation period), (2) the ten day negotiation period, and (3) the ten days following the Agreement (post-negotiation period).

[12]Generally, studies on the link between environmental and financial performance rely on crude, discrete proxies, based on self-disclosed information. For example, green firms have been identified based on voluntary membership to an environmental program (e.g. Fisher-Vanden and Thorburn, 2011), voluntary adoption of environmental management standards (e.g. Cañon-de Francia and Garcés-Ayerbe, 2009), environmental certification (e.g. Jacobs et al., 2010) or inclusion in sustainability stock indices (e.g. Oberndorfer et al., 2013). These indicators are limited in coverage. The small sample sizes and the limited variation in the environmental performance indicators present external validity issues and pose difficulties in teasing out the direction of causality between shifts into or away from environmental activities and market performance.

[13]The smallest feasible cutoff is the top 30%. It is not possible to look at the top 10 or 20% separately due to equal values.

Green Firms

We first focus on green firms at the top 30% of green revenue share (GR 97-100%). Figure 3 presents three-day "rolling" cumulative average abnormal returns (CAARs), and the vertical bars show confidence intervals. The portfolios of firms are not systematically different from the market in the pre-negotiation window. The presence of the heads of state during the first days of the negotiations contributed to early optimism that an agreement could be reached. This early optimism shifted towards uncertainty in the last three trading days before the Agreement was signed as negotiations were extended beyond the official deadline (December 11, 2015). The abnormal returns before the Agreement was passed are not significantly different from zero. Strikingly, on the first trading day after the Agreement (Monday December 14, 2015 or day 0), the uncertainty around the returns is diminished and the confidence intervals become much narrower. Following the Paris Agreement, there is an increase of 6% in the returns in the days. We observe a gradual onset of the effects that persist for approximately five days. The abnormal returns then gradually level off and are no longer significantly different from zero in the second week after the Agreement.[14]

This effect implies a level shift in green firms' market capitalization rather than a short-term rise in abnormal returns due to increased media attention. Moreover, the effect is economically large. To assess the magnitude of the effect, we use the (non-rolling) AARs over the five days following the Paris Agreement (in line with Oberndorfer et al., 2013).[15] In the five days post-event window, green firms among the top 30% in terms of green revenue shares experienced a nearly 10% higher returns (Figure E.1a in the Appendix). This is significant at the 5% level. This represents a market capitalization increase of USD 149 million per firm following the Paris Agreement compared to the overall market. Put differently, the Paris Agreement led to a total increase of USD 7.6 billion in the market valuation.[16] To put this into perspective, this figure represents a fraction of the overall market capitalization of all domestic US companies, which was approximately USD 25 trillion over the same time period (World Bank, 2019).[17]

Intensive Margin of Green Revenue

One interesting insight from the green revenue data is that most green revenue is generated by firms that combine both green and non-green products and services. The question is then

[14] The event study design is not well suited to estimate longer-term effects. The presence of other confounding factors that influence returns make it difficult to attribute any observed changes in the return solely to the event in question as time passes (Fama and French, 1993). Abarbanell and Bushee (1997) look at the length of time that abnormal returns persist following earnings announcements, and find that the abnormal returns tend to be short-lived, with most of the impact occurring on the announcement date or the following day.

[15] Using a wider window also provides a more conservative robustness check in terms of significance of the coefficients. If the true effect for a particular sub-sample only exists for the first two days, then the likelihood of a type II error (i.e. the likelihood of failing to reject a false null hypothesis) increases as we average over a wider time window.

[16] We multiply firms' market capitalization with the firm-specific five-day returns following the event to get the average market capitalization per firm and sum the firm-specific change in the market capitalization across green firms to get the total increase in market valuation.

[17] It is important to remember that in the US, the vast majority of stocks are owned by large-scale investors rather than individuals. The latest available data from 2010 shows that 67% of all common shares were owned by large institutional investors (having more than USD 100 million) (Gompers and Metrick, 2001; Blume and Keim, 2012) and has been increasing continuously since the 1950s.

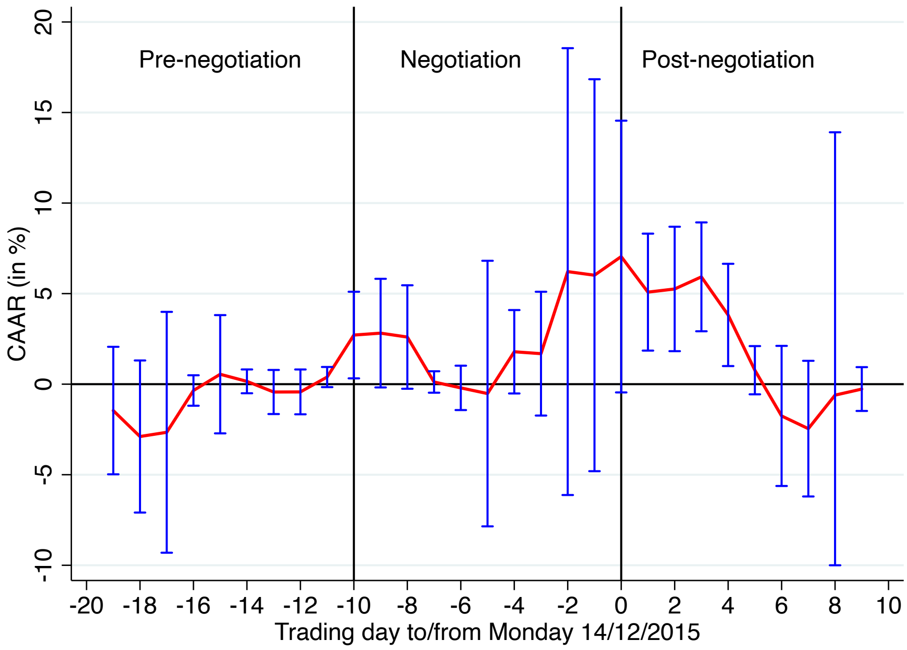
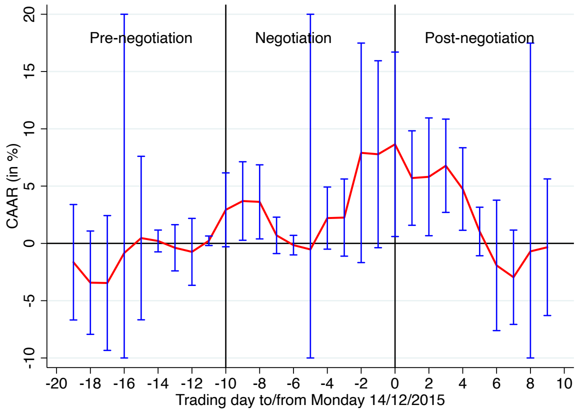


Figure 3: Abnormal returns for top 30% green firms (GR 97-100%)
Note: This figure shows the event path for top 30% of green firms (GR share 97-100%). The red line shows the rolling 3-day CAARs. The blue bars show the 95% Corrado-Cowan confidence intervals.

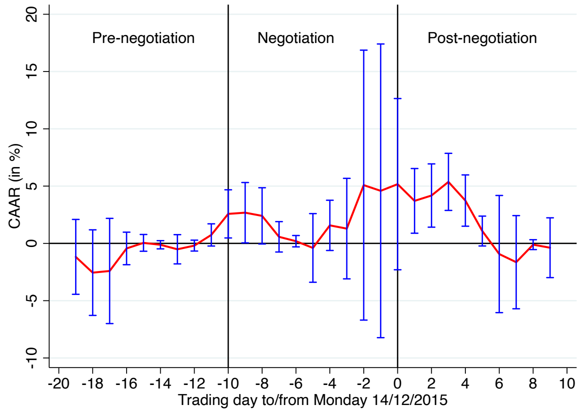
whether stock market investors can differentiate firms by their level of green activity. We explore the intensive margin in Figure 4. First, we focus on the "greenest" firms that have all of their revenue from green activities (Figure 4a). The result is similar in magnitude with CAARs between 6 and 7%. Second, we examine green firms at the top 40% of green revenue share (i.e. GR 70-100%) and observe significant CAARs between 4 and 5% (Figure 4b). For both these samples we observe very similar trends as for our main specification. We observe that the variance in returns increases substantially before the event, as seen by the large confidence intervals. The confidence intervals are narrower following the Paris Agreement. Third, we look at the median of green firms (i.e. GR 24-42%). Even for this relatively small portfolio of firms, the effects remain significant at the 5% level. We observe CAARs between 2 and 3% (Figure 4c). Finally, we look at firm with at least some green revenue (i.e. GR>0) between 2009 and 2013 (Figure 4d). We observe significant CAARs between 2 and 3%. Given that this sample is our most conservative sample of green firms and consists of relatively heterogeneous firms, it not surprising that the effects are smaller in magnitude compared to the main sample of firms among the top 30% in green revenue share (GR 97-100%).[18] Nevertheless, the magnitude of the effect is considerable. It represents an increase in market capitalization of on average USD 39 million per firm compared to the overall market and a total increase of USD 8.7 billion in market capitalization.

In Table D.1 in Appendix D, we test whether the returns of these various samples of green firms are statistically different from one another. In particular, we compare the returns of the sample

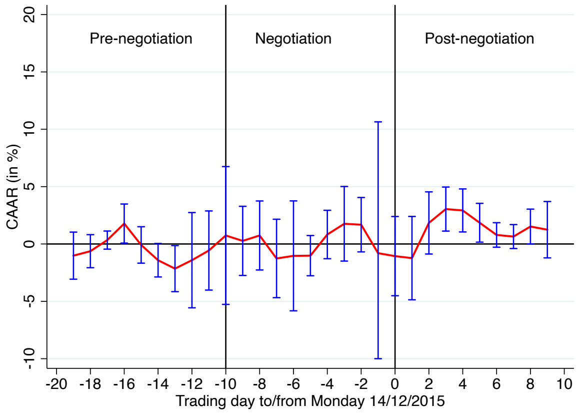
[18]Figure D.1 in Appendix D presents the results for green firms in the 50-70th percentiles (i.e. GR 25-96%).



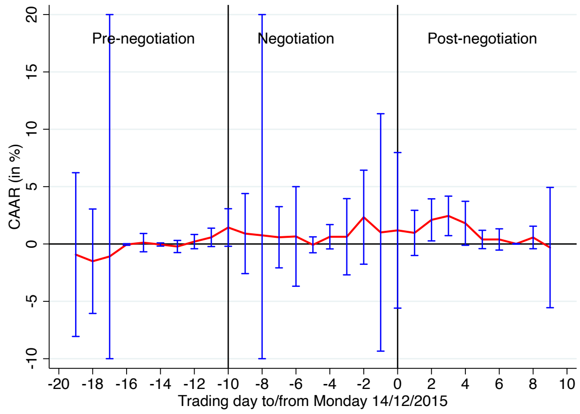
(a) Firms with only green revenue (GR 100%)



(b) Top 40% green firms (GR 70-100%)



(c) Median of green firms (GR 25-42%)



(d) Any green revenue between 2009-13 (GR>0)

Figure 4: Abnormal returns for portfolios consisting of firms with different green revenue intensity

Note: This figure shows the event path for firms with 100% green revenue (panel a), for firms at the top 40% of green revenue share (panel b), for firms at the median of green revenue share (panel c), for firms with any positive green revenue between 2009-13 (panel d). The red line shows the rolling 3-day CAARs. The blue bars show the 95% Corrado-Cowan confidence intervals.

consisting of firms with the greenest share (i.e. firms in the top 30 percentiles and fully green firms), firms in the top 40% (i.e. GR 70-100%), firms in the median (i.e. GR 24-42%), and firms with any green revenue share (i.e. GR>0). Across all six combinations, we observe significant differences, with the greenest firms experiencing significantly higher abnormal returns than the other three groups. Our results therefore point to effects at both the intensive and extensive margins. The greener the firm, the higher its CAAR following the Paris Agreement. This result compliments previous studies that have mostly focused on the extensive margin because firm's environmental performance has so far been measured using indicator variables such as sustainability stock index (Oberndorfer et al., 2013), adoption of ISO norms (Cañon-de Francia and Garcés-Ayerbe, 2009; Jacobs et al., 2010) or membership to the Climate Leaders program (Fisher-Vanden and Thorburn, 2011).

6 Isolating Green Opportunities

While the mechanism underlying our result is hard to pin down conclusively, this section provides suggestive evidence that financial markets are responding to climate-related opportunities. To do so, we examine an alternative measure of green business activity based on patenting in clean technologies, and identify firms' exposure to green opportunities.

Patenting in Clean Technologies

To assess green business activity intensity, we conduct our analysis on an alternative measure of "green" firms based on their clean patents. Despite significant limitations,[19] patent data offer a relatively homogeneous measure of firm innovation activity on both process and products, and are available for a long time period. Using the World Patent Statistical Database (PATSTAT), we exploit the low-carbon patent classification (Y02) recently developed by the European Patent Office to identify patents in low-carbon technologies.[20]

We construct a measure of clean patent intensity based on the share of granted Y02-patents over all patents granted between 2000 and 2013, similar to previous studies (Lanjouw and Mody, 1996; Jaffe and Palmer, 1997; Veugelers, 2012; Dechezleprêtre et al., 2018).[21] We focus on firms in the top 10% of clean patenting firms. For these firms, 67% of granted patents are clean. Figure 5 shows that these clean patenting firms experienced a significant increase in CAARs of around 2-3% following the Paris Agreement, thereby confirming our main results.

[19]For example, not all innovations are patented, different technologies are differently patentable, and the propensity to patent innovations varies considerably across types of firms, sectors and countries (Malerba and Orsenigo, 1995). Granted patents capture only successful innovations, therefore representing only a fraction of innovation activity (Lychagin et al., 2016). Moreover, they mainly capture inventions and do not capture the diffusion or adoption of new technologies. Also, given that some sectors rely more on patents than others, using patent data may lead to a biased view of the green economy.

[20]For a detailed account of the data see Dechezleprêtre et al. (2018).

[21]We allow for a slightly longer time period compared to the green revenue since it takes time for patents to affect firms' products, production processes, or other tangible outputs. Also, many firms do not file a (clean) patent each year, which prevents us from using a single year to define the quantiles.

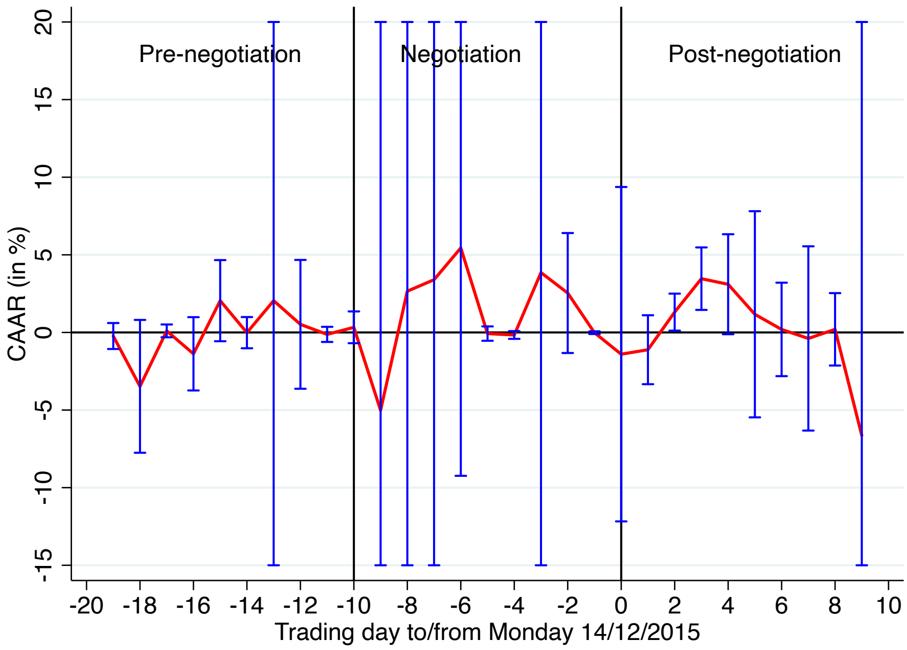


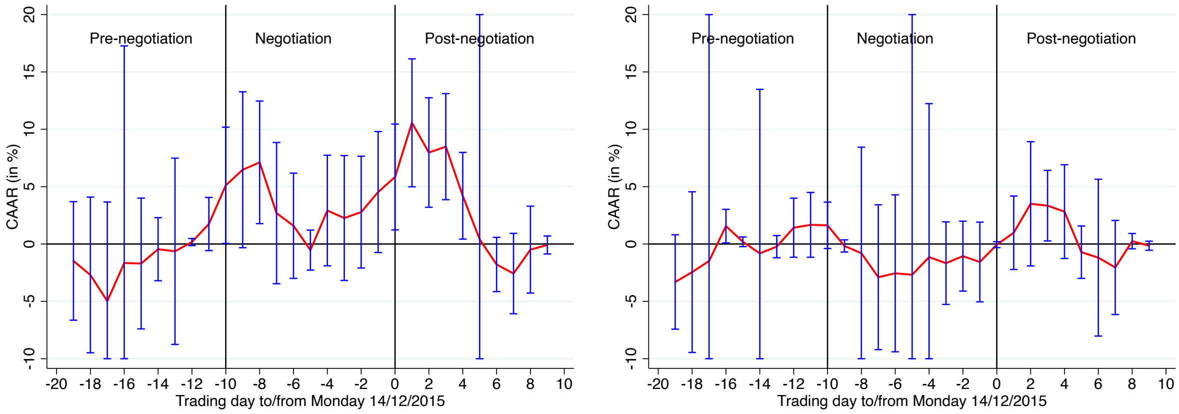
Figure 5: Abnormal returns of top 10% of green patenting firms

Note: This figure shows the event paths for the top 10% of firms (N=37) with the highest clean patent intensity. The red line shows the rolling 3-day CAARs. The blue bars show the 95% Corrado-Cowan confidence intervals.

Measures of Green Opportunities

We also exploit a more direct measure of firms' green opportunities. Based on text analysis of discussions related to climate change in earnings calls between analysts and management, Sautner et al. (2022) have created an index that measures the risk premium for firm-level climate change exposure from 2003 to 2019. Exposure is captured by the proportion of earnings calls devoted to talk about climate change. Of particular interest to our study is the creation of a measure of the perception of firms' exposure related to opportunities associated with climate change.

Among our baseline sample of green firms with a green revenue between 97-100%, we separate firms high and low climate-related opportunity exposure based on the median value in 2014, before the Paris Agreement. Consistent with our baseline findings, firms exposed to high climate change opportunity experienced a 15% CAARs over the five days following the Paris Agreement (Figure 6a). In contrast, firms exposed to low climate change opportunity experienced a 4% CAARs (Figure 6b). Moreover, the difference between high and low climate-related opportunities is statistically significant (Table D.2 in the Appendix). These results provide supporting evidence that climate-related opportunities play an important role in the reaction to the Paris Agreement.



(a) High climate opportunity exposure

(b) Low climate opportunity exposure

Figure 6: Abnormal returns for firm with high and low climate opportunity exposure
Note: This figure shows the event path for firms with above (panel a) and below (panel b) median exposure to climate-related opportunities. The red line shows the rolling 3-day CAARs. The blue bars show the 95% Corrado-Cowan confidence intervals.

7 Alternative Explanations

As a large international event, the Paris Agreement raised awareness of climate change issues. Previous analysis has shown that higher climate awareness can also lead to lower stock returns of polluting firms (Choi et al., 2020). Moreover, the market's response to the Paris Agreement may be capturing not only opportunities but also physical and transitional climate risks. Such risks have in fact been the focus of most studies (e.g. Ardia et al., 2022; Bolton and Kacperczyk, 2021a). We examine both alternative explanations in turn.

Climate Awareness

The effects of the Paris Agreement on green firms' market value could be driven by increased climate awareness around the time of the event. One way to examine this is to contrast our results with the stock market response to the Trump election. This event arguably affected climate opportunities but did not affect awareness to the same extent as the Paris Agreement. During his campaign, Trump promised to roll back policies to address climate change, including the withdrawal of the United States from the Paris Agreement, which he did on June 1, 2017. The Trump election on November 8, 2016 was therefore an unexpected and negative event for green firms. We indeed find evidence of negative abnormal returns (Figure D.2 in the Appendix). The cumulative average abnormal return fell from -2 to -4% the week before the election, and further fell to -6% after the election before bouncing back. This is in line with Mukanjari and Sterner (2018) who find negative abnormal returns for solar energy stocks following this election. The Paris Agreement and the Trump election generated responses of similar magnitude but with opposite signs. This suggests that while climate awareness may play a role, investors are also responding to changes in commitment to climate policy, whether it is in favor of or against green firms.

We also explore climate awareness by looking at the effect of the Paris Agreement in regions where climate awareness was already high before the Paris Agreement (Stokes et al., 2015). We focus on Europe and Japan (Figures D.3 and D.4 in the Appendix).[22] Any subsequent re-pricing of green firms in these countries is less likely to be attributed to climate awareness.[23] For Europe, we see a somewhat similar but less pronounced picture than for the US, with a high level of uncertainty in the last days of negotiation, followed by positive returns for four days following the Paris Agreement. For Japan, green companies' returns did experience a slight increase, though not significantly in response to the Paris Agreement.[24] Overall, we cannot rule out that increased climate awareness may play a role, but this does not invalidate our results.

Finally, awareness to climate change issues around the Paris Agreement can be examined using Google trends. We see that web-searches increased during that period and fell afterwards, as shown in Figure B.2 in the Appendix. Interest in climate change may have peaked in the period leading up to the COP21. Importantly, it appears that awareness did not rise again after the signing of the Paris Agreement. This suggests that our result captures the repricing of the green firms' stock following the Paris Agreement, while increased climate awareness was likely already priced into stock values in the months leading up to the Paris Agreement.

Climate Risks

The green revenues of a firm may correlate with both climate-related opportunities and risks. To account for climate-related risk, we exploit two complementary measures. First, we account for daily physical climate risk exposure as a fourth factor in the Fama-French model (Gostlow, 2021). Using data from Gostlow (2021), we build a physical climate risk exposure as a risk factor-mimicking portfolio. This time series is used to control for risk exposure over time.[25] Figure D.5 in the Appendix shows that the cumulative average abnormal returns remain the same when accounting for the physical climate risk exposure. However, the volatility is smaller than in our baseline sample.

Second, we distinguish the event path of firms with high and low climate change risk exposure. For this, we use a measure created by Sautner et al. (2022) that captures the perception of firms' exposure related to physical shocks associated with climate change.[26] Among our base-

[22] Climate policies in Europe in particular were relatively well established and less contingent on a global climate deal, such that the Paris Agreement was perhaps a lesser shock to European investors.

[23] Choi et al. (2020) show that attention to climate change is higher during periods with abnormally hot weather and that stock market reactions (carbon-intensive firms earning lower stock returns) are weaker for countries that experienced increasing drought trends in the late 20th century before climate change became a global issue. They argue that "countries that have reacted earlier may now show weaker reactions (to abnormal temperatures) - as most people in these countries might have already become aware of climate change.".

[24] There are several reasons for these limited reactions. For example, Japan's commitments under Paris were widely criticized as unambitious, and this may have triggered a limited response by Japanese investors. In general, the results on the EU and Japan samples are less robust for several reasons including smaller sample size, lower trading volume, and lower precision of the three-factor model for Europe due to the Fama-French European three-factors being created at the European level combining several markets.

[25] This is not a firm-specific measure. Rather, it is built as a risk factor-mimicking portfolio in a time-series approach. Specifically, for each month, stocks are grouped into three terciles based on their physical climate risk score. A value-weighted (monthly rebalanced) return for each tercile is then calculated. The risk factor is then constructed as the top tercile minus the bottom tercile, mimicking the Fama-French risk factors.

[26] Unfortunately the frequency of the data is quarterly or yearly, so we cannot introduce it in our model to

line sample of green firms with a green revenue between 97-100%, we distinguish firms with high and low exposure to climate physical risk based on the median value in 2014 before the Paris Agreement. Both groups experienced a positive repricing following the Paris Agreement. However, in contrast to our previous results related to firms with high and low climate-related opportunities, the difference between firms with high and low levels of exposure to physical shocks is not statistically significant (Figures D.6 and D.7 in the Appendix).

Finally, we shed light on whether capital markets respond to green revenue firms that are also exposed to high transitional risks. Focusing on firms in the electric generation and services sector, we compare two samples. The first sample includes high carbon-emitting firms. We use data on the emissions intensity from the *Trucost* Emissions dataset to identify power generators, which has high emissions and thus faces transitional risk.[27] We categorize firms into emissions-intensity percentiles using firms' average carbon intensity for the period between 2009 and 2013 to smooth potential outliers, and focus on the top 10% in terms of CO_2 emissions intensity. These firms are highly exposed to transitional risk but also generate green revenues, primarily through renewable energy, with a mean of 7% and maximum of 35% in green revenue. The second sample consists of green electricity firms that are among the top 30% of all green firms, with green revenue shares ranging between 97% and 100%.

Results show that green revenue firms faced with high transition risk still experienced a small positive and marginally significant effect of less than 4% on stock prices following the Paris Agreement (Figures D.8 and D.9 in the Appendix). For firms that have low-carbon portfolios, the effects are larger with a 12% CAARs after the Paris Agreement. Interestingly, we find that the production of green goods is rewarded by the stock market even for emission-intensive firms. This suggests that while investors face trade-offs between climate transitional risks and opportunities, carbon-intensive firms (at least in the electricity sector) can obtain access to financing by reorienting themselves towards low-carbon goods and services.

8 Validity of the Event Study Design and Robustness

Validity of the Event Study

The absence of confounding events is essential for the validity of event studies. Of particular concern in our setting are events that differentially affect green or emissions-intensive firms from the overall market. Using the Factiva database, we first search for news on any other events or policy announcements in the week following the Agreement. We look for events using the keywords "climate", "renewables", or "emissions" and found no significant events in the week following the Agreement.[28] To further dispel concerns of confounding events, we also screen the most important general political and business news events in the week following

control for climate risk at the daily level.

[27] *Trucost* provides detailed emissions and emissions intensity information for firms representing approximately 93% of global market capitalization. Emission intensity is defined as emissions (in tons) of carbon dioxide equivalents (CO_2) divided by revenue in million US dollars.

[28] Mukanjari and Sterner (2018) state that on December 16, 2015, news articles on record highs of global temperature as well as on solar energy were published. However, they conclude the news coverage on these topics were not sufficient important or prominent to invalidate the event study design.

the Agreement. Two particular events are note worthy. First, in a widely expected move, the US Federal Reserve increased its interest rate by 0.25 percentage points on December 16, 2015. While this may be regarded as a positive signal, indicating that the US economy was growing stronger, it also increased the cost of borrowing for firms and households (The New York Times, 2015). However, this event was not only anticipated but also affected the entire market. Second, on the night of December 15, 2015, the US Congress reached a deal to prevent a year-end government shutdown (The Washington Post, 2015). This deal was reached as a compromise between the Obama White House and the Republican-controlled Congress. It included a USD 1.1 trillion appropriation package and a USD 650 billion tax break package. The bill also lifted a ban on crude oil exports and a tax break for wind and solar energy producers for five years. The effect of lifting the ban on crude oil would, if anything, work in the opposite direction from what we observe for emissions-intensive firms in oil and gas extraction. The tax breaks for solar and wind industries could potentially inflate our results. However, these specific deductions were a relatively small part of the overall deal which included for instance state and local sales tax deductions for businesses. These would have affected the overall market. The industry-specific extensions in tax breaks covered only a small set of renewable energy industries. Since our results also hold when excluding electricity generating firms (see Section E.2), we are not concerned that this deal is driving our results.

Event study results can also be sensitive to the event windows used. Our baseline results are based on a three-day window. However, they are robust to using the entire post event window (days 0-5) (see Appendix E.1). We still see that green firms significantly outperform the market following the Paris Agreement. Using the wider event windows provides a conservative robustness check in terms of the significance of the results. If, for instance, the true effect for a particular sub-sample only exists for the first two days, then the likelihood of a type II error (i.e. failing to reject a false null hypothesis that there is no difference) increases as we average over a wider time window.

Robustness Checks

We present various robustness checks. First, as a placebo check, we perform our analysis on a randomly selected sample of 96 firms without any green revenue (Figure E.7 in the Appendix). Reassuringly, we did not find any statistically significant effect of the Paris Agreement. Second, the average abnormal returns were constructed using equal-weighted averages. As a check, we examine the sensitivity of our results to using a value-weighted portfolio based on firms' market capitalization in 2013 before the Paris Agreement. The positive and significant CAAR in the five days following the Paris Agreement are robust to this specification (see Appendix E.7). Third, we also estimate a difference-in-difference comparing the returns of green, less green and emission intensive firms around the Agreement as an alternative specification (see Appendix E.8). Consistent with our baseline results, we find that green firms in our baseline sample experienced a significant positive return for the five days following the Agreement compared with emission-intensive firms. We also find that firms with a higher share of green revenue experienced statistically significant higher returns than firms with a lower share of green revenue.

We conduct further tests to ensure that our results are not misspecified (Marks and Musumeci, 2017). Instead of using the Corrado test as in our main results, we perform the BMP test statistics (Boehmer et al., 1991) and the KP statistic (Kolari and Pynnonen, 2010) (see Figures in Appendix E.3). Using the BMP test statistics, we observe smaller standard errors than in our baseline results. On the other hand, the standard errors increase compared to our baseline results using KP statistics. We still observe significant effects at 5% across the different portfolios (see Appendix E.4). We also report the average abnormal returns in Appendix E.5. Our results are robust to these alternative specifications.

The opportunities associated with climate change are often synonymous with renewable energy investments. This is not surprising because the generation of renewables has been the main target for subsidies and other policy efforts on climate change (Capros et al., 2011). Indeed, electricity generating firms (US SIC 491) form the largest group, accounting for approximately 18% of our sample of green firms. In a survey of institutional investors, Krueger et al. (2020) find evidence that opportunities related to climate change have so far been limited to renewable energy.

To assess the external validity of our baseline results and test if they are driven by renewable investments, we look at a subsample excluding electricity-generating firms. Figure E.2 shows that the effect persists when excluding electricity generation. They experience a significant abnormal returns of around 4-5%. We also present the results when excluding all public utilities in electricity, gas, and sanitary services (SIC 49) (see Figure E.3). Although the sample size is reduced, the results remain significant. This suggests that investors are valuing firms within the environmental market place across a broad range of economic sectors, not limited to renewable energy.

9 Conclusion

Sustainable finance is an important strategy to mobilize private investment into sustainable economic activities and projects. However, shifting the global economy towards a sustainable path represents both risks and opportunities for market participants. While the literature has mainly focused on the risks associated with this transition (e.g. "asset stranding"), this paper examines the responses by the capital market to green opportunities. We exploit the 2015 Paris Agreement as an exogenous shock to determine whether it channeled capital towards firms engaging in green activities.

This paper provides new evidence that the stock market responds to opportunities associated with the low-carbon transition. We find causal evidence that "green" firms that generate a share of their revenue from producing green goods and services significantly outperformed the market in the week following the Paris Agreement. The results are both statistically significant and economically meaningful. We identify a level shift in green firms' market capitalizations following the Agreement which persists for the entire post-event period. The sample of the greenest firms observed on average a 10% higher returns for the entire post-event period (days 0-5) compared to the overall market. This is roughly equivalent to a relative increase of approximately USD 149 million in the market capitalization per firm. Our results also reveal that the market values green firms at the intensive margin. Firms with higher green revenue shares experienced a larger effect following the Paris Agreement than those with lower green revenue shares. The results can be interpreted in an economy-wide context and are not limited to renewable investments. Our results remain even after controlling for climate risk and awareness. In sum, we provide new evidence that financial markets place value on green business activities and can help allocate financial resources towards action on climate change.

The positive abnormal returns for green firms following the Paris Agreement demonstrate the importance of robust policy signals in the form of international climate change treaties in signaling commitment to future climate action. Our findings also suggest that efforts to improve the availability of information help investors better identify firms with green products and services. Our analysis uses an objective, transparent and detailed quantitative indicator of firms' revenue derived from green goods and services. This information is only available via proprietary commercial data. There is a need to update the financial market architecture to reduce information asymmetries, and to level the playing field for access to information. Standardizing climate change-related metrics on risk and opportunity and increasing their availability can help reallocate financial resources towards firms at the forefront of the low-carbon transition. Momentum has been building in Europe with the EU Taxonomy Regulation that came into effect in January 2022. More research on market responses can help fine-tune these efforts and eventually help shift investments where they are most needed.

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References

Abarbanell, J. S. and Bushee, B. J. (1997). Fundamental analysis, future earnings, and stock prices. *Journal of Accounting Research*, 35(1):1–24.

Akgiray, V. (1989). Conditional heteroscedasticity in time series of stock returns: Evidence and forecasts. *Journal of business*, pages 55–80.

Aklin, M. (2018). How robust is the renewable energy industry to political shocks? Evidence from the 2016 U.S. elections. *Business and Politics*, 20(4):523–552.

Alok, S., Kumar, N., and Wermers, R. (2020). Do fund managers misestimate climatic disaster risk. *The Review of Financial Studies*, 33(3):1146–1183.

Ardia, D., Bluteau, K., Boudt, K., and Inghelbrecht, K. (2022). Climate change concerns and the performance of green vs. brown stocks. *Management Science*, 0(0):0.

Baker, M., Bergstresser, D., Serafeim, G., and Wurgler, J. (2018). Financing the response to climate change: The pricing and ownership of US green bonds. Technical report, NBER working paper No. 25194.

Bansal, R., Kiku, D., and Ochoa, M. (2019). Climate change risk. *mimeo*.

Blume, M. E. and Keim, D. B. (2012). Institutional investors and stock market liquidity: Trends and relationships. Jacobs Levy Equity Management Center for Quantitative Financial Research Paper, Available at SSRN 2147757.

Bodansky, D. (2016a). The Legal Character of the Paris Agreement. *Review of European, Comparative & International Environmental Law*, 25(2):142–150.

Bodansky, D. (2016b). The Paris Climate Change Agreement: A New Hope. *American Journal of International Law*, 110(2):288–319.

Boehmer, E., Musumeci, J., and Poulsen, A. B. (1991). Event Study Methodology Under Conditions of Event Induced Variance. *Journal of Financial Economics*, 30:253–272.

Bolton, P. and Kacperczyk, M. (2021a). Do investors care about carbon risk? *Journal of Financial Economics*, 142(2):517–549.

Bolton, P. and Kacperczyk, M. (2021b). Global pricing of carbon-transition risk. *NBER working paper No. 28510*.

Cañon-de Francia, J. and Garcés-Ayerbe, C. (2009). ISO 14001 Environmental Certification: A Sign valued by the market? *Environmental and Resource Economics*, 44:245–262.

Capros, P., Mantzos, L., Parousos, L., Tasios, N., Klaassen, G., and Van Ierland, T. (2011). Analysis of the eu policy package on climate change and renewables. *Energy policy*, 39(3):1476–1485.

Chatterji, A. K., Durand, R., Levine, D. I., and Touboul, S. (2015). Do ratings of firms converge? implications for managers, investors and strategy researchers. *Strategic Management Journal*, 37(8):1597–1614.

Choi, D., Gao, Z., and Jiang, W. (2020). Attention to global warming. *The Review of Financial Studies*, 33(3):1112–1145.

Clements, L., Dai, L., and Hugo, C. (2020). Investing in the green economy –sizing the opportunity. Index insights, FTSE Russell.

ClimateHome (2015). As it happened: Paris COP21 climate talks run into overtime. https://www.climatechangenews.com/2015/12/11/cop21-live-deadline-delayed-as-talks-get-tense/.

Corrado, C. J. (1989). A nonparametric test for abnormal security-price performance in event studies. *Journal of Financial Economics*, 23:385–395.

Cowan, A. R. (1992). Nonparametric event study tests. *Review of Quantitative Finance and Accounting*, 2:343–358.

Dechezleprêtre, A., Martin, R., and Mohnen, M. (2018). Knowledge spillovers from clean and dirty technologies. *Grantham Research Institute Working Paper*.

Delis, M. D., de Greiff, K., and Ongena, S. (2020). Being stranded with fossil fuel reserves? climate policy risk and the pricing of bank loans. *Swiss Finance Institute Research Paper No. 18-10*.

Ding, Z. and Granger, C. W. (1996). Modeling volatility persistence of speculative returns: a new approach. *Journal of econometrics*, 73(1):185–215.

Dugoua, E. and Dumas, M. (2021). Green product innovation in industrial networks: A theoretical model. *Journal of Environmental Economics and Management*, 107:102420.

Engle, R. (2001). Garch 101: The use of arch/garch models in applied economics. *Journal of Economic Perspectives*, 15(4):157–168.

Falkner, R. (2016). The Paris Agreement and the new logic of international climate politics. *International Affairs*, 92(5):1107–1125.

Fama, E. F. and French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, 33:3–56.

Fama, E. F. and French, K. R. (2004). The Capital Asset Pricing Model: Theory and Evidence. *Journal of Economic Perspectives*, 18(3):25–46.

Fisher-Vanden, K. and Thorburn, K. S. (2011). Voluntary corporate environmental initiatives and shareholder wealth. *Journal of Environmental Economics and Management*, 62(3):430–445.

Flammer, C. (2020). Green bonds: effectiveness and implications for public policy. *Environmental and Energy Policy and the Economy*, 1(1):95–128.

Friede, G., Busch, T., and Bassen, A. (2015). ESG and financial performance: aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, 5(4):210–233.

FTSE Russell (2010). The low carbon economy industrial classification system. Technical report, FTSE Russell.

Gillan, S. L., Koch, A., and Starks, L. T. (2021). Firms and social responsibility: A review of ESG and CSR research in corporate finance. *Journal of Corporate Finance*, page 101889.

Gilley, K. M., Worrell, D. L., Davidson, W. N., and El-Jelly, A. (2000). Corporate Environmental Initiatives and Anticipated Firm Performance: The Differential Effects of Process-Driven Versus Product-Driven Greening Initiatives. *Journal of Management*, 26(6):1199–1216.

Gompers, P. and Metrick, A. (2001). Institutional investors and equity prices. *Quarterly Journal of Economics*, pages 229–12.

González-Benito, J. and González-Benito, Ó. (2005). Environmental proactivity and business performance: an empirical analysis. *Omega*, 33(1):1–15.

Gostlow, G. (2021). Pricing physical climate risk in the cross-section of returns. Technical report, Available at SSRN 3501013.

Griffin, P. A., Jaffe, A. M., Lont, D. H., and Dominguez-Faus, R. (2015). Science and the stock market: Investors' recognition of unburnable carbon. *Energy Economis*, 52:1–12.

Guardian (2015). Environment blog COP 21: UN climate change conference, Paris. Guardian Live Blog from the Paris Negotiations, written by A. Vaughan. `https://www.theguardian.com/environment/blog/live/2015/dec/11/paris-climate-talks-deal-in-sight-but-negotiations-stretch-into-weekend-live`, accessed on 8 June 2015.

Harrington, S. E. and Shrider, D. B. (2007). All events induce variance: Analysing abnormal returns when effects vary across firms. *Journal of Financial and Quantitative Analysis*, 42(1):229–256.

Hong, H., Li, F. W., and Xu, J. (2019). Climate risks and market efficiency. *Journal of Econometrics*, 208(1):265–281.

Hsu, P.-H., Li, K., and Tsou, C.-Y. (2020). The pollution premium. *mimeo, available at SSRN 3578215.*

Ilhan, E., Krueger, P., Sautner, Z., and Starks, L. T. (2019). Institutional investors' views and preferences on climate risk disclosure. *Swiss Finance Institute Research Paper.*

Jabbour, C. J. C., Jugend, D., Jabbour, A. B. L. d. S., Gunasekaran, A., and Latan, H. (2015). Green product development and performance of Brazilian firms: measuring the role of human and technical aspects. *Journal of Cleaner Production*, 87:442–451.

Jacobs, B. W., Singhal, V. R., and Subramanian, R. (2010). An empirical investigation of environmental performance and the market value of the firm. *Journal of Operations Management*, 28(5):430–441.

Jaffe, A. B. and Palmer, K. (1997). Environmental Regulation and Innovation: A Panel Data Study. *The Review of Economics and Statistics*, 79(4):610–619.

Kogan, L., Papanikolaou, D., Seru, A., and Stoffman, N. (2017). Technological innovation, resource allocation, and growth. *Quarterly Journal of Economics*, 132(2):665–712.

Kolari, J. W. and Pynnonen, S. (2010). Event study testing with cross-sectional correlation of abnormal returns. *The Review of Financial Studies*, 23(11):3996–4025.

Kolari, J. W. and Pynnonen, S. (2011). Nonparametric rank tests for event studies. *Journal of Empirical Finance*, 18:953–971.

Kooroshy, J., Dai, L., and Clements, L. (2020). Sizing the green economy: Green revenues and the eu taxonomy. Technical report, FTSE Russell.

Kothari, S. and Warner, J. B. (2006). Econometrics of event studies. In Eckbo, B., editor, *Handbook of Corporate Finance: Empirical Corporate Finance*, chapter 1, pages 1–53. Elsevier/North-Holland, Amsterdam.

Krueger, P., Sautner, Z., and Starks, L. T. (2020). The importance of climate risks for institutional investors. *The Review of Financial Studies*, 33(3):1067–1111.

Kumar, A., Xin, W., and Zhang, C. (2019). Climate sensitivity and predictable returns. *Available at SSRN 3331872*.

Lanjouw, J. O. and Mody, A. (1996). Innovation and the international diffusion of environmentally responsive technology. *Research Policy*, 25(4):549–571.

Litterman, B. (2020). Managing climate risk in the U.S. financial system. Report of the Climate-Related Market Risk Subcommittee.

Lychagin, S., Pinkse, J., Slade, M. E., and Reenen, J. V. (2016). Spillovers in Space: Does Geography Matter? *The Journal of Industrial Economics*, 64(2):295–335.

MacKinlay, A. C. (1997). Event studies in economics and finance. *Journal of Economic Literature*, 35(1):13–39.

Malerba, F. and Orsenigo, L. (1995). Schumpeterian patterns of innovation. *Cambridge Journal of Economics*, 19(1):47–65.

Marcus, M. and Sant'Anna, P. H. (2021). The role of parallel trends in event study settings: An application to environmental economics. *Journal of the Association of Environmental and Resource Economists*, 8(2):235–275.

Marks, J. M. and Musumeci, J. (2017). Misspecification in event studies. *Journal of Corporate Finance*, 45:333–341.

Matsumura, E. M., Prakash, R., and Vera-Muñoz, S. C. (2014). Firm-value effects of carbon emissions and carbon disclosures. *The Accounting Review*, 89(2):695–724.

Monasterolo, I. and de Angelis, L. (2020). Blind to carbon risk? An analysis of stock market reaction to the Paris Agreement. *Ecological Economics*, 170(April 2020).

Mukanjari, S. and Sterner, T. (2018). Do Markets Trump Politics? Evidence from Fossil Market Reactions to the Paris Agreement and the US Election. *University of Gothenburg Working Paper*.

Nguyen, J. H. and Phan, H. V. (2020). Carbon risk and corporate capital structure. *Journal of Corporate Finance*, 64:101713.

Oberndorfer, U., Schmidt, P., Wagner, M., and Ziegler, A. (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*, 66:497–509.

OECD (2017). Investing in climate, investing in growth. *OECD Publishing, Paris,*.

OECD (2020). *Developing Sustainable Finance Definitions and Taxonomies.* OECD Publishing, Paris.

Palmer, M. and Truong, Y. (2017). The impact of technological green new product introductions on firm profitability. *Ecological Economics*, 136:86–93.

Pástor, L., Stambaugh, R. F., and Taylor, L. A. (2020). Sustainable investing in equilibrium. *Journal of Financial Economics*, 142.

Pham, H., Nguyen, V., Ramiah, V., Saleem, K., and Moosa, N. (2019). The effects of the paris climate agreement on stock markets: evidence from the german stock market. *Applied Economics*, 51(57):6068–6075.

Ramelli, S., Wagner, A. F., Zeckhauser, R. J., and Ziegler, A. (2018). Investor rewards to climate responsibility: Evidence from the 2016 climate policy shock. *NBER Working Paper No 25310.*

Sautner, Z., van Lent, L., Vilkov, G., and Zhang, R. (2022). Firm-level climate change exposure. Finance Working Paper 686/2020, European Corporate Governance Institute.

Seltzer, L., Starks, L. T., and Zhu, Q. (2020). Climate regulatory risks and corporate bonds. *Available at SSRN 3563271.*

Sen, S. and von Schickfus, M.-T. (2020). Climate Policy, Stranded Assets, and Investors' Expectations. *The Journal of Environmental Economics and Management*, 100:102–277.

Stokes, B., Wike, R., and Carle, J. (2015). Global concern about climate change, broad support for limiting emissions. Report, Pew Research Center.

Tang, D. Y. and Zhang, Y. (2018). Do shareholders benefit from green bonds? *Journal of Corporate Finance.*

The European Parliament and The Council of the Eurpean Union (2020). Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 june 2020 on the establishment of a framework to facilitate sustainable investment, and amending regulation (eu) 2019/2088. *Official Journal of the European Union*, PE/20/2020/INIT(OJ L 198, 22.6.2020):13–43.

The New York Times (2015). Fed Raises key interest rate for first time in almost a decade. written by A. Applebaum. `https://www.nytimes.com/2015/12/17/business/economy/fed-interest-rates.html?rref=collection%2Fnewseventcollection%`

2Ffed-interest-rates-dec-2015&action=click&contentCollection=economy&region=rank&module=package&version=highlights&contentPlacement=1&pgtype=collection, accessed on: 2019-06-21.

The Washington Post (2015). Congress reaches year-end deal on taxes and spending. written by D. Snell, and K. DeBonis. accessible from: https://www.washingtonpost.com/news/powerpost/wp/2015/12/15/congress-reaches-year-end-deal-on-taxes-and-spending/?utm_term=.5928a193efcf, accessed on 20.06.2019.

UNFCCC (2016). Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015 - Addendum - Part Two: Action Taken by the Conference of the Parties at its twenty-first session. The White House Office of the Press Secretary. accessible from: https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/FCCC_CP_2015_10_Add.1.pdf, accessed on 8 June 2019.

Veugelers, R. (2012). Which policy instruments to induce clean innovating? *Research Policy*, 41(10):1770–1778.

World Bank (2019). The World Development Indicators (WDI), 2019: Market capitalisation of listed domestic companies (current USD). accessible from: https://data.worldbank.org/indicator/CM.MKT.LCAP.CD, accessed on 15 April 2019.

Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance*, 98:39–60.

Online Appendix

Appendix A FTSE Russell Low Carbon Economy Sector Classification

ENERGY GENERATION — EG
- **Bio Fuels**
  - Bio Gas
  - Bio Mass (Grown)
  - Bio Mass (Waste)
- **Cogeneration**
  - Cogeneration (Biomass)
  - Cogeneration (Renewable)
  - Cogeneration (Gas)
- **Fossil Fuels**
  - Clean Fossil Fuels
- **Geothermal**
- **Hydro (General)**
  - Large Hydro
  - Small Hydro
- **Nuclear**
- **Ocean & Tidal**
- **Solar (General)**
- **Waste to Energy**
- **Wind (General)**

ENERGY EQUIPMENT — EQ
- **Bio Fuels**
  - Bio Fuel (1st & 2nd Gen)
  - Bio Fuel (3rd Generation)
  - Bio Gas
  - Bio Mass (grown)
  - Bio Mass (waste)
- **Cogeneration Equipment**
  - Cogeneration (Biomass)
  - Cogeneration (Renewable)
  - Cogeneration (Gas)
- **Fossil Fuels (Integrated)**
  - Carbon Capture & Storage
  - Fuel Cells
- **Geothermal**
- **Hydro (General)**
  - Large Hydro
  - Small Hydro
- **Nuclear**
- **Ocean & Tidal**
- **Solar (General)**
- **Waste to Energy**
- **Wind (General)**

ENERGY MANAGEMENT AND EFFICIENCY — EM
- **Buildings & Ppty (Integrated)**
- **Controls**
- **Energy Mgmt Log & Support**
- **Industrial Processes**
- **IT Processes**
  - Cloud Computing
  - Efficient IT
- **Lighting**
- **Power Storage**
  - Power Storage (Battery)
  - Power Storage (Pumped Hydro)
- **Smart & Efficient Grids**
- **Sustainable Ppty Operator**

ENVIRONMENTAL RESOURCES — ER
- **Advanced & Light Materials**
- **Key Raw Minerals & Metals**
  - Cobalt
  - Lithium
  - Platinum & Platinum-Group
  - Rare Earths
  - Silica
  - Uranium
- **Recyclable Prods & Matls**
  - Recyclable Materials
  - Recyclable & Resusable

ENVIRONMENTAL SUPPORT SERVICES — ES
- **Environmental Consultancies**
- **Finance & Investment**
  - Carbon Credits trading
  - Sustainable Investment Funds
- **Smart City Des & Engineering**

FOOD & AGRICULTURE — FA
- **Agriculture**
  - GM Agriculture
  - Machinery
  - Meat & Dairy Alternatives
  - Non GM Advanced Seeds
  - Organic & Low-Impact Farming
- **Aquaculture**
  - Aquaculture (General)
  - Aquaculture (Sustainable)
- **Land Erosion**
- **Logistics**
- **Food Safe, Process & Pack'g**
  - FSP&P - no single use plas
  - FSP&P - with single use plas
- **Sustainable Planations**
  - Sustainable Forestry
  - Sustainable Palm Oil

TRANSPORT EQUIPMENT — TE
- **Aviation**
- **Railways**
  - Railway (Infrastructure)
  - Trains (Electric / Magnetic)
  - Trains (General)
- **Road Vehicles**
  - Advanced Vehicle Batteries
  - Bikes and Bicycles
  - Bus and Coach Manufacturers
  - Electrified Vehicles & Devices
  - Energy Use Reduction Devices
- **Shipping**

TRANSPORT SOLUTIONS — TS
- **Railways Operator**
  - General Railways
  - Electrified Railways
- **Road Vehicles**
  - Bike Sharing
  - Bus and Coach operators
  - Car Clubs
  - Ride Hailing
- **Video Conferencing**

WATER INFRASTRUCTURE & TECHNOLOGY — WI
- **Adv Irrigation Sys & Devices**
- **Desalination**
- **Flood Control**
- **Meteorological Solutions**
- **Natural Disaster Response**
- **Water Infrastructure**
- **Water Treatment**
  - Water Treatment Chemicals
  - Water Treatment Equipment
- **Water Utilities**

WASTE & POLLUTION CONTROL — WP
- **Cleaner Power**
- **Decontam Services & Devices**
  - Air Decontamination
  - Land & Soil Decontamination
  - Sea & Water Decontamination
- **Environ. Test. & Gas Sens.**
- **Particles & Emiss. Reduc. Dev.**
  - Industrial Pollution Reduction
  - Transport Pollution Reduction
- **Recycling Equipment**
- **Recycling Services**
- **Waste Management (General)**
  - Hazardous Waste Management
  - Organic Waste Process
  - General Waste Management

Table A.1: FTSE Russell Low carbon Economy Sectors and Sub-sectors

Appendix B Google Trend Statistics

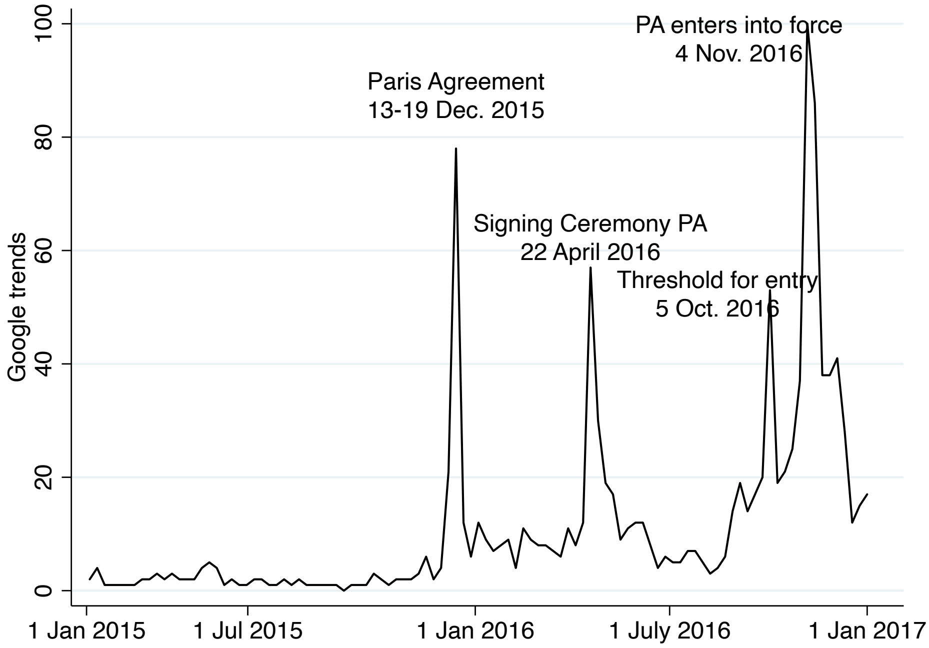

Figure B.1: Google Trend Statistics for the term 'Paris Agreement' (searched for in the US between March 2015 and December 2016).

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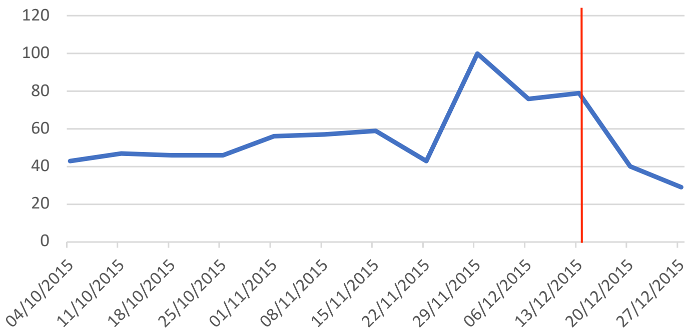


Figure B.2: Google trends index for "climate change" searches
Notes: https://trends.google.com/trends/?geo=GB

Appendix C Additional Descriptives

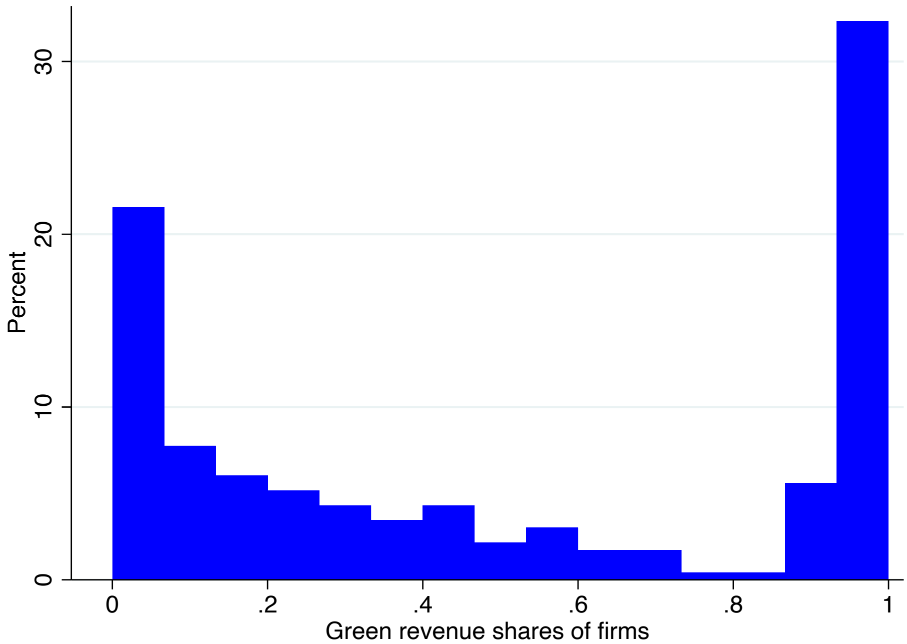


Figure C.1: The distribution of minimum green revenue shares across US firms, with a minimum green revenue share >0 between 2009-2013 (N=249).

	Mean	Median	Std. Dev	Bottom 1%	Bottom 5%	Top 5%	Top 1%	Min.	Max.
Daily Returns (in %)									
Green firms (top 30%)	-0.16	0	5.87	-12.82	-6.49	6.02	13.35	-163.14	268.17
Emission intensive firms (scope 1, top 10%)	-0.21	0	3.46	-9.20	-4.41	3.44	7.92	-98.40	45.87
Emission intensive firms (scope 2, top 10%)	-0.14	0	2.81	-7.35	-4.05	3.49	7.38	-98.40	28.04
Clean patenting firms (top 10%)	-0.17	0	10.31	-13.28	-4.30	3.99	15.42	-230.26	230.26
Market Capitalization (in million USD)									
Green firms (top 30%)	2,147.29	362.16	4,286.54	14.06	21.83	11,965.28	20,834.07	14.061	20,834.07
Emission intensive firms (scope 1, top 10%)	12,092.59	7,060.63	13,880.84	281.48	927.91	37,244.70	75,698.73	231.73	76,608.17
Emission intensive firms (scope 2, top 10%)	13,759.27	8,792.16	13,373.65	927.91	1,118.32	39,373.53	60,226.28	784.76	75,698.73
Clean patenting firms (top 10%)	6,867.26	1,236.98	10,962.36	33.71	66.47	37,584.89	39,9953.48	33.71	39,953.48
Average market capitalization (2013)	5,750.00								
3-factor parameters									
r_{mt} (in %)	-0.03	-0.07	1.13	-2.95	-2.03	1.81	2.52	-3.9	3.68
r_{ft} (in %)	0	0	0	0	0	0	0	0	0
SMB (in %)	-0.05	-0.08	0.55	-1.36	-0.87	0.85	1.43	-1.69	1.86
HML (in %)	-0.03	-0.07	0.59	-1.20	-0.9	1.14	1.87	-1.50	1.96

Table C.1: Descriptives Statistics

Note: Daily values are for the period covered in the event study. Event days [-121; +10]. Subsample market capitalization is for 2013, the last pre-treatment year. The average market capitalization is based on all listed domestic US firms in 2013 (World Bank Data). It is calculated by dividing the 2013 market capitalization of listed domestic companies in the US over the total number of listed domestic companies in the US (The World Development Indicators, 2019).

Appendix D Additional Results

D.1 Intensive Margin

(1) Sample A "Greenest"	(2) Mean (Std.dev) CAAR [0;5]	(3) Sample B "Green"	(4) Mean (Std.dev) CAAR [0;5]	(5) Two-sided p-value
GR 100%	10.74 (16.72)	GR>0	2.77 (11.55)	0.000
		GR 25-96%	3.77 (12.37)	0.012
		GR 25-42%	1.60 (6.71)	0.015
GR 97-100%	8.91 (15.48)	GR>0	2.77 (11.55)	0.001
		GR 25-96%	3.77 (12.37)	0.042
		GR 25-42%	1.60 (6.71)	0.035

Table D.1: Difference in intensive green revenue margin for CAAR

Note: This table tests the difference in the post-event CAARs (days 0-5) between different definition of "green" portfolios. The mean and standard deviation of the CAARs for the greenest samples are reported in column 2. The mean CAARs of the firms in the relatively less green portfolios are reported in column 4. Column 5 reports the results from the two sided t-test.

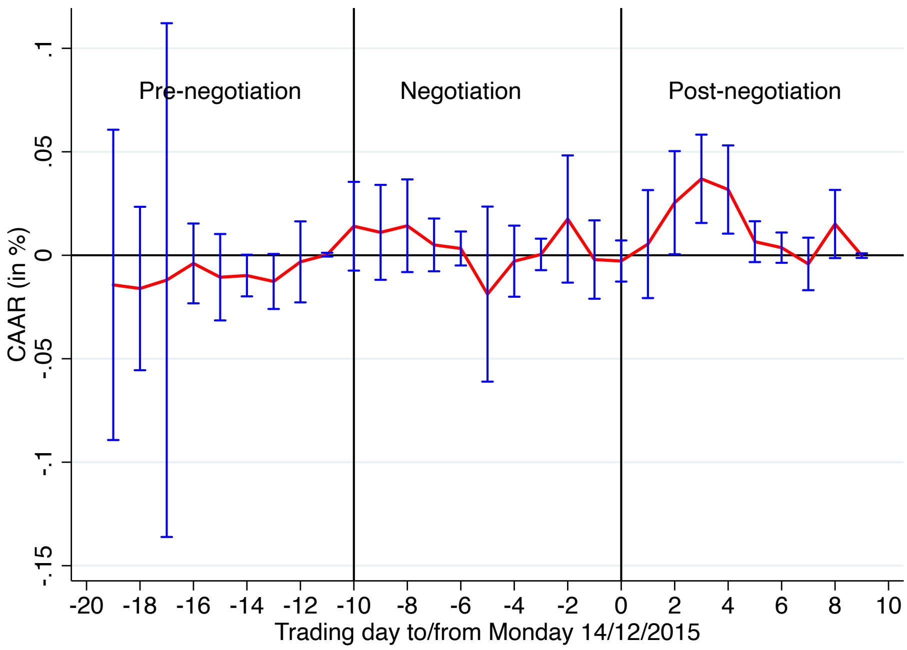


Figure D.1: Abnormal returns for firms in the 50-70% of minimum green revenues (N=63, GR 25-96%)

Note: This red line shows the event path using the rolling 3-day CAARs of firms in the 50-70% of minimum green revenues (N=63, GR 25-96%). The blue bars show the 95% Corrado-Cowan confidence intervals. Monday 14 December 2015 is event day 0. The estimation window is the 100 days prior to the pre-negotiation period.

D.2 The Trump Election

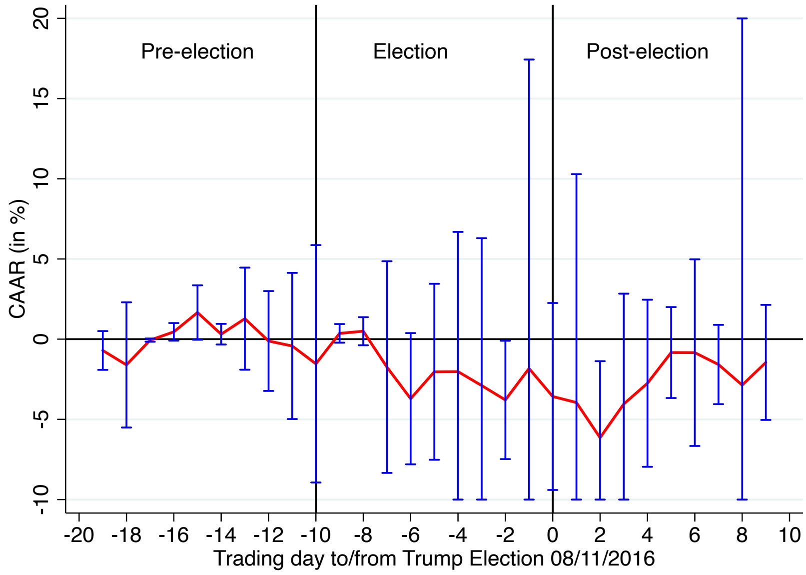


Figure D.2: Abnormal returns for top 30% green revenue firms in the US following the Trump Election

Note: This figure shows the event paths for top 30% green firms (N=128). The red line shows the rolling 3-day CAARs. The blue bars show the 95% Corrado-Cowan confidence intervals.

D.3 Green firms in Europe and Japan

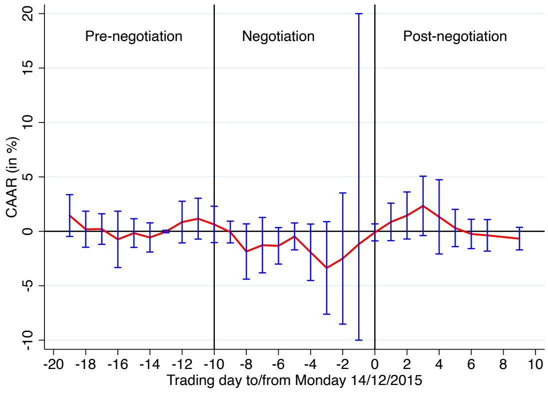


Figure D.3: Abnormal returns for top 30% green revenue firms in Europe

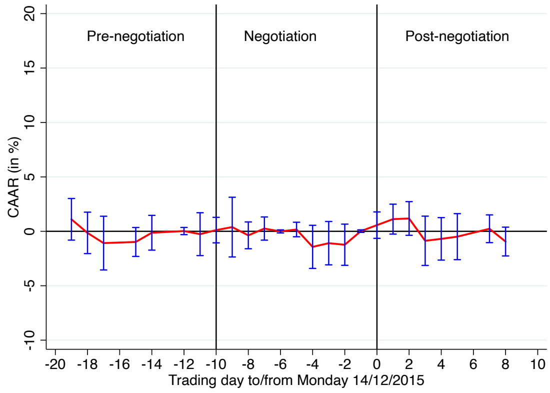


Figure D.4: Abnormal returns for top 30% green revenue firms in Japan

Note: This figure shows the event paths for top 30% green firms in Europe (N=61) and Japan (N=48). The red line shows the rolling 3-day CAARs. The blue bars show the 95% Corrado-Cowan confidence intervals.

D.4 Controlling for climate risk

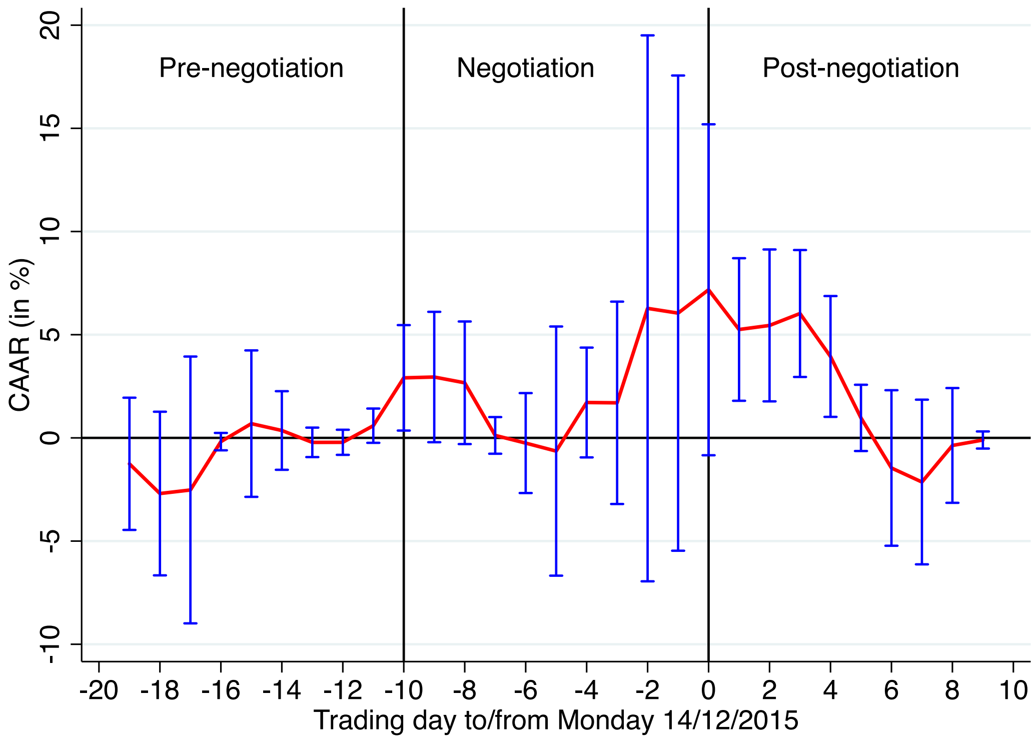


Figure D.5: Abnormal returns for top 30% green firms (GR 97-100%) controlling for climate risk

Note: The red line shows the event path using the 3-day rolling CAARs for top 30% of green firms (GR share 97-100%, N = 63). Here we are additionally controlling for climate-related physical risk exposure as a fourth factor, using data from Gostlow (2021). The blue bars show the 95% Corrado-Cowan confidence intervals.

D.5 Distinguishing by climate related exposure to physical risk

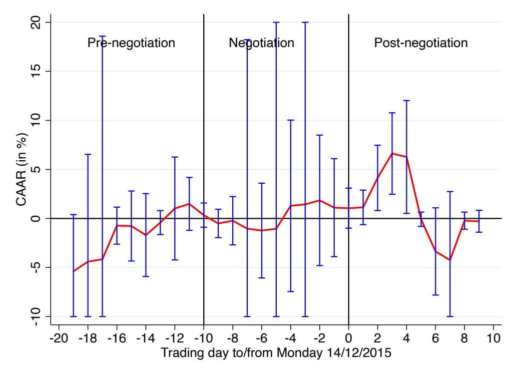


Figure D.6: High climate physical risk exposure

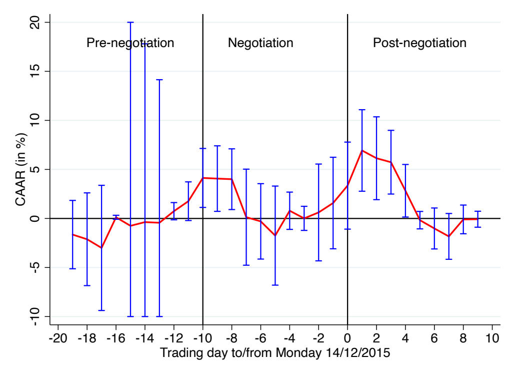


Figure D.7: Low climate physical risk exposure

Note: These figures show the event path for firms exposed to high climate opportunity (N = 20, Figure D.4), to low climate opportunity (N = 20, Figure D.5), to high climate physical risk (N = 8, Figure D.6), and low climate physical risk (N = 32, Figure D.7), using the climate opportunity and physical risk factors from Sautner et al. (2022). The red line shows the rolling 3-day CAARs. The blue bars show the 95% Corrado-Cowan confidence intervals.

Table D.2: CAARs by climate related exposures

H_a : 5-day CAARs of high ≠ 5-day CAARs of low			
	Mean 5-day CAARs (Std.dev.)		
Climate change exposure	High	Low	Diff. [p-value]
related to opportunities	0.148	0.039	0.109***
	(0.165)	(0.067)	[0.009]
related to physical shocks	0.075	0.098	-0.024
	(0.072)	(0.148)	[0.668]

Note: This table tests the difference in the post-event CAARs (days 0-5) between High and Low climate change opportunity and physical risk portfolios. The mean and standard deviation of the CAARs for the High and Low portfolios are reported in the left and middle columns respectively. The right column reports the results from the two sided t-test. *,**,***= significant at 10% 5%, 1%.

D.6 Green revenues of carbon intensive firms in electric services

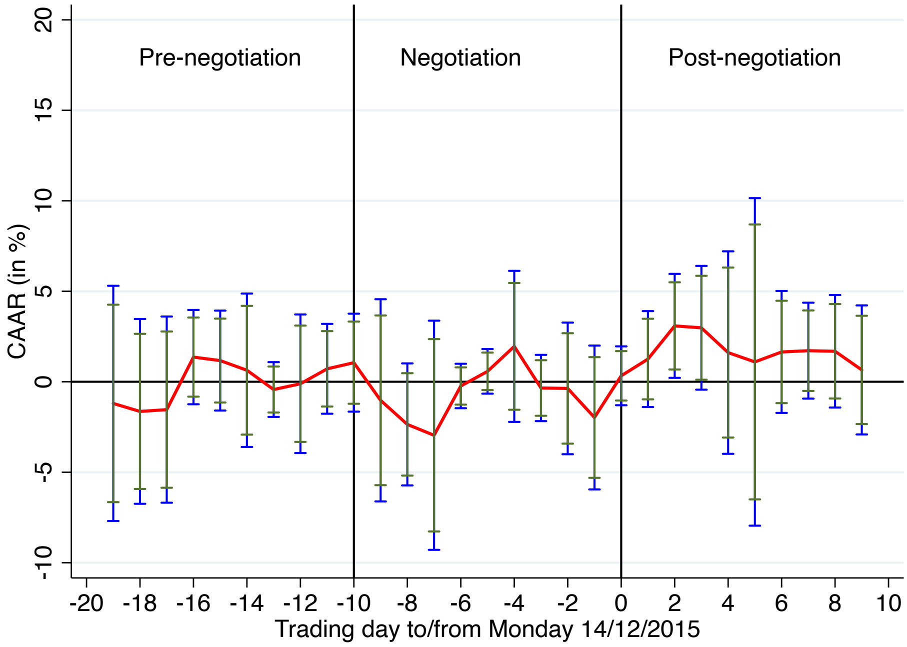


Figure D.8: Abnormal returns for the most emissions intensive firms in electric services
Note: This figure shows the event paths for firms among the 10% most carbon intensive within electric services (SIC=491; N=23). The red line shows the rolling 3-day CAARs. The blue bars show the 95% Corrado-Cowan confidence intervals. The grey bars show the 90% Corrado-Cowan confidence intervals.

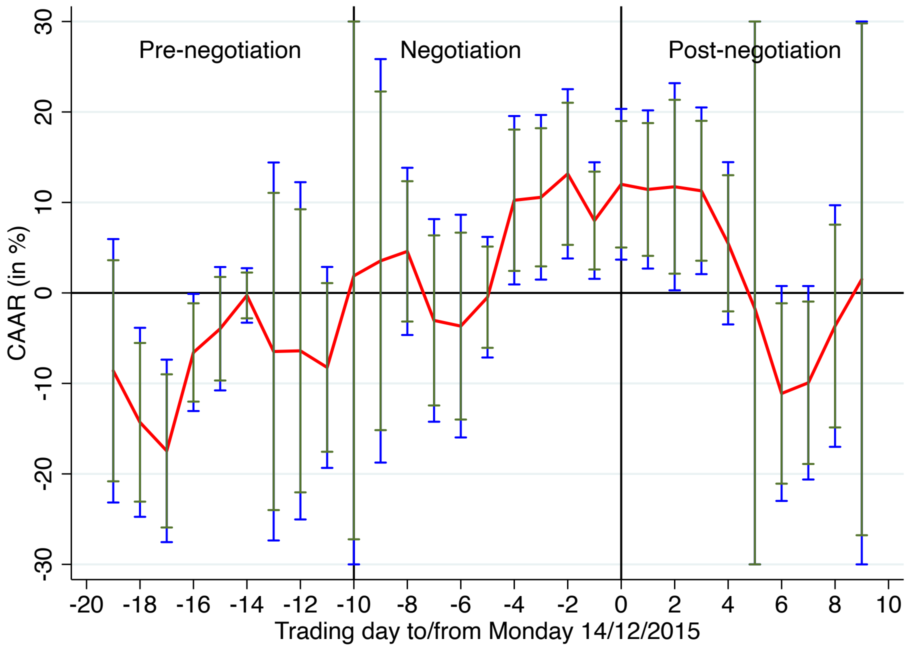
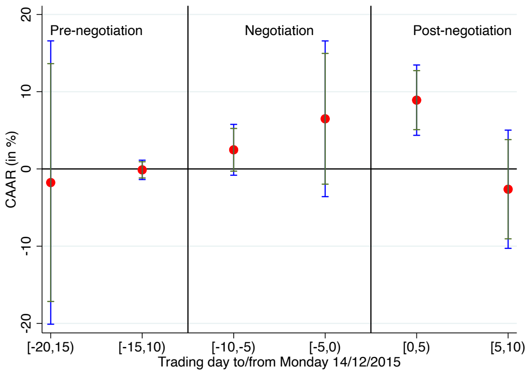


Figure D.9: Abnormal returns for the lowest emissions intensity firms in electric services

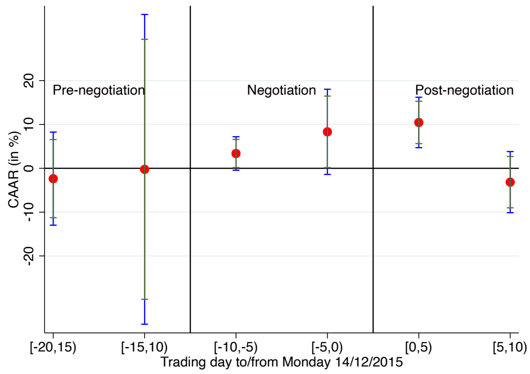
Note: This figure shows the event paths for top 30% green firms in electric services (SIC=491; N=10). The red line shows the rolling 3-day CAARs. The blue bars show the 95% Corrado-Cowan confidence intervals. The grey bars show the 90% Corrado-Cowan confidence intervals.

Appendix E Robustness Checks

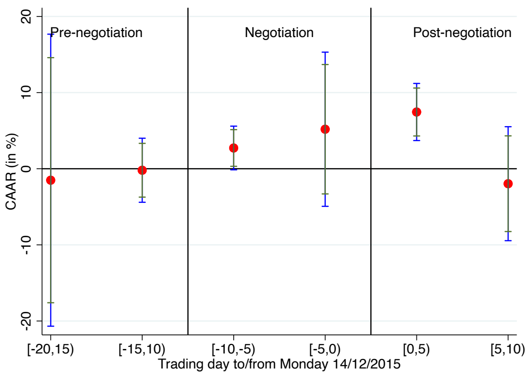
E.1 Results with a 5-day event window



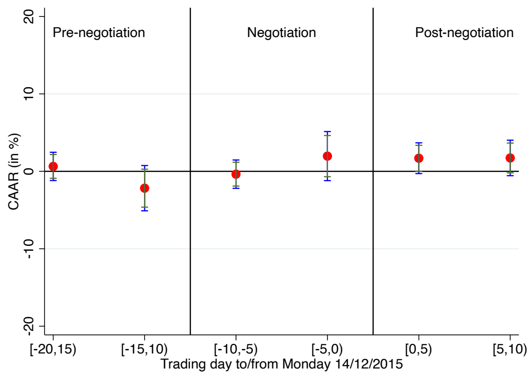
(a) Top 30% green firms



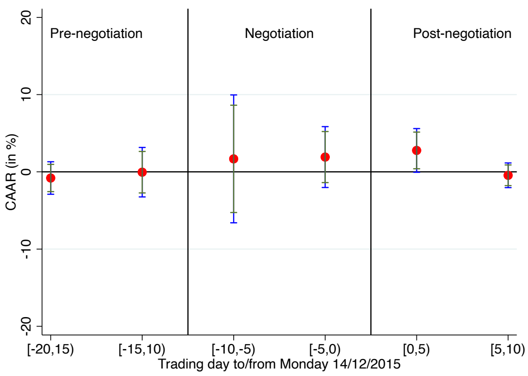
(b) Firm with 100% GR



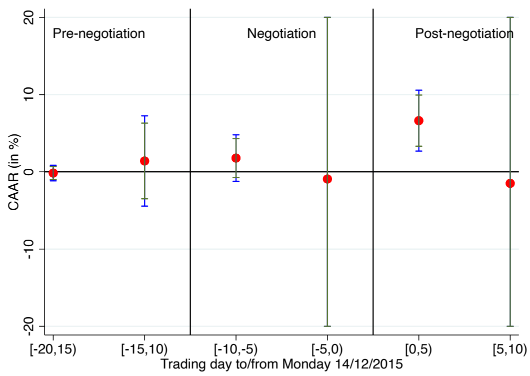
(c) Top 40% green firms



(d) Median of green firms



(e) Any green revenue (>0) between 2009-13



(f) Top 30% of green firms excluding electricity generation (SIC 491)

Figure E.1: Abnormal returns using 5-day CAARs

Note: This figure shows the 5-day CAARs of the different green portfolios. The blue (grey) bars are 95% (90%) Corrado-Cowan confidence intervals.

E.2 Excluding Renewable Energy

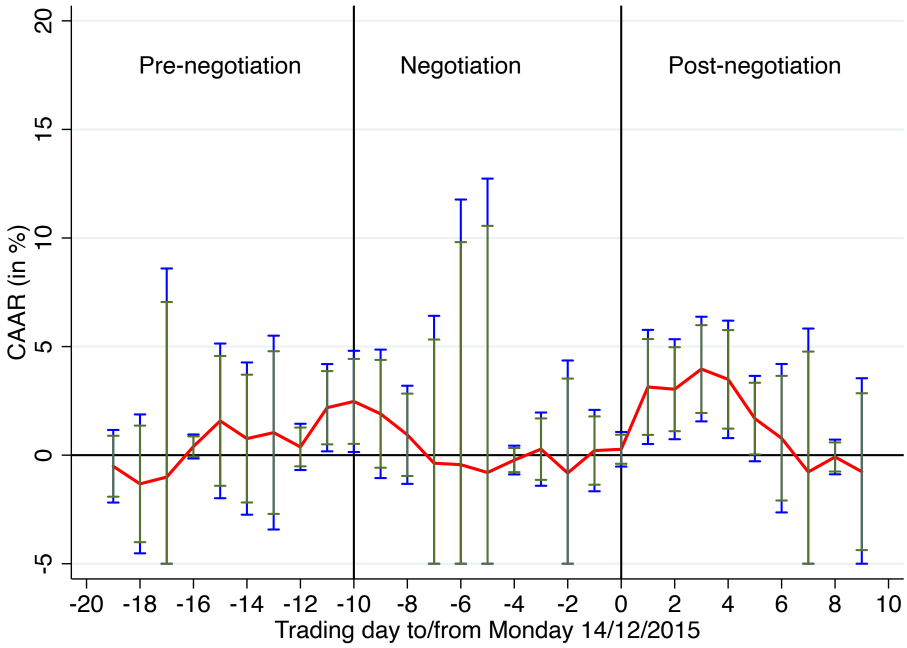


Figure E.2: Abnormal returns for top 30% green firms excluding electricity generation (SIC491)

Note: This figure shows the event paths for the top 30% of green firms, excluding firms in electricity generation (excluding SIC 491). The red line shows the rolling 3-day CAARs. The black bars show the 95% Corrado-Cowan confidence intervals. The grey bars show the 90% Corrado-Cowan confidence intervals.

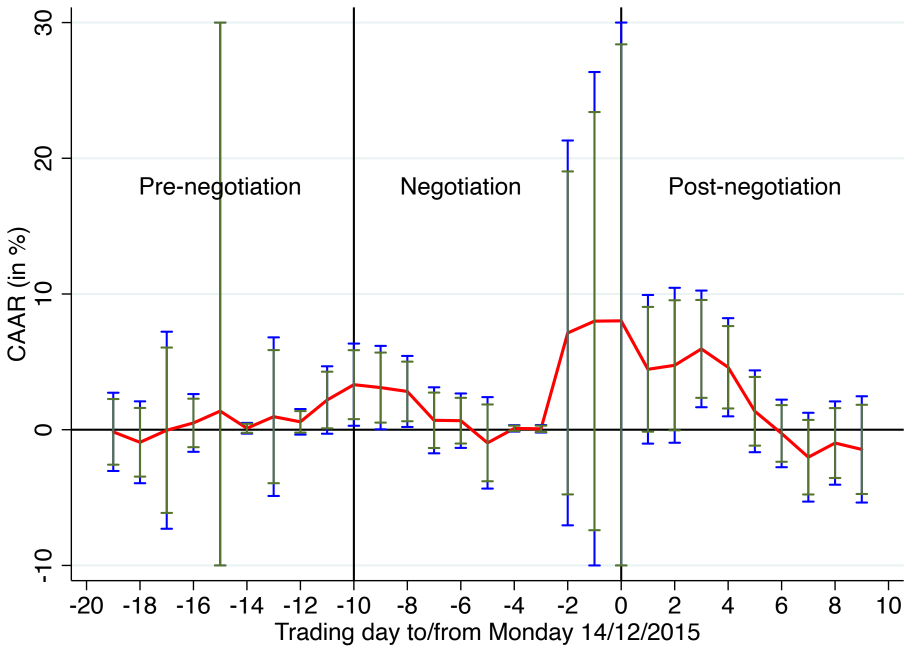
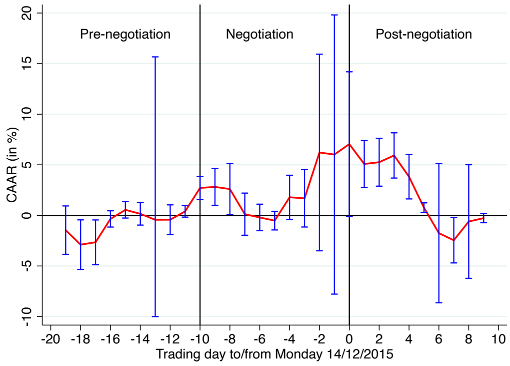


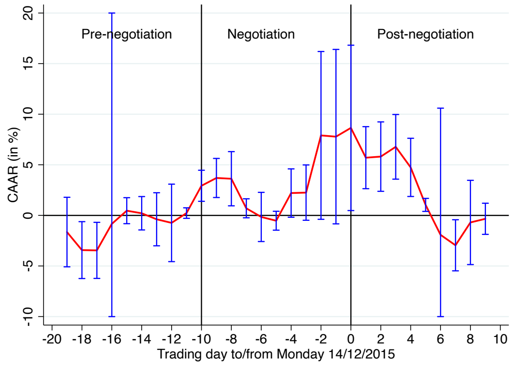
Figure E.3: Abnormal returns for top 30% green firms (GR 97-100%) excluding public utilities: Electricity, Gas, and Sanitary Services (SIC 49)

Note: The red line shows the event path using the 3-day rolling CAARs for top 30% green firms (top 30% excluding public utilities: Electricity, Gas, and Sanitary Services (excl. SIC 49, N=38). The blue bars are 95% Corrado-Cowan confidence intervals. The grey bars are 90% Corrado-Cowan confidence intervals).

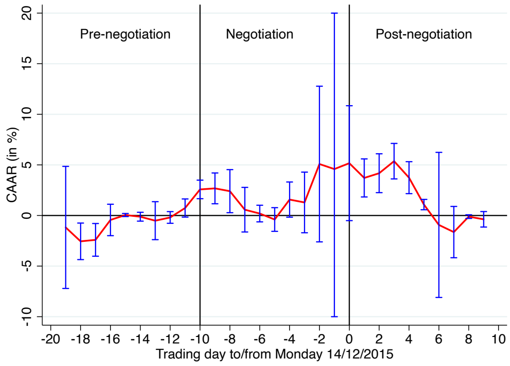
E.3 Robustness check using the BMP test statistic



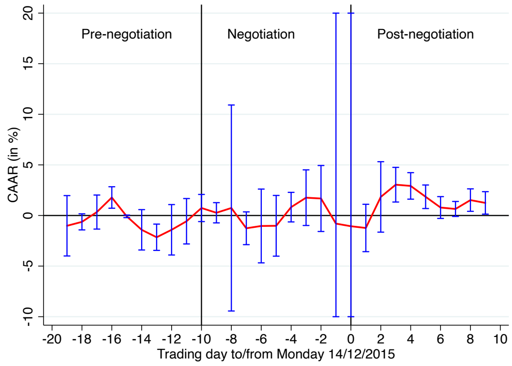
(a) Top 30% green firms



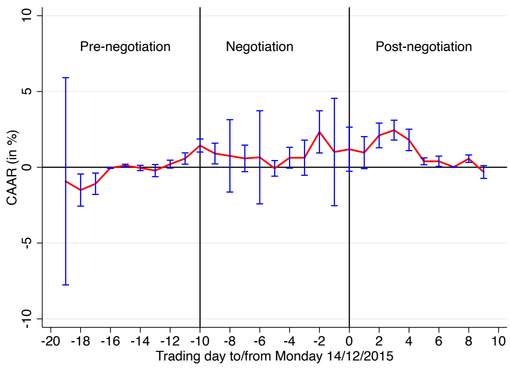
(b) Firm with 100% GR



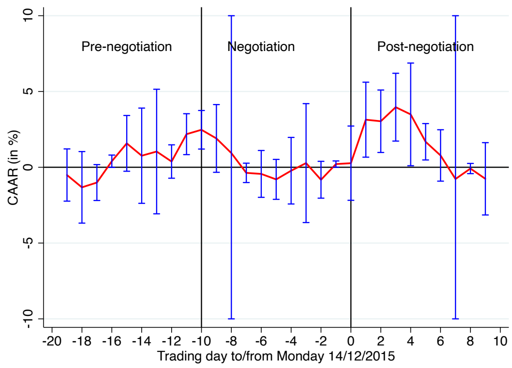
(c) Top 40% green firms



(d) Median of green firms



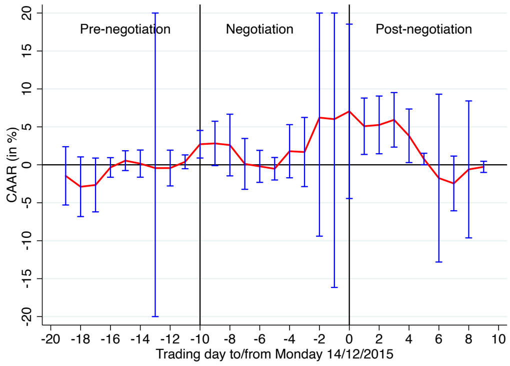
(e) Any green revenue (>0) between 2009-13



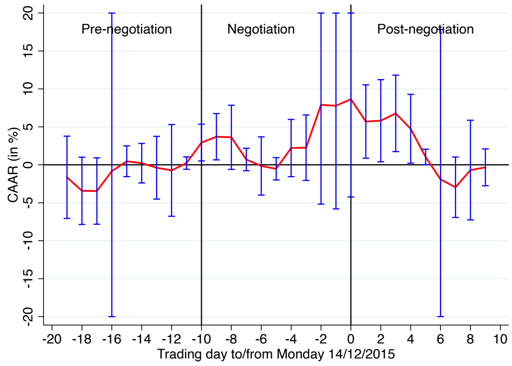
(f) Top 30% of green firms excluding electricity generation (SIC 491)

Figure E.4: Abnormal returns for top 30% green revenue firms using BMP test statistic
Note: This figure shows the 3-day CAARs of the different green portfolios with BMP confidence intervals (Boehmer et al., 1991)

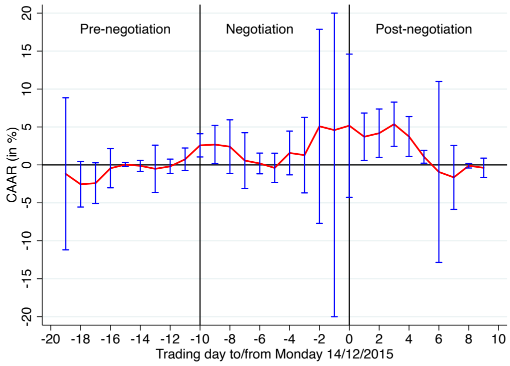
E.4 Robustness Check using the KP test statistic



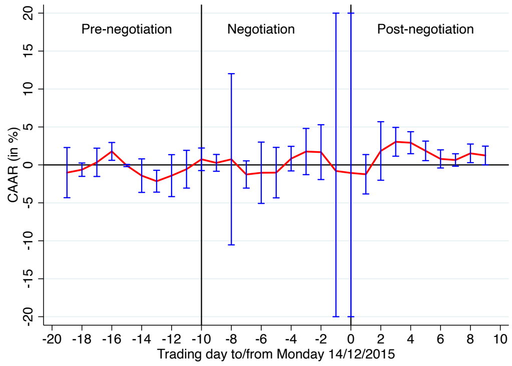
(a) Top 30% green firms



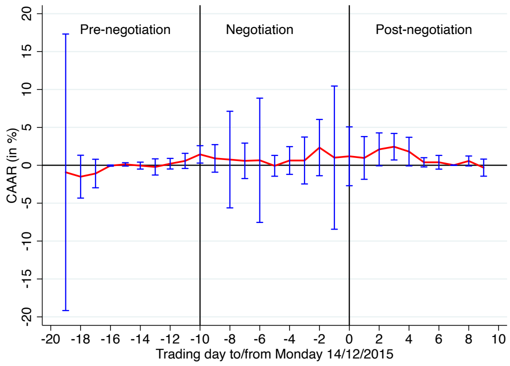
(b) Firm with 100% GR



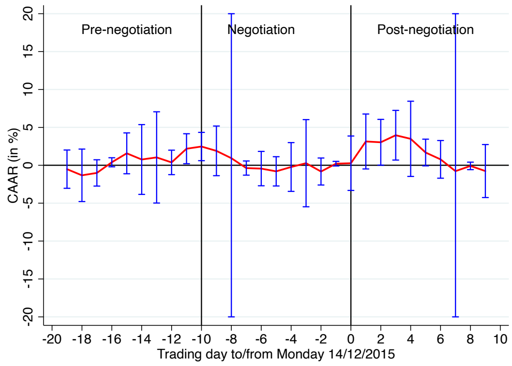
(c) Top 40% green firms



(d) Median of green firms



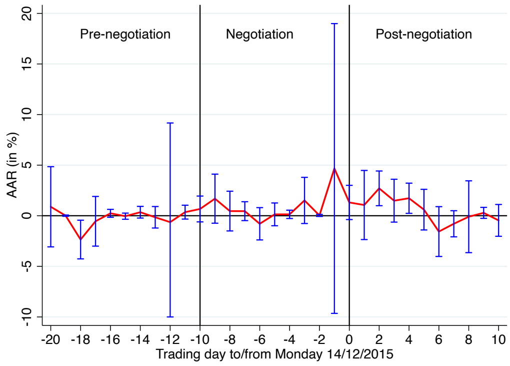
(e) Any green revenue (>0) between 2009-13



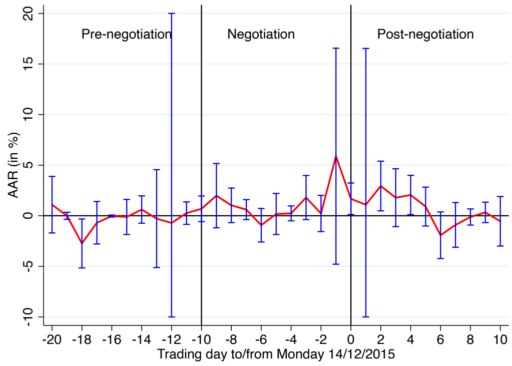
(f) Top 30% of green firms excluding electricity generation (SIC 491)

Figure E.5: Abnormal returns for top 30% green revenue firms using KP test statistic
Note: This figure shows the 3-day CAARs of the top 30% green portfolios with KP confidence intervals (Kolari and Pynnonen, 2010).

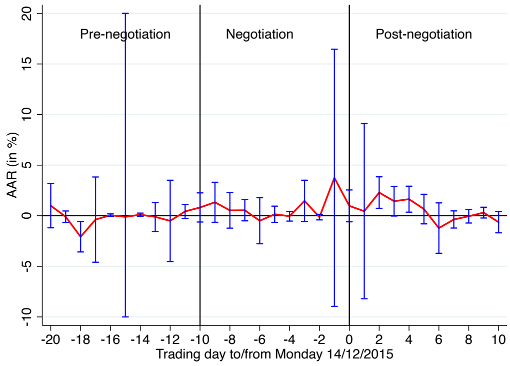
E.5 Average Abnormal Returns (AARs)



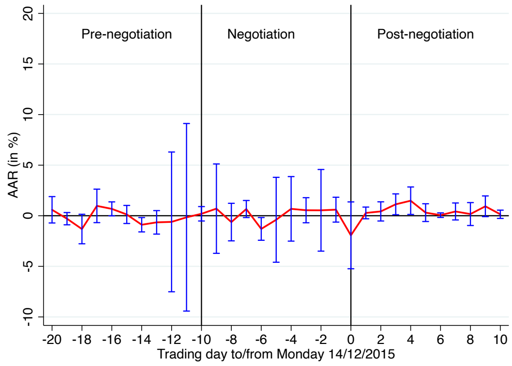
(a) Top 30% green firms



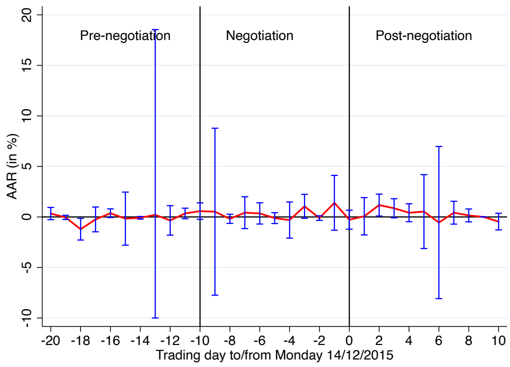
(b) Firm with 100% GR



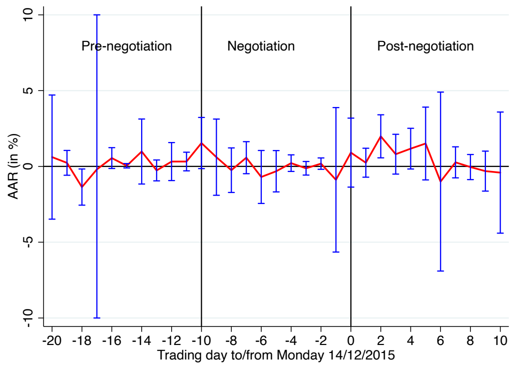
(c) Top 40% green firms



(d) Median of green firms



(e) Any green revenue (>0) between 2009-13



(f) Top 30% of green firms excluding electricity generation (SIC 491)

Figure E.6: Average Abnormal Returns (AARs)
Note: This figure shows the Average Abnormal Returns (AARs) of the green portfolios with Corrado-Cowan confidence intervals.

E.6 Robustness check using a random sample of firms without any green revenues

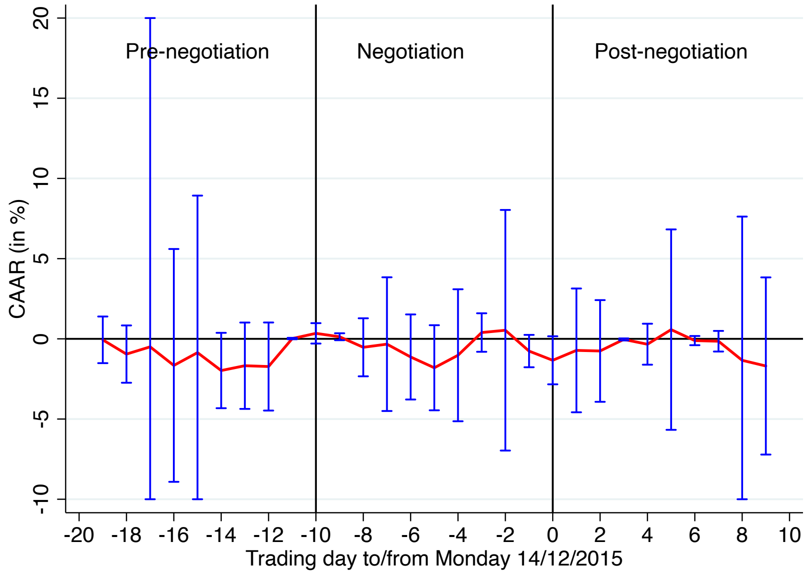


Figure E.7: Abnormal returns for random non-green firms

Notes: This figure presents the event path using rolling 3-day CAARs of the random sample of 96 firms without any green revenues.

E.7 Robustness check using a value-weighted returns

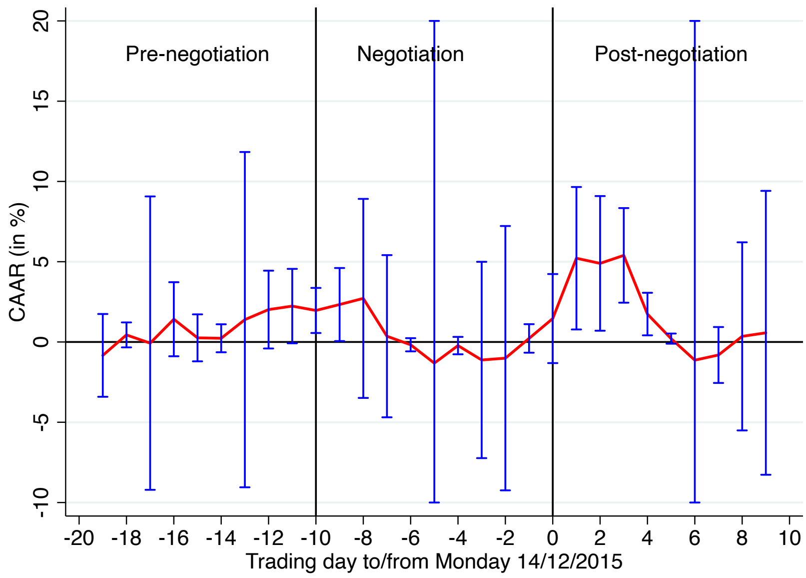


Figure E.8: Abnormal returns for to 30% green revenue share firms with value-weighted portfolio

Notes: This figure presents the event path using rolling 3-day CAARs of the baseline sample weighted by their market capitalization in 2013.

E.8 Alternative estimator - Difference-in-Difference

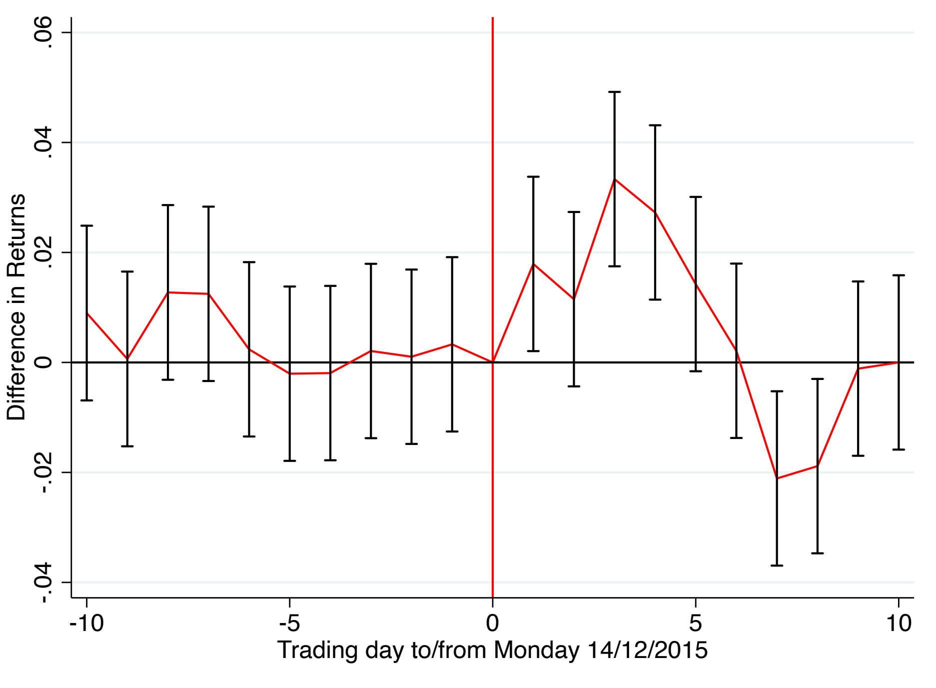


Figure E.9: 97-100% green revenue vs. Emissions intensive firms (scope 1 and 2 emissions)

Notes: This figure shows the treatment effect of the top green firms with 97-100% green revenue compared to emission intensive firms around the Paris Agreement, along with the 95% confidence intervals.

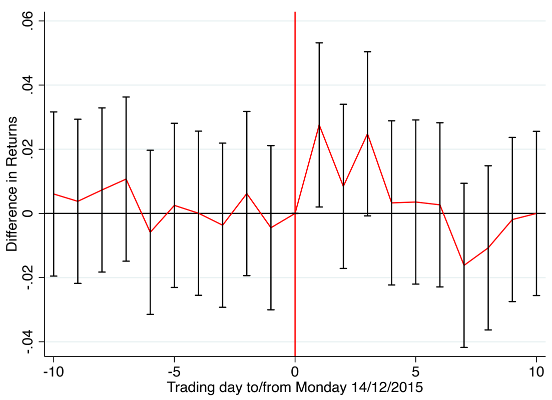


Figure E.10: 97-100% green revenue vs. 25-42% green revenue

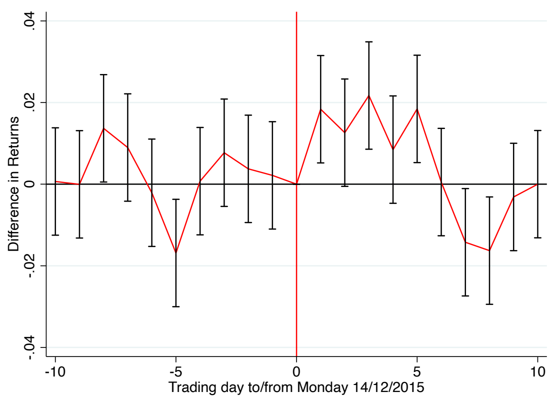


Figure E.11: 97-100% green revenue vs. positive min green revenue

Notes: These figures show the treatment effect of the firms with 97-100% green revenue compared to 25-42% and positive min. green revenue around the Paris Agreement, along with the 95% confidence intervals.

References

Boehmer E, Musumeci J, Poulsen A (1991) Event Study Methodology Under Conditions of Event Induced Variance. *Journal of Financial Economics* 30:253-272.

Corrado C (1989) A nonparametric test for abnormal security-price performance in event studies. *Journal of Financial Economics* 23:385-395.

Kolari JW, Pynnonen S (2010) Event study testing with cross-sectional correlation of abnormal returns. *The Review of Financial Studies* 23(11):3996-4025.
The World Bank (2019) The World Development Indicators (WDI), 2019: Market capitalisation of listed domestic companies (current USD). Accessible from: `https://data.worldbank.org/indicator/CM.MKT.LCAP.CD`, accessed on 15 April 2019.