Climate Regulatory Risks and Corporate Bonds

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Abstract

Investor concerns about climate and other environmental risks suggest that these risks, particularly those arising from expected changes in regulations, should affect the assessed risk and pricing of corporate bonds. We consider the influence that a firm's environmental profile, combined with the firm's regulatory conditions, has on its bond credit ratings and yield spreads. Using the Paris Agreement as a shock to expected climate regulation, we provide evidence of a causal relation between climate regulatory risks and the credit ratings and yield spreads of bonds from issuers with problematic environmental profiles.

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I. Introduction

In recent years investors have become more concerned about the environmental, social and governance (ESG) risks embedded in their investments, particularly climate risks in corporate bonds.[1] In fact, research shows climate risk to be an important factor in institutional investors' portfolio decisions, as well as corporate managers' leverage decisions, affecting the tail risk of stock returns and the pricing of stocks and municipal bonds in the cross-section (Ginglinger and Moreau, 2019; Krüger, Sautner, and Starks, 2020; Ilhan, Sautner, and Vilkov, 2020; Bolton and Kacperczyk, 2020; Painter, 2020). Of the three components of climate risk (physical, transitional and regulatory), regulatory risk is the one that investors believe has already started to materialize (Krüger, Sautner, and Starks, 2020), which suggests that regulation is a major channel through which firms internalize the costs associated with climate and other types of environmental risks.[2] In fact, environmental regulatory costs can have significant effects on firms' operating costs and cash flows (Karpoff, Lott, and Wehrly, 2005). More importantly, regulatory uncertainty itself poses costs to firms and their investors (Pindyck, 1993). For example, political uncertainty, such as modeled by Pastor and Veronesi (2013), can be an important source of climate risk, as provided by evidence in the Ilhan et al. (2020) study of regulatory uncertainty and stock option prices. In addition, Kaviani, Kryzanowski, Maleki, and Savor (2020) provide evidence of a strong relation between movements in the Baker et al. (2015) economic policy uncertainty index and corporate credit spreads.

In this paper we address the issue of whether and how climate and other environmental regulatory risks affect firms' securities. We test for the effects using firms' bonds because as pointed out by Gourio (2013), for many corporations, the bond market, rather than the equity market, is the "marginal source of finance." Further, climate and environmental risks are fundamentally downside risks for most firms and Bai, Bali, and Wen (2019) show that, in the cross-section, downside risk is the strongest predictor of future bond returns. Thus, effects from climate risk should be more easily captured in firms' bond credit ratings and yield spreads than in their equity securities. Moreover, a firm's regulatory conditions should heighten or lower these risks. Specifically, firms located in areas with stricter regulatory conditions more likely face elevated environmental regulatory risk.

[1] See, for example, Shultz (2017), Furtado (2017), Frick (2020) and Arnold (2020).

[2] As Krüger, Sautner, and Starks (2020) show in their survey on climate risk, as of 2018, 55% of the institutional investors believe that the regulatory risk of climate change is already materializing and another 36% believe that it will materialize within the next few years.

Consequently, we test the hypothesis that corporate bonds' treatments in financial markets become more affected by a firm's environmental profile when regulatory risks are heightened.

Testing this hypothesis requires measuring firms' environmental profiles as well as their regulatory risk exposures. We capture environmental profiles in two ways. First, we use an assessment of the firm's environmental quality by a third-party ESG rating agency (Sustainalytics). Second, we employ an industry categorization that reflects common environmental problems – whether the firm belongs to a Top Polluting Industry as defined by Ilhan, Sautner, and Vilkov (2020), who use CDP emission disclosures to measure pollution. We estimate firms' regulatory risk exposures based on their locations. Significant environmental legislation exists at the federal level in the United States, but state governments, who generally hold the main responsibility for enforcing those laws, vary widely in their enforcement practices. Further, some states also impose additional environmental restrictions. Thus, even when firms have objectively similar levels of environmental quality, depending on their locations, they face differences in regulatory risk.

Recognizing the potential endogenous relationship between a firm's environmental policies and market participants' perceptions of the firms' risks, we consider a setting where expectations regarding future climate regulations received an exogenous shock—the December 2015 Paris Agreement, under which world governments agreed to take actions to limit global temperature increases. When the Agreement was announced, a natural implication that could be drawn by rating agencies and bond investors was that governments, including U.S. federal and state governments, would tighten their environmental regulations related to the mitigation of climate change.[3] In fact, consistent with this assumption, after the Paris Agreement at least one rating agency adjusted their baseline scenarios to include expectations of increased regulations.[4] This shock implies that U.S. firms would face greater climate regulatory risk, especially those firms expected to be more exposed to that risk due to their business activities and to being located in states with more stringent enforcement of environmental rules.[5]

[3]The fact that so many nations would sign on to the Paris Agreement does not appear to have been foreseen far in advance of the UN Climate Change meeting in December 2015. For example, a headline in a British newspaper on November 1, 2015 stated "Why climate treaty will be the flop of the year." In mid-November there still existed divisions among the world's leading countries regarding a deal. As late as Nov 23, the EU's climate and energy czar warned that an agreement was far from certain.

[4]Moody's Environmental Services June 28, 2016 report "Moody's to Analyse Carbon Transition Risk Based on Emissions Reduction Scenario Consistent with Paris Agreement."

[5]For example, Brian Cahill, a Moody's Managing Director, stated that the voluntary nature of a country's actions "makes more detailed assessment of the credit impact of the Paris Agreement difficult, although the trend is clear and

To test the hypothesis that the Paris Agreement had greater effects on the corporate bonds more exposed to climate regulatory risks as compared to other corporate bonds, we employ difference-in-differences analyses of changes in credit ratings and yield spreads. The treated bonds are those issued by firms with low environmental scores (below-the-median scores) or in a top polluting industry. Using bonds issued at least twelve months prior to the Agreement and traded during the testing period, we find that after the Paris Agreement, bonds from firms with low environmental scores experience an average decrease in rating of 0.5 notch relative to bonds from other firms. Similarly, bonds from firms in top polluting industries experience an average 0.6 notch credit rating decrease relative to bonds from other firms. These results, which control for time invariant firm characteristics and macroeconomic trends, support the hypothesis that changes in climate regulatory risk affect bond credit ratings for firms with poor environmental profiles. Further, this evidence suggests that expectations of regulatory changes enter into credit rating analysts' evaluations of the effects of climate risk on firms' default risk.

We also employ difference-in-differences analyses for the bonds' yield spreads. The evidence suggests that besides credit rating analysts, bond investors also react to potential future regulatory changes. Yield spreads for regulation-sensitive issuers increase after the passage of the Paris Agreement: the spreads for bonds issued by firms with low environmental scores increased by about 26 bps after the Paris Agreement relative to bonds issued by other firms. Similarly, the relative spreads for bonds issued by top polluting-industry firms increased by about 33 bps.

If the changes in bond ratings and spreads we observe after the Paris Agreement are, in fact, due to climate risk affecting bonds through the channel of expected climate change regulation, then the results should be stronger in those states with stricter regulatory enforcement. To test this corollary hypothesis, we conduct a triple-difference analysis in which we include an indicator variable for firms located in states with more relative enforcement actions. The results show that following the Paris Agreement, the changes in relative credit ratings and yield spreads for the regulation-sensitive firms tend to be more concentrated in states where regulatory enforcement is more stringent. That is, bonds from the environmentally-problematic firms located in the stricter states experience an additional decrease in credit ratings of approximately 0.9 notch and an additional increase in bond

broadly negative for those sectors with the highest exposure to carbon emissions regulation that we have identified." (Moody's, 2015) yield spreads of approximately 60 bps.

Our results support the hypothesis that expected increases in climate regulatory requirements lower credit ratings and raise yield spreads for issuers with poor environmental profiles. Given our shock and the subsequent events, a natural question is whether the changes in ratings and yield spreads reverse if the market expects climate regulatory requirements to decrease in the future. We test this proposition through the November 2016 presidential election and the June 2017 announcement that the U.S. would withdraw from the Paris Agreement. While these events suggest that the treated firms' regulatory risk could lessen, there appears to have been much more uncertainty attached to the regulatory outcome of these events than to the original Paris Agreement. For example, although during the campaign the winning candidate, Donald Trump, promised to loosen environmental regulations, including a U.S. withdrawal from the Paris Agreement, whether and how he would achieve these goals was uncertain.[6] Thus, although his election was unexpected (Berlinger, 2016) and thus, a shock to the environmental regulatory setting for polluting firms, there was uncertainty regarding the extent of the shock. In addition, the June 2017 announcement that the U.S. would withdraw from the Paris Agreement was less of a shock given the widespread speculation before the event. Moreover, even with the announcement, there still existed uncertainty given that the actual official withdrawal could not occur until the day after the November 2020 presidential election and the winner of that election could reverse the decision.[7] Further, even with the June 2017 withdrawal announcement, individual states could impose greater environmental regulatory conditions themselves. Examining these two events, we find some evidence of reversal in credit ratings and yield spreads.

Our analysis and results contribute on a number of dimensions. First, we contribute to the literature on the pricing of firm securities with respect to climate and environmental risk. Our evidence that corporate bond investors demand higher interest rates from issuers with poor environmental performance is consistent with earlier work on the higher cost of bank loans for firms with poorer environmental performance (Chava, 2014), the relationship between climate risk and municipal bonds (Painter, 2020), and evidence regarding carbon premia in equity markets (Bolton and Kacperczyk, 2020). Further, we provide a mechanism through which climate and environmental

[6]See, for example, Parker and Davenport (2016).

[7]Joe Biden, the winner of the 2020 election did indeed announce that the U.S. would re-enter into the Paris Agreement.

risk affect security pricing: the regulatory risk.[8]

Our paper also contributes to the literature on investor preferences for environmentally friendly securities such as the work on the emerging importance of green bonds (Baker et al., 2018; Flammer, 2015; Tang and Zhang, 2018; Zerbib, 2019), and the relation between ESG and bond prices, such as the research showing a strong relation between country ESG characteristics and the pricing of their sovereign bonds (Margaretic and Pouget, 2018; Capelle-Blancard et al., 2019).[9] We contribute by showing that ratings and spreads for corporate bonds are affected by not only a firm's environmental activities but also their regulatory risk exposure. Similarly, our paper is related to Amiraslani et al. (2017) and Jiraporn et al. (2014) in that we also examine the relationship between some aspect of ESG and measures of bond risk and pricing. However, these papers examine the relation between a firm's social capital (as reflected by the firm's CSR rating) and the firm's bond spreads or a firm's ESG scores and the firm's credit rating, while our focus is on the relation between a firm's environmental actions and quality and perceptions of the firm's riskiness as reflected in its credit ratings and yield spreads. We also differ from Amiraslani et al. (2017) in that we employ a shock (the Paris Agreement) that could affect bond pricing through the channel of regulatory risk, while their shock is the 2008 financial crisis, which they argue makes trust more important to investors.[10]

Our paper is related to several papers that use political changes regarding environmental issues to examine how prospects for future governmental actions affect different aspects of firms' actions and investor expectations. Ramelli et al. (2018) examine stock market reactions to Donald Trump's election and Scott Pruitt's EPA appointment, two events that seem to reflect the changing political assessment of environmental issues in the U.S.[11] Ginglinger and Moreau (2019) examine the relation between climate risk and firms' capital structures. They provide evidence that firms reduced their leverage after the Paris Agreement with both a demand effect on the part of the firm and a supply effect on the part of lenders, especially bankers. Our paper is complementary in that we find

[8]Other research provides insights into the effects of physical climate risk such as Ginglinger and Moreau (2019). However, there also exists mixed evidence on the effects of physical climate risk on real estate values(Bernstein et al., 2019; Murfin and Spiegel, 2020; Baldauf et al., 2020).

[9]In addition, Fernando et al. (2017) find that institutional investors avoid firms with very poor environmental performance and Hong et al. (2019) provide evidence of negative stock return predictability of occurrence of droughts.

[10]Our examination of a shock that affects corporate bond risk and pricing is also related to examinations of the opioid crisis by Cornaggia et al. (2020) and Li and Zhu (2019). It is also related to work that shows how changes in rating agency methodology affects real firm outcomes (Fracassi and Weitzner, 2020).

[11]Our paper is also related to Li et al. (2019) who examine how a change in environmental policy in China affected investor choices and Kempf and Tsoutsoura (2020) who examine how the Trump election affected credit ratings by partisan analysts.

decreased credit ratings and higher yield spreads, suggesting that the Paris Agreement increased costs of debt for firms in top polluting industries with more stringent regulatory oversight.

Similarly, our paper contributes to the research showing the relation between firms' cost of debt and liability risk and political uncertainty risk (Gormley and Matsa, 2011; Bradley et al., 2016; Kaviani et al., 2020; Ilhan et al., 2020). Our paper is particularly complementary to that of Ilhan, Sautner, and Vilkov (2020), who examine the effects of the Paris Agreement on firms' tail risk by using out-of-the-money put options on firms' equity securities. They conclude that the Paris Agreement was followed by significantly increased tail risk for the top polluting industry firms. We also focus on risks and acknowledge that an important risk for the bondholders would be the downside risk examined in Ilhan et al. (2020), but our interest is in rating agencies' and bondholders' perceptions and actions, while their interest is in the equity holders' perceptions and actions. Our analyses and results are consistent in finding credit ratings to be decreasing after the Paris Agreement for firms with problematic environmental profiles located in stricter regulatory environments, which suggests increasing perceived climate regulatory risk. The results between the two papers are supportive of the hypothesis that climate regulatory risk is an important factor in the pricing of both equity and fixed income securities.

Finally, we contribute to the literature on the financial market responses to corporate environmental news. Previous work has examined the stock market response. For example, in examining CSR events, Krüger (2015) finds the strongest reactions occur for community and environmental news. In addition, Karpoff, Lott, and Wehrly (2005) provide evidence that a firm's equity investors respond negatively to new information regarding EPA violations and that this response is tied to the expected legal penalties. Our focus is on how bond investors respond to changes in perceptions of firms' environmental regulatory risks.

II. Data

A. Sample Construction

Our sample includes bonds issued by U.S. public non-financial companies over the 2009-2017 period, which are classified as corporate debentures and corporate medium term notes with maturities ranging from one month to 30 years.[12] We obtain data on these bonds and their issuing firms from a number of sources: Mergent FISD, Trade Reporting and Compliance Engine (TRACE), CRSP, Compustat and Sustainalytics. We use Mergent FISD for characteristics of the bonds such as offering terms, bond maturity, the principal amount outstanding and bond credit ratings. We employ Moody's ratings as the primary source of credit ratings. If Moody's did not rate the security, we use the S&P rating, and if that rating is also unavailable, we employ the Fitch rating. For our analysis, we transform the bond credit rating to a quantitative measure by assigning each rating a numerical value, giving a 1 to the lowest rating (D) and increasing by 1 for each notch such that the Moody's Aaa rating (or the S&P and Fitch equivalent) receives a value of 22. This approach has the advantage that when a credit rating is downgraded, the representative number is lower.

We combine the Mergent FISD bond characteristics data with data on secondary market pricing for corporate bonds from the TRACE database.[13] We calculate monthly bond yields as the median yield on all trades of that security occurring on its last active-trading day of a given month.[14,15] Yields are linearly interpolated for months with missing yields. Observations with either missing ratings or which do not have enough information to linearly interpolate a yield are dropped. The risk-free rates are obtained from the US Treasury to calculate yield spreads.[16]

We further obtain data for the issuing firms through CRSP and Compustat, using the six-digit CUSIP, year and month to merge the databases.[17] We employ two measures of a firm's environmental profile. First, we employ ratings provided by Sustainalytics. Sustainalytics reports proprietary ratings along many dimensions within the environmental, social, and governance spheres. The Sustainalytics environmental scores are calculated based on 57 environmental indicators and range from 0-100, with a higher score indicating stronger environmental performance. We employ the summary

[12]We omit any non-standard corporate bonds such as Yankee bonds, convertible bonds, puttable bonds, exchangeable bonds, Canadian bonds, bonds listed in foreign currency, private placement and Rule 144A bonds, variable rate bonds and zero coupon bonds

[13]Data errors in TRACE are filtered following the procedure in Dick-Nielsen (2009).

[14]All trades deviating from the daily median price for that security by greater than 10% are dropped. Additionally, all price reversals greater than 10% are dropped. These additional steps are suggested by Edwards et al. (2007).

[15]Trades for equity-linked-notes reported in TRACE are excluded, as well as those with missing CUSIPs.

[16]The Treasury provides data on one month, three month, six month, one year, two year, three year, five year, seven year, 10 year, 20 year and 30 year bonds. For other maturities, we linearly interpolate rates using available data. Month-end Treasury rates are used in calculating yield spreads.

[17]We drop all observations with missing ticker, missing fiscal year, missing total assets, or missing market value. Data on firm characteristics comes from Compustat. From CRSP, it is possible to obtain a unique mapping of 6 digit CUSIP and ticker by time period, which we use to merge with TRACE.

environmental score, which is calculated as a weighted average of the indicators, where the weights used are industry specific and proprietary, that is, the environmental scores are industry adjusted. Sustainalytics uses a variety of sources including firm code-of-conducts, UN documents, SEC filings, CSR reports, news reports and materials from NGOs and other non-profit organizations. We merge the corporate bond data with the Sustainalytics data by ticker, year, and month.

We also use the categorization of firms into top polluting industries (using two-digit SIC classifications and CDP emissions data as defined in Ilhan, Sautner, and Vilkov (2020).[18]

B. State Environmental Regulation Data

U.S. environmental policy is designed as a shared responsibility between the federal government and the individual states — in general, the federal environmental policy is established through laws passed by Congress and rules developed by the EPA. Individual states typically enforce the federal policy. In particular, state personnel evaluate compliance with regulations and issue enforcement actions if they come to the conclusion that compliance standards are not being met. Federal enforcement protocol is such that states are authorized and expected to enforce EPA regulations for violations within the state using as a minimum the regulatory standards established by the EPA. While states are allowed to create and enforce laws stricter than EPA regulations, they are expected to handle enforcement at least as stringently as EPA standards. Since some states enforce regulations with the bare minimum standards and others enforce them more strictly, this allows us to observe cross-sectional variation in regulatory standards.

We use EPA enforcement data provided in the Integrated Compliance Information System for Federal Civil Enforcement Case Data to measure firms' exposures to environmental regulatory actions. We construct our measure of regulatory costs by employing methodology used in the political science literature (Konisky, 2007). The measure of regulatory strictness we employ captures compliance and enforcement actions for the Clean Water Act (CWA), Clean Air Act (CAA) and Resource Conservation and Recovery Act (RCRA) in a given state in a given year. Specifically,

[18] In particular, Ilhan et al. (2020) rank two digit SIC industries by average carbon emissions between 2010 and 2017, and using this ranking they define the Top 15 Polluting Industries as Petroleum & Coal Products, Primary Metal Industries, Electric, Gas & Sanitary Services, Transportation by Air, Trucking & Warehousing, Water Transportation, Oil & Gas Extraction, Railroad Transportation, Stone, Clay & Glass Products, Paper & Allied Products, Metal Mining, Non-Classifiable Establishments, Chemical and Allied Products, General Merchandise Stores and Textile Mill Products.

we employ the number of enforcement actions, which include both informal enforcement actions (notifications of violation) and formal actions (fines and administrative orders).[19] We normalize the number of enforcement actions by the total number of facilities regulated by the EPA in that state (measured in thousands).[20] This state-year measure is then merged with our data by firms' headquarters state and year.

C. Summary Statistics

Our final data set contains 3,928 corporate bonds, corresponding to 451 firms over the 2009-2017 sample period. In Table I we report the sample summary statistics. Panel A contains summary statistics for the full sample. The average bond in the sample has a yield of 3.46%, a yield spread of 1.66%, a credit rating of about 14.7 (which is in between a Baa2 and Baa1 rating), and an average maturity of 10 years. For the average bond issued during the sample period, the offering yield is 3.48% with a spread of 1.49%, and a credit rating of about 15.3 (which is a little higher than a Baa1 rating).

Examining the issuers, the average environmental score in the sample is about 54.9, a little higher than the halfway point of the 0-100 range, with a standard deviation of 13.2. About 41% of all firms in the sample belong to a top polluting industry. While this is a large percentage of the sample firms, it appears reasonable considering many of the polluting industries are economically important and contain a large number of bond issuers.[21] Table I also shows that, on average, each state engages in an average 0.6 enforcement actions per thousand facilities present in the state each year.

In Panel B, we include summary statistics divided by whether the bond is from a firm classified as being in a polluting or non-polluting industry. The sample contains 70,934 security-year observations from polluting industries and 99,258 observations from non-polluting industries. As can be seen from the table, bonds from firms in the polluting industries differ along security-level and

[19] Analysis is limited to those facilities for which we can obtain the facility-location.

[20] If states fail to enforce regulations at the minimally acceptable level, the EPA has the option to enforce the laws themselves through their regional offices. States for which this is relevant are detailed at `https://www.epa.gov/compliance/state-review-framework-compliance-and-enforcement-performance`.Since we cannot observe whether the EPA or the state is the lead investigator on a given case, we drop all enforcement actions occurring in the few states in which the EPA is responsible for enforcement.

[21] In comparing the sample of firms with bonds to the full sample of firms in Compustat, we find a similar percentage of firms that are described as being in a top 15 polluting industry using the Ilhan, Sautner, and Vilkov (2020) definition.

issuer-level dimensions from the other bonds. Consequently, we control for these characteristics in the later analyses and account for the differences in our identification strategy.

III. Difference-in-Differences: The Paris Agreement

A firm's environmental profile and its regulatory conditions may interact and create endogeneity issues. For example, state governments could impose stricter environmental regulations because the economic conditions in the state are favorable; such favorable economic conditions might in turn attract polluting industry firms to locate there. In fact, Panel B of Table I shows issuers who are part of the top polluting industries are more likely to be located in states with a stricter environmental enforcement. Thus, to mitigate the endogeneity, we exploit a shock that increases the climate regulatory risks faced by firms, while not changing either the performance or environmental profile of the firms, that is, without affecting firms' fundamentals.

The shock we employ is the Paris Agreement, announced on December 12, 2015. The Paris Agreement has a primary goal of limiting global temperature rise in this century to 1.5 degrees Celsius above pre-industrial levels. As such the Agreement calls for the signing countries to submit national action plans that would reduce emissions with sufficient speed to achieve the goal. Such plans imply the development of expectations of more stringent environmental regulations since the national action plans would need to include regulatory responses that induce firms to help achieve the climate goal. We hypothesize that the Paris Agreement shock resulted in firms with poor environmental practices facing higher climate regulatory risks relative to other firms. Such effects should be reflected in changes in firms' bond credit ratings and spreads.

To test this hypothesis, we conduct difference-in-differences analyses to compare changes in the credit ratings and yield spreads of bonds from firms with problematic environmental profiles versus those from other firms before and after the Paris Agreement. We use two assessments of environmental profiles: (i) whether a firm is in a Top 15 polluting industry (according to the Ilhan et al. (2020) definition) and (ii) whether a firm has a below-median Sustainalytics environmental score. While the assignment of a firm to a polluting industry is clearly unrelated to the Paris Agreement, the Sustainalytics score (similar to credit ratings) could have been affected by the Agreement. Thus, we employ the Sustainalytics score associated with the firm in July 2015 (five months before the Paris Agreement) to counteract possible anticipation of the outcome of the Paris climate talks. The five month allowance should be more than sufficient given the significant uncertainty that existed regarding whether the talks would be successful even just days before the Agreement was announced.

A. Average bond credit ratings and spreads by environmental profile

Before conducting the formal difference-in-differences analyses, we examine changes in the average credit ratings and spreads for bonds issued by firms in high polluting industries and by firms with different environmental scores. Figure 1(a) displays the average credit ratings for each of the Top 15 Polluting Industries before and after the December 2015 Paris Agreement. It should be noted that unconditionally, there exists significant variation in the credit ratings across industries. Issuers in certain industries such as Petroleum and Coal Products, Transportation by Air, Trucking and Warehousing, Non-Classifiable Establishments, Chemical and Allied Products, and General Merchandise Stores tend to be more creditworthy, on average, with investment grade ratings. In other polluting industries such as Water Transport, Stone, Clay and Glass, or Metal Mining, the bond issuers appear to be less creditworthy, on average.

Overall, the figure demonstrates observable differences in credit ratings across the two periods, which supports the hypothesis that an association exists between the Paris Agreement event and a ratings decrease for firms in polluting industries. Furthermore, the industries whose ratings are most affected by the announcement of the Paris Agreement include Primary Metal, Water Transport and Metal Mining. These industries are relatively less sensitive to oil prices, suggesting that the effect is unlikely driven by changes in oil prices (which we examine in more depth below).

Figure 1(b) contains similar results with respect to changes in yield spreads for top polluting industry bonds around the Paris Agreement. As in the case of the credit ratings, substantial differences exist across industries in the spreads and their changes. Nonetheless, in most cases, large increases in spreads occurred after the Agreement with the largest increases in Primary Metals, Water Transport, Oil and Gas Extraction and Metal Mining industries. Some industries, such as Petroleum and Coal, have little change in credit ratings but noticeable increases in spreads. This difference may arise because credit ratings for petroleum and coal companies are unconditionally high and may not be near their credit rating boundaries. Consequently, although investors react with price changes, the expected effects of the Paris Agreement may not be deemed sufficiently large to warrant downgrades for these bonds.

In Figures 2(a) and 2(b), we report results of similar analyses across firms' environmental scores. We first sort bonds by the issuer's July 2015 Sustainalytics environmental score into ten groups and compare credit ratings and bond spreads across the decile environmental score bins. Figure 2(a) contains the distribution of the average decile credit ratings from the lowest environmental scores on the left to increasingly higher environmental scores as one moves right. The figure clearly demonstrates that, unconditionally, bond issues from firms with lower environmental scores tend to have lower average credit ratings, consistent with evidence in Chava (2014) regarding bank loans. Additionally, after the Paris Agreement, the average credit ratings decrease substantially for bonds from firms with lower environmental scores, whereas there appears to be little effect for bonds from firms with higher environmental scores.

Figure 2(b) displays the average spreads for bonds across the environmental score deciles. Again the figure shows dramatic changes around the Paris Agreement for issues from firms with environmental scores below 60, and very little change for those with environmental scores above 60. Since the average environmental score in the sample is 55 (as shown in Table I), corporate bond issues with above average environmental scores tend to have minimal changes in yield spreads after the Paris Agreement, while those with below average scores have increases in their spreads. These figures imply that the Paris Agreement led credit rating agencies and bond investors to view firms with poor environmental practices more negatively, while at the same time not significantly affecting their views of the bond issues from firms with higher environmental scores.

B. Tests for Changes in Credit Ratings around the Paris Agreement

In this section we conduct more formal tests of whether the Paris Agreement had a causal effect on the corporate bond market. We first test changes in bond credit ratings in the two-year period around the December 2015 Paris Agreement through the following regression:

$$Rating_{it} = \alpha + \beta_1(AfterParis_t \times EnvProfile_j) + \beta_2(EnvProfile_j) + \epsilon_{it}, \quad (1)$$

where $AfterParis_t$ is a dummy for months starting in December 2015 and continuing through the following 12 months. We include time fixed effects and, in some specifications, security fixed effects. Since the Paris Agreement is a time-series shock, our sample consists of bonds issued before the Paris Agreement in order to capture changes in ratings influenced by the Agreement. In constructing our test sample, we include a pre-event period of twelve months prior to the Agreement and a post-event period of twelve months following the Agreement, i.e., the testing period runs from December 2014 through November 2016. The panel is constructed as a balanced panel, limiting the testing sample further to those securities for which it is possible to observe data in both the pre- and post-period surrounding the Agreement.[22]

In Equation 1, β_1 is equal to the difference in rating changes after the Paris Agreement between bonds issued by firms with below-median environmental scores (or alternatively, firms in polluting industries) and bonds issued by firms with above-median environmental scores (firms in non-polluting industries). Thus, β_1 is designed to capture the effects of the Paris Agreement on bond risk for a firm with a poor environmental profile, controlling for time-invariant bond characteristics and for macroeconomic trends that affect all bond issues. We cluster standard errors at the issuer level to account for correlated error terms within firm. However, the results are robust to clustering at the industry or state level as well.

Table II reports the results of the difference-in-differences regressions. In Columns (1) and (2), it is clear that controlling for time-invariant firm characteristics and macroeconomic trends, bonds from firms with below-median environmental scores experience an average decrease in ratings of around half a notch (0.5) following the Paris Agreement relative to other bonds. Similarly, Columns (3) and (4) show that bonds from firms in the Top 15 Polluting Industries, on average, experience about a 0.6 notch ratings decrease following the Paris Agreement relative to other bonds. In our tests, we define polluting industry as Top 15 polluting industries, but the results are robust to other definitions.

The tests in Table II are based on bond issues. A question may arise as to whether the results also hold at the issuer level. Table III reports results of tests in which we aggregate outcome

[22]For this test to be interpreted causally, the parallel trends assumption should hold, which in this context means that ratings would have evolved similarly for issues from firms with poor environmental profiles relative to other issues in the absence of the Paris Agreement, controlling for time invariant issue characteristics and macroeconomic trends. We examine in later analysis whether this assumption appears reasonable.

variables at the issuer-level (rather than the bond issue level). We find the results to be quite similar. Issuers with below-median environmental scores have decreased credit ratings of about one-third notch, and those in the top polluting industries have decreased credit ratings of about 0.6 notch.

To further examine the dynamics of treatment effects in relation to the Paris Agreement event, we construct a series of tests to examine differences over time between ratings for firms in the treatment and the control groups. To do so we run the following regressions:

$$Outcome_{it} = \sum_{k=-11}^{11} \beta_k [(t = k) \times EnvProf_j] + \gamma_i + \kappa_t + \epsilon_{it}. \tag{2}$$

where the outcome variables are either the credit ratings or spreads for bond i at time t. The interacted time dummy for the first period (November 2014) is excluded, so all treatment effects are relative to November 2014.

Figure 3(a) shows the time-series results for these regressions when the outcome variables are the bond credit ratings and we examine the treatment effects for bonds issued by firms with a below-median environmental score. The figure shows the treatment effect for each period in our sample, allowing us to examine the effects before and after the Agreement. The blue line and dots indicate the coefficient estimates, and the red and green lines are bands of a 95% confidence interval around these estimates. Examining the effects before the Agreement, we find that the treatment effect is not significantly different from zero in the entire pre-event period, indicating the parallel trends assumption appears to hold. However, after the Paris Agreement in December 2015, the treated firms' bonds have significantly lower credit ratings, consistent with the results reported in Table II.

Figure 3(b) illustrates the results for Equation (4) where the treated firms are from the Top 15 Polluting Industry. The illustrations in this figure, combined with the very similar movements in Figure 3(a) for the below-median environmental scores, provide strong evidence that the parallel trends assumption is likely satisfied, in addition to showing clearly observable changes in ratings for treated bonds, i.e., bonds from issuers with poor environmental performance, after the Paris Agreement.

The findings in this section imply a direct consequence of the Paris Agreement for firms with problematic environmental profiles. In particular, the results imply that subsequent to the Paris Agreement, issuer with a low environmental score, or a member of a top polluting industry, could expect their bond credit ratings to decrease by about half a notch relative to other bonds. These results provide evidence that credit rating agency analysts appear concerned about future regulatory changes when evaluating the effects of environmental risk on a bond's default risk.

C. Tests for Changes in Yield Spreads around the Paris Agreement

To test for changes in bond yield spreads around the Paris Agreement we use the following regressions:

$$Spread_{it} = \beta_1(AfterParis_t \times EnvProfile_j) + \beta_2 EnvProfile_j + \gamma_i + \kappa_{tp} + \epsilon_{it}. \tag{3}$$

To better control for noise in spreads and compare bonds with similar creditworthiness, we conduct a one-to-one Mahalanobis matching with replacement (Mahalanobis, 1936). The Mahalanobis measure weights the distance in terms of covariance and the intuition behind this approach is to identify and match for every treated firm, the control firm with the shortest distance.[23,24] This distance is calculated as of July 2015 using the bond's credit rating, the size of the issuing firm, the firm's equity oil beta and the bond's time to maturity as covariates.

We believe it is particularly important to match on oil beta in order to alleviate any concerns that the results on bond pricing may be driven by price movements in the oil market, particularly given the changes in oil prices over this period. We use the following model to calculate firms' equity oil betas:

$$R_{it} = \alpha + \beta_{market} MktRet_t + \beta_{oil} OilRet_t + \epsilon_{i,t}, \tag{4}$$

where $MktRet$ is proxied by the CRSP value-weighted index and $OilRet_t$ is the monthly return

[23] We use a caliper of 0.40, meaning if for a given treatment firm there does not exist a control firm whose Mahalanobis distance is 0.40 or less, we drop it from the sample.

[24] It has been shown that with two or more continuous variables the Mahalanobis distance is biased. To address this, we use the appropriate bias adjustment in conducting the matching (Abadie and Imbens, 2006).

on Brent Crude Oil for month t. We calculate this value for all firms in our sample for which we observe 36 months or more of stock price data before November 2015.[25]

We construct separate matched samples for the top polluting firm indicator and the below-median environmental score indicator. We include all observations occurring in November 2015 or earlier so as to evaluate whether the control and treatment groups were similar prior to the Agreement. In Table IV we report the summary statistics for both matched samples (as of July 2015). Panel A reports statistics for the control and treatment samples matched on the below-median environmental score indicator and Panel B reports the sample matched on the top polluting industry indicator. The last columns of each panel provide difference-in-means tests between the treatment and control groups. As differences between these two groups are generally statistically insignificant and economically small, it is reasonable to conclude the control and treated groups are observationally similar.[26]

Table V reports the results from the difference-in-differences regression in which bond spread is the dependent variable. In Equation (3), instead of employing a time fixed effect, we include a time-matched pair fixed effect κ_{tp}. As a result, this test can be interpreted as comparing the change in yield spread for a treated security to the spread for its matched control security after the Paris Agreement, thus, controlling for the time-invariant security characteristics. The effects of the Paris Agreement on treated firms' spreads are both large and statistically significant. Furthermore, similar to the results for the credit ratings, these results are similar whether they include or exclude the security fixed effects. After the Paris Agreement, spreads for bonds issued by firms with below-median environmental scores increased by about 26 bps relative to other bonds. Similarly, for bonds issued by top polluting firms, the spreads increased by about 33 bps relative to other bonds.[27]

These results use a sample of bonds in which each treatment bond is matched with a control bond. We also conduct the same regressions in which we aggregate across bonds from the same issuer. Table VI shows the results at the issuer-level, which are qualitatively similar to those using issue-level data.

[25]We only use data from periods prior to the Paris Agreement to avoid controlling for price changes that may have occurred due to regulatory changes associated with the Paris Agreement.

[26]Results are similar if we match as of November 2015 instead of July 2015.

[27]A common concern when conducting tests using matching estimators is that results may be driven by the matching procedure itself. To alleviate this concern, we also conducted the analysis using the full unmatched sample. These results are provided in Table A.1. Using the unmatched sample, the results not only continue to hold, but they are also stronger.

We examine the dynamics of treatment effects for yield spreads in relation to the Paris Agreement event by constructing a series of tests to examine differences over time between spreads for firms in the treatment and the control groups using Equation 2. Figure 4(a) illustrates the changes in bond spreads over time where the below-median environmental score is the treatment. The pattern shows that around the Paris Agreement there exists a sizable initial increase in spreads for bonds issued by poor environmental firms relative to other bonds, although the initial effect somewhat reverses in the later months. A similar pattern is observed in 4(b) where the treatment effect is based on membership in a top polluting industry. One explanation for the partial reversals is the uncertainty surrounding which policy would ultimately result from the Agreement. This uncertainty arose because of the 2016 presidential election and subsequent June 2017 announcement of U.S. intention to withdraw from the Agreement. We examine the issue more thoroughly in section IV.

The substantial increases in bond spreads for firms with poor environmental profiles that we observe support the hypothesis that investors developed expectations that these firms would soon need to abide by new regulations, which increases their climate regulatory risk. The increase in climate regulatory risk leads to increases in bond spreads and thus, these firms' cost of debt rises relative to that of the more environmentally friendly firms. These results are consistent with other research showing that environmental policies are related to firms' costs of debt (Chava, 2014), that the Paris Agreement increased perceptions of downside risk (Ilhan et al., 2020) and that the Paris Agreement changed firms' leverage (Ginglinger and Moreau, 2019). The result is also consistent with previous literature that shows that firms' cost of debt increases with political uncertainty risk and increased liability risk (Bradley et al., 2016; Gormley and Matsa, 2011).

D. Triple-difference tests

While the Paris Agreement increased the prospect of future environmental regulatory risks, we expect its effects to differ across companies in part due to variations across state governments in their enforcement of environmental regulations. In a scenario in which the U.S. government imposes new environmental regulation at the federal level, we hypothesize that firms located in high-enforcement states would be the most affected. To examine this hypothesis, we conduct a triple-difference regression in which we include an indicator variable for firms headquartered in states with stricter regulatory environments. To define the stricter regulatory environments, we sort states by the total of EPA penalties issued from 2012 through 2015 (the four years leading up to the Paris Agreement). States with an above-median number of penalties are defined as high regulatory enforcement states, and those with a below-median number of penalties as low regulatory enforcement states.

Using these definitions, we run the following analyses:

$$
\begin{aligned}
Outcome_{it} = \beta_1(AfterParis_t \times EnvProfile_j \times HighReg_s) \\
+ \beta_2(AfterParis_t \times EnvProfile_j) + \beta_3(EnvProfile_j \times HighReg_s) \\
+ \beta_4(AfterParis_t \times HighReg_s) + \beta_5 EnvProfile_j + \beta_6 HighReg_s + \gamma_i + \kappa_t + \epsilon_{it},
\end{aligned}
\tag{5}
$$

where $Outcome_{it}$ is alternately, $Rating_{it}$ or $Spread_{it}$. The primary parameter of interest is β_1, which captures the effects of the Paris Agreement for polluting firms that are located in a state with strict regulatory enforcement relative to a state with less strict regulatory enforcement. If β_1 is negative in Equation 5 when the Outcome variable is Rating and positive when the Outcome variable is Spread, these results would imply that firms with poor environmental profiles suffered more after the Paris Agreement in states where they could expect any potential new regulations to be enforced more strictly. This suggests that regulatory risk is the channel through which the Paris Agreement affects bond credit ratings and spreads. We again use both the below-median environmental score indicator and the top polluting industry indicator to define treated firms.

Table VII provides the results of the triple-difference regressions where the dependent variable is credit ratings. In Columns (1) and (2), in which the environmental measure is the below-median environmental score indicator, the results show that relative to other firms, credit ratings decreased by about 0.8 notches for firms with low environmental scores located in high regulatory enforcement states following the Paris Agreement. Columns (3) and (4) display results using the top polluting industry indicator. The coefficient is negative and statistically significant in all columns, showing that the decrease in credit ratings for firms with poor environmental profiles relative to other firms is more severe in states with stricter regulatory enforcement. Our estimate of β_1 in Equation 5 indicates that credit ratings for polluting firms located in high enforcement states, on average, dropped by about 0.9 notches relative to those located in low regulation states following the Paris

Agreement.

Table VIII reports the results for the triple-difference tests in which bond spreads are the dependent variable. When using the below-median environmental score indicator, as shown in Columns (1) and (2), bond spreads increased by 55 bps for firms with poor environmental profiles located in high regulatory enforcement states relative to those with low regulatory enforcement states. Columns (3) and (4) display results using the top polluting industry indicator. The triple-difference estimate of $AfterParis_t \times TopPolluter_j \times HighReg_s$ is positive and statistically significant, implying that following the Paris Agreement bond spreads increase for polluting firms located in high regulation states relative to those located in low regulation states. Based on the estimate for β_1 from Equation 5, controlling for regulation, bond spreads do not exhibit a change that is statistically significantly different from zero for top polluting firms located in low regulation enforcement states. However, bond spreads increased by about 60 bps for top polluting firms located in high regulatory enforcement states relative to other firms. Thus, the results show that regardless of whether the below-median environmental score indicator or the top polluting industry indicator is used, credit ratings decreased and bond spreads increased following the Paris Agreement for bond issues from environmentally problematic firms.

The triple-difference results imply that most of the effect of the Paris Agreement on firms' cost of debt is through the channel of regulatory costs, which suggests that both credit rating agencies and bond investors believed the Paris Agreement had a greater effect on the cost of debt for issuers located in high-regulation states. This implication is consistent with the hypothesis that bond market participants expected the Paris Agreement to lead to increased future regulation for environmentally problematic firms, which would most likely be enforced through the state governmental agencies. These results are also consistent with previous research documenting that firms face costs due to environmental regulation in the form of legal and regulatory penalties (Karpoff et al., 2005).

IV. Reversals around the 2016 Presidential Election and Announcement of the U.S. Withdrawal from the Paris Agreement

The empirical results in the previous sections support the hypotheses that environmental regulatory risk is important to bond credit ratings and pricing and that bond market participants view bonds issued by firms with poor environmental performance as relatively more risky following expectations of additional environmental regulation from the Paris Agreement. Events after the Paris Agreement, namely the 2016 U.S. presidential election and the 2017 announcement that the U.S. would withdraw from the Paris Agreement, allow us to further test the hypotheses. After the Paris Agreement, one of the candidates in the U.S. presidential election, Donald Trump, actively campaigned on withdrawal from the Paris Agreement.[28] Moreover, when Mr. Trump was elected President of the United States on November 8, 2016, the investment community and public, in general, appeared to view the result as a surprise.[29] As a result, the 2016 election provides a setting in which bond market participants may have re-evaluated the likelihood of severe new climate regulation. In addition to examining the responses in the bond market to the election result, we also analyze whether changes occurred upon the announcement of an actual policy change, which occurred on June 1, 2017, when the U.S. President announced that the country would withdraw from the Paris Agreement.

An important complicating factor in the market responses to these events is that any actual withdrawal from the Paris Agreement could not occur before November 4, 2020.[30] Thus, the outcome of the 2016 election, while suggesting that the United States would withdraw from the Agreement, still contained uncertainty about whether the President would actually follow through on the withdrawal and even if he did so, whether the decision could be reversed in the 2020 election. In addition, given the documented conservatism of credit rating analysts in adjusting their ratings,

[28]The BBC News had the headline "Donald Trump would 'cancel' Paris climate deal." BBC News. May 27, 2016; See also Parker and Davenport (2016).

[29]On November 9, 2016, *The Wall Street Journal* ran an article with the headline "Trump's Surprise Ends Election, Begins Uncertainty for Markets." Similarly, CNN had an article wire with the headline, "Trump's Victory in U.S. Election, The Latest in a Year of Shocks."

[30]The Paris Agreement entered into force on November 4, 2016. According to Article 28 of the Paris Agreement a party to the agreement may withdraw by written notification after three years and the withdrawal will take effect one year after the written notification "or on such later date as may be specified in the notification of withdrawal."

it is not clear that the ratings would have changed following the 2016 Presidential election because there was not a definitive change in policy at that point.[31] Anecdotal evidence suggests this to be the case.[32]

A further complicating factor in the market response to the withdrawal announcement is the degree to which the individual states would impose their own climate change regulation, even without federal regulation. In fact, upon the announcement of the withdrawal, the governors of Washington, New York and California announced that they were forming an alliance of states that would be committed to upholding the Paris accord.[33]

To test the extent of any changes in ratings and spreads that occurred around these two events, we conduct the following regressions:

$$Outcome_{it} = \beta_1(EnvProfile_j \times Event_t) + \beta_2 EnvProfile_j + \gamma_i + \kappa_t + \epsilon_{it}, \tag{6}$$

where $Outcome_{it}$ is alternately, $Rating_{it}$ or $Spread_{it}$, $EnvProfile_j$ is based on environmental score or industry, and $Event_t$ is an indicator variable equal to 1 if the observation occurs in November 2016 or later (for the 2016 election regression) or after June 1, 2017 (for the official withdrawal announcement). In each of these tests, our pre- and post-event periods are set at 6 months (as opposed to the 12 months we used previously) so that the Paris Agreement announcement (or the 2016 election) is not included in the pre-event period. In these specifications, β_1 can be interpreted as the change in each outcome variable following the respective event for bond issues from polluting firms relative to those from non-polluting firms.

The results for the changes in credit ratings after the 2016 election are displayed in Panel A of Table IX with below-median environmental score (Low Env Score) as the environmental profile variable in Columns (1) and (2) and top polluting industry as the environmental profile indicator in Columns (3) and (4). In both specifications for the 2016 election, the result is statistically

[31]The argument is that credit rating analysts are conservative in adjusting their ratings as they want to avoid short-term fluctuations in the ratings. Thus, they tend to change ratings only with sufficient certainty regarding changes in issuer default risk (Altman and Rijken, 2004; Gredil et al., 2019; Löffler, 2005). Consequently, bond credit ratings are typically far less volatile than bond spreads.

[32]In the February 16, 2017 Moody's Report "Shift in US Climate Policy Would Not Stall Global Efforts to Reduce Emissions," the agency notes that as of time of publication, it was too early to tell exactly what climate policy will be reversed.

[33]See Tabuchi and Fountain (2017). This alliance has grown into a bipartisan coalition of 25 states representing 55 percent of the U.S. population (http://www.usclimatealliance.org/)

indistinguishable from zero, thus, the rating agencies did not meaningfully change ratings for environmentally poor issuers following the 2016 election outcome.

Panel B of Table IX reports the results for the regressions after the June 2017 announcement that the U.S. planned to withdraw from the Paris Agreement. The results for the below-median environmental score firms reported in Columns (1) and (2) provide strong evidence that credit ratings improved for these firms after the withdrawal announcement. Similarly, the results for the credit ratings of firms in the top polluting industries, reported in Column (4), provide some evidence that following the withdrawal announcement, ratings for bonds issued by top polluting industries improved by 0.06 notches relative to those issued by firms in other industries.

In contrast, there exists some evidence that bond investors reacted differently to the two events as shown in Table X, where Panel A provides the results for changes in yield spreads after the 2016 election and Panel B reports the results for changes after the announcement of the Paris Agreement withdrawal. Columns (3) and (4) of Panel A show that for the top polluters, the yield spreads significantly declined following the 2016 election. In fact, the bond spreads declined by 11.3 bps for bonds from polluting issuers relative to those from non-polluting issuers. Given that after the Paris Agreement, as shown in Table V, bond spreads for polluting issuers increase by about 33.3 bps, the results suggest that the reversal in spreads after the 2016 election is about one third of the initial increase in bond spreads following the Paris Agreement announcement.

However, as shown in Panels A and B, Columns (1) and (2), there was little change in yield spreads for firms with low environmental scores for either event. Similarly, in Columns (3) and (4) of Panel B, the results show that bond spreads for top polluters did not significantly change following the withdrawal announcement.

The results from the analyses in this section provide some support for the hypothesis that bond investors reacted to the potential policy change affecting polluting issuers after the November 2016 election, but that credit rating analysts waited for a definitive change in policy before adjusting ratings for climate regulatory risk. These results suggest that these market participants may have been responding to the announcements in ways that are consistent with existing research regarding differences between investors' and credit ratings analysts' actions, e.g., (Altman and Rijken, 2004; Gredil et al., 2019; Löffler, 2005).

V. Conclusions

Environmental and climate risk have received more focused attention from financial market participants over the past few years. In this study, we provide empirical evidence that suggests uncertainty about future regulatory actions can be a major reason why bond market participants respond to firms' environmental performance, and particularly, changes in firms' exposures to climate risks.

Using a difference-in-differences analysis, we show that having poor environmental performance is associated with lower credit ratings and higher bond yield spreads, particularly for firms located in states with stricter environmental regulations. We find that the December 2015 Paris Agreement appears to have had negative consequences for firms that are in top polluting industries or have poor environmental performance in general. More importantly, we find that these consequences on bond ratings and yields are observed to be stronger in states that enforce regulation more strictly, suggesting that they are stronger because potential new regulations were expected to be enforced more strictly.

The results imply that these firms face a higher probability of regulatory costs such as fines or possibly reputation losses, which in turn increases their default risk. These results are consistent with the legal cost evidence provided by Karpoff et al. (2005). Although these authors conclude there exist no reputational losses for EPA violations during their sample period, investors, including institutional investors, have become much more concerned about firms' environmental activities over the approximately two decades since their sample ended. Our results, which are also consistent with previous research showing the greater negative consequences for firms that pollute under stricter regulatory regimes, imply strictness in regulation forces firms to internalize the costs of pollution (Greenstone, 2002).

Our results have important implications for how firms' environmental profiles are related to market participants' assessments of their corporate bonds. The results suggest that credit rating analysts and bond investors are concerned with issuers' environmental profiles because of potential regulatory costs. Thus, if bond investors expect an issuer to be punished for poor environmental performance, they are more likely to price those costs into the firms' bonds.

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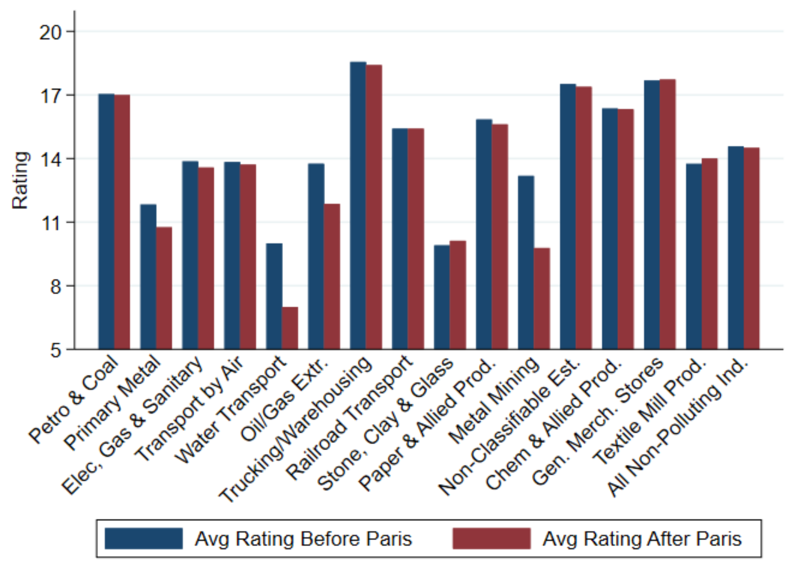
Figure 1

Credit ratings and yield spreads by polluting industry around the Paris Agreement

This figure displays average bond ratings and yield spreads for bond issues that are segmented by industry, where the pre-event period runs from December 2014 through November 2015, and the post-event period runs from December 2015 through November 2016. The ratings are assigned such that a higher number indicates a better rating. A numerical rating of 1 corresponds to a D rating, a rating of 5 to a Caa2 rating, a rating of 10 to a Ba3 rating, a rating of 15 to a Baa1 rating a rating of 20 to a Aa2 rating and a rating of 22 to a Aaa rating.

(a) Ratings



(b) Spreads

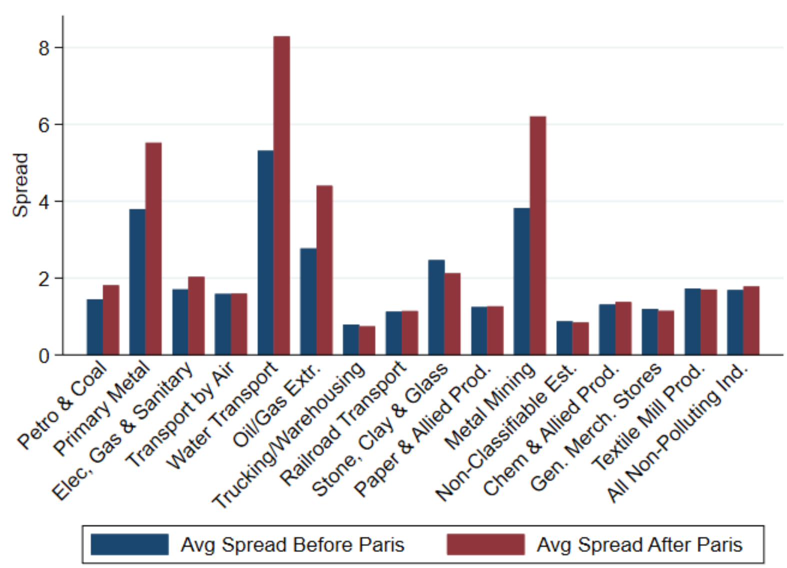
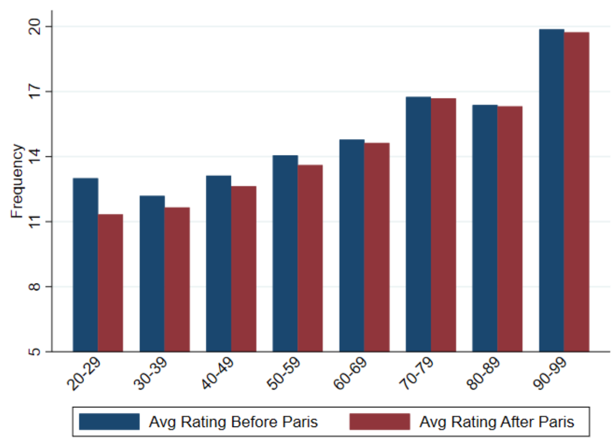


Figure 2

Credit ratings and yield spreads by environmental scores around the Paris Agreement

This figure displays average ratings and spreads segmented by industry where the pre-event period runs from December 2014 through November 2015, and the post-event period runs from December 2015 through November 2016. A numerical rating of 1 corresponds to a D rating, a rating of 5 to a Caa2 rating, a rating of 10 to a Ba3 rating, a rating of 15 to a Baa1 rating a rating of 20 to a Aa2 rating and a rating of 22 to a Aaa rating.

(a) Ratings



(b) Spread

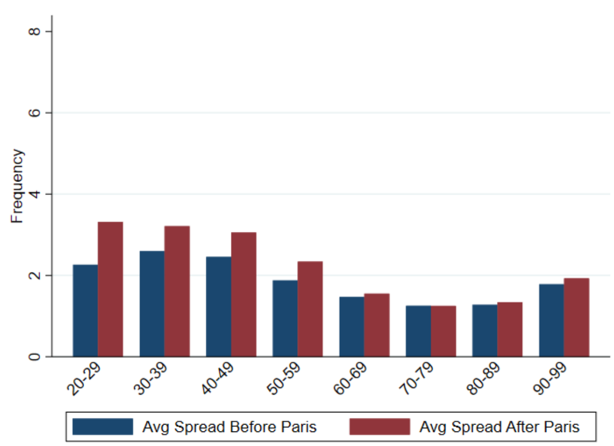
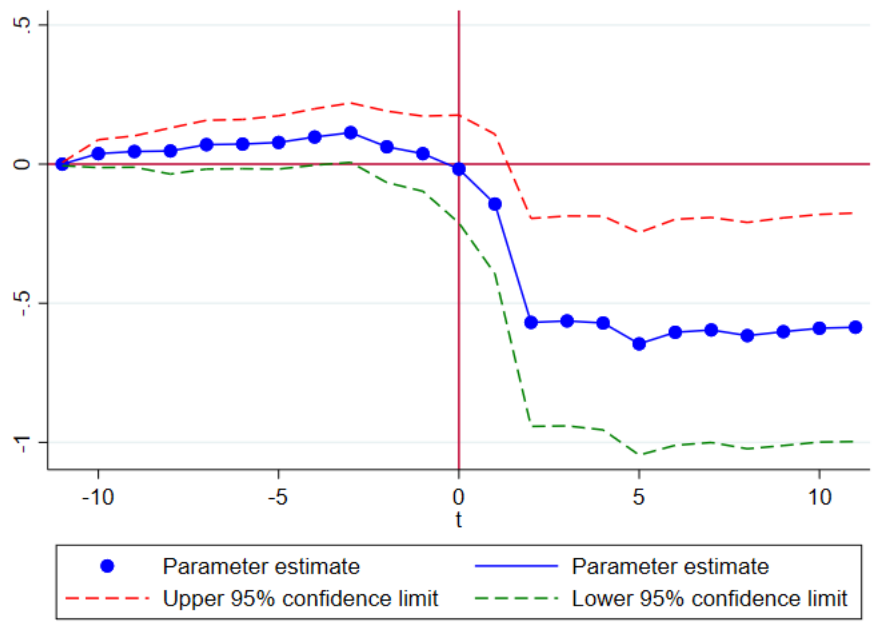


Figure 3

Bond credit ratings around the Paris Agreement

This figure plots the coefficients from $Rating_{it} = \sum_{k=-11}^{11} \beta_k[(t = k) \times EnvProf_j] + \gamma_i + \kappa_t + \epsilon_{it}$. pre-event period runs from November 2014 through September 2015 and post-event period runs December 2015 through November 2016. The chart includes all interaction terms except for November 2014, so the regression coefficient can be interpreted as the effect of belonging to a top polluting industry on bond credit ratings in each period relative to November 2014. (Higher numerical scores indicate better credit ratings.)

(a) $EnvProf_j = BelowMedEnv_j$



(b) $EnvProf_j = PollutingInd_j$

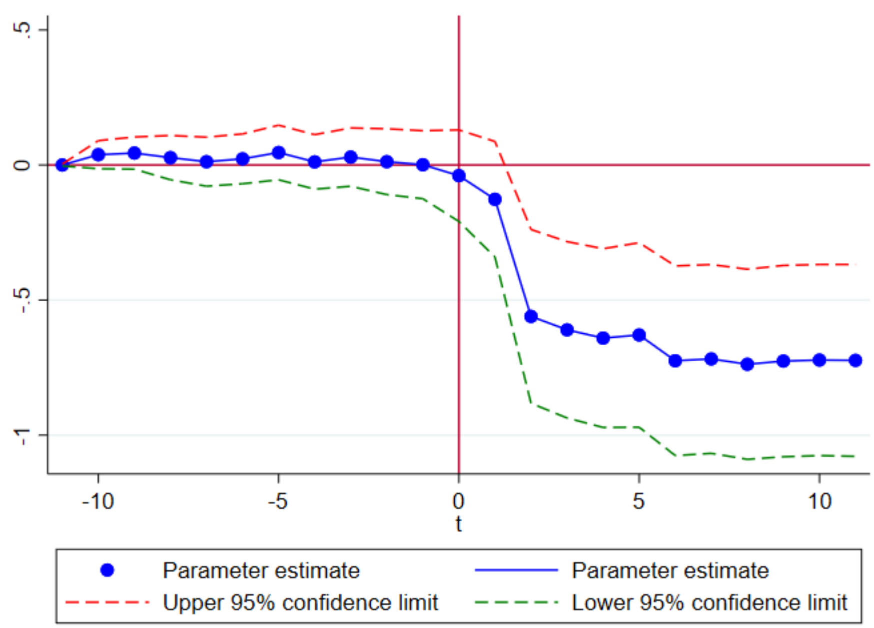
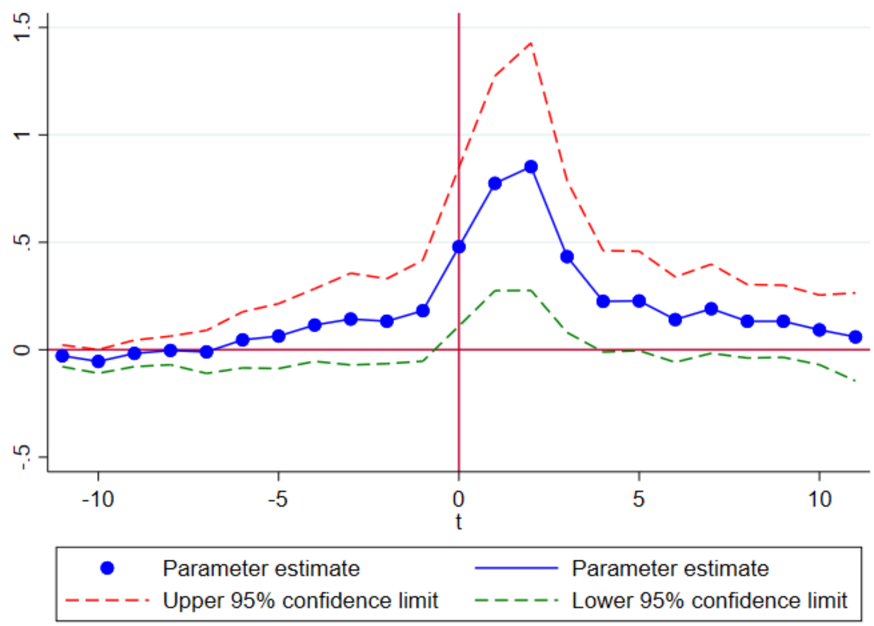


Figure 4
Yield spreads around the Paris Agreement
This figure plots the coefficients from $Spread_{it} = \sum_{k=-11}^{11} \beta_k[(t = k) * EnvProf_j] + \gamma_i + \kappa_{tp} + \epsilon_{it}$. pre-event period is November 2014 through September 2015 and post-event period is December 2015 through November 2016. The chart includes all interaction terms except from November 2014, so the regression coefficient can be interpreted as the effect of belonging to a top polluting industry on bond yield spreads in each period relative to November 2014.

(a) $EnvProf_j = BelowMedEnv_j$



(b) $EnvProf_j = PollutingInd_j$

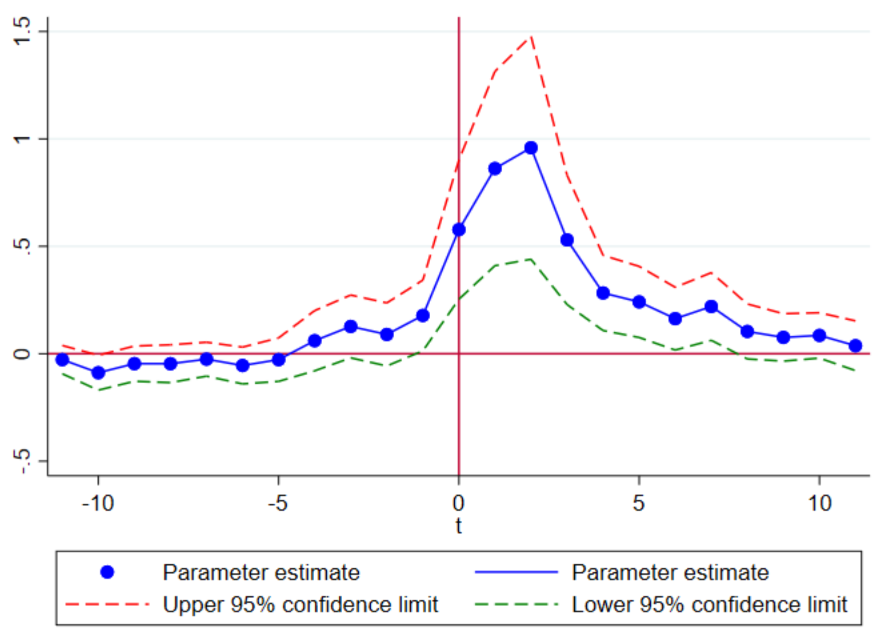


Table I
Summary Statistics

Panel A: Full sample

Variable	Units	Mean	Median	Std. Dev.
Security-Year-Level Variables				
Credit Rating	Rating	14.709	15	3.027
Yield	Percent	3.461	3.280	2.022
Yield Spread	Percent	1.662	1.249	1.605
Time to Maturity	Year	9.622	6.583	8.592
Coupon	Percent	5.032	5.1	1.933
ln(1 + Principal Outstanding)		13.176	13.122	0.704
At-issue Security-Year Variables				
Credit Rating	Rating	15.273	15	2.815
Offering Yield	Percent	3.479	3.344	1.464
Offering Yield Spread	Percent	1.489	1.219	1.050
ln(1 + Principal Outstanding)		13.379	13.305	0.603
Time to Maturity	Year	9.967	10	7.246
Issuer-Year-Level Variables				
Environmental Score	Points	54.879	53.24	13.172
Polluting Industry Indicator		0.411	0	0.492
Pretax Interest Coverage	(OIBDP-Int)/Int	13.608	8.391	18.365
ln(Std. Dev. of Returns)		0.919	0.872	0.303
Profitability	Rev/TA	0.227	0.179	0.179
Leverage	TD/TA	0.317	0.296	0.156
Tangibility of Assets	PPE/TA	0.331	0.238	0.263
Annualized Stock Return	Percent	15.067	16.748	96.517
MV Equity (in billions)	Dollars	18.800	11.400	18.200
ln(Total Assets)		9.458	9.281	1.131
Cash/Assets	Ratio	0.100	0.066	0.109
State-Year Level Variables				
Penalties per Thousand Facilities	Number/Yr	0.664	0.403	1.007

Panel B: Sample by Polluting Industry

Variable	Polluting Mean	Non-polluting Mean	Difference
Security-Year-Level Variables			
Credit Rating	14.882	14.592	0.290***
Yield Spread	1.680	1.656	0.024***
Yield	3.497	3.447	0.050***
Time to Maturity	9.795	9.535	0.260***
Coupon	5.068	5.008	0.061***
ln(1 + Principal Outstanding)	13.166	13.162	0.004
Penalties per Thousand Facilities	0.614	0.478	0.136***
# Observations	70,934	99,258	
At-issue Security-Year Variables			
Credit Rating	15.193	15.211	-0.018
Offering Spread	1.478	1.496	-0.017
Offering Yield	3.479	3.479	0
ln(1 + Principal Outstanding)	13.357	13.391	-0.035
Time to Maturity	10.217	9.789	0.428
Issuer-Year-Level Variables			
Environmental score	53.543	55.707	-2.167***
Pretax Interest Coverage	11.421	15.191	-3.770***
ln(Std. Dev. of Returns)	0.936	0.912	0.024***
Profitability	0.172	0.265	-0.093***
Leverage	0.313	0.320	-0.008***
Tangibility of Assets	0.521	0.200	0.321***
Annualized Stock Return	11.987	17.067	-5.080***
MV Assets (in billions)	20.1	17.9	2.2***
ln(Total Assets)	9.676	9.295	0.381***
Cash/Assets	0.069	0.123	-0.055***

The table provides summary statistics for bond, issuer and state regulatory variables over the 2009–2017 sample period. The full sample statistics are reported in Panel A. In Panel B, the full sample is divided between issues and issuers that are part of the top polluting industry and others. Excess bond returns, yield spread, yield, coupon rate, principal amount, profitability, leverage, tangibility, market value of equity and the ln(totalassets) are winsorized at the 1% and 99% levels. The ratings variable is assigned such that a higher number indicates a better rating. A numerical rating of 1 corresponds to a D rating, a rating of 5 to a Caa2 rating, a rating of 10 to a Ba3 rating, a rating of 15 to a Baa1 rating a rating of 20 to a Aa2 rating and a rating of 22 to a Aaa rating.

Table II
Effects of the Paris Agreement on Credit Ratings

	(1)	(2)	(3)	(4)
After Paris × Low Env Score	-0.515***	-0.534***		
	(0.160)	(0.159)		
Low Env Score	-2.237***			
	(0.387)			
After Paris × Top Polluter			-0.580***	-0.597***
			(0.143)	(0.141)
Top Polluter			0.475	
			(0.456)	
Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.152	0.046	0.003	0.061
Obs	34,734	34,734	34,734	34,734

The table displays results from the following regression:
$Rating_{it} = \beta_1(AfterParis_t \times EnvProfile_j) + \beta_2 EnvProfile_j + \gamma_i + \kappa_t + \epsilon_{it}$,
where $Rating_{it}$ is the credit rating applicable to bond issue i at time t and the ratings are assigned such that a higher number indicates a better rating. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later and $EnvProfile_j$ is either a dummy equal to one if issuer j has a below-median environmental score ($LowEnvScore$), or a dummy equal to one if the issuer belongs to a top polluting industry ($TopPolluter$). Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table III
Effects of the Paris Agreement on Credit Ratings – Issuer-level

	(1)	(2)	(3)	(4)
After Paris × Low Env Score	-0.335***	-0.349***		
	(0.122)	(0.118)		
Low Env Score	-1.921***			
	(0.314)			
After Paris × Top Polluter			-0.605***	-0.614***
			(0.132)	(0.127)
Top Polluter			0.292	
			(0.341)	
Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.113	0.019	0.002	0.057
Obs	7,842	7,842	7,842	7,842

The table displays results from the following regression:
$Rating_{jt} = \beta_1(AfterParis_t \times EnvProfile_j) + \beta_2 EnvProfile_j + \gamma_j + \kappa_t + \epsilon_{jt}$,
where $Rating_{jt}$ is the principal-weighted average rating of all issues by issuer j at time t and the ratings are assigned such that a higher number indicates a better rating. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later and $EnvProfile_j$ is either a dummy equal to one if the issuer has a below-median environmental score or a dummy equal to one if the issuer belongs to a top polluting industry. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table IV
Summary Statistics – Matched Sample

Group		**Treatment**			**Control**			Diff Mean
Variable	Unit	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	
Panel A: Env Profile = Below-Median Env score								
Security-Year-Level Variables								
Credit Rating	Rating	221	14.249	1.96	221	14.267	2.057	-0.018
Yield Spread	Percent	221	1.810	1.234	221	1.602	.758	0.208**
Time to Maturity	Year	221	8.27	7.322	221	8.268	7.265	0.002
ln(1 + Principal Out)		221	13.237	0.513	221	13.202	.552	0.035
Firm-Year-Level Variables								
Profitability	Rev/TA	62	0.212	0.197	62	0.220	0.184	-0.008
ln(Total Assets)		62	9.643	0.961	62	9.856	1.034	-0.213
Leverage	TD/TA	62	0.295	0.103	62	0.321	0.155	-0.026
Oil Beta		62	0.164	0.111	62	0.145	0.100	0.019
Panel B: Env Profile = Top Polluting Industry								
Security-Year-Level Variables								
Credit Rating	Rating	240	14.975	1.795	240	15.054	1.795	-0.079
Yield Spread	Percent	240	1.527	0.913	240	1.479	0.689	0.048
Time to Maturity	Year	240	9.376	8.372	240	9.534	8.437	-0.158
ln(1 + Principal Out)		240	13.295	0.554	240	13.351	0.565	-0.056
Firm-Year-Level Variables								
Profitability	Rev/TA	57	0.15	0.127	51	0.229	0.152	-0.079***
ln(Total Assets)		57	9.929	1.029	51	9.787	1.045	0.142
Leverage	TD/TA	57	0.329	0.116	51	0.327	0.138	0.001
Oil Beta		57	0.143	0.104	51	0.149	0.1	-0.006

The table reports summary statistics for the sample matched on the bond issuer's environmental profile as of July 2015 (five months before the Paris Agreement). The matched sample is constructed by using 1 to 1 nearest-neighbor Mahalanobis matching on the top polluting industry firms by oil beta, size, time to maturity, and credit rating in July 2015. Yield Spread, Principal Outstanding, Profitability, Leverage, and the ln(Total Assets) are winsorized at the 1% and 99% levels. The ratings are assigned such that a higher number indicates a better rating. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table V
Effects of the Paris Agreement on Yield Spreads

	(1)	(2)	(3)	(4)
After Paris × Low Env Score	0.264***	0.264***		
	(0.098)	(0.098)		
Low Env Score	0.192			
	(0.117)			
After Paris × Top Polluter			0.333***	0.333***
			(0.091)	(0.091)
Top Polluter			0.087	
			(0.077)	
Pair-Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.058	0.024	0.061	0.046
Obs	10,608	10,608	11,520	11,520

The table displays results from the following regression:
$Spread_{it} = \beta_1 AfterParis_t \times EnvProfile_j + \beta_2 EnvProfile_j + \gamma_i + \kappa_{tp} + \epsilon_{it}$,
where $Spread_{it}$ is the yield spread for bond issue i at time t. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later. $EnvProfile_j$ is either a dummy equal to one if the issuer belongs to a top polluting industry or a dummy equal to one if the issuer has a below-median environmental score. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table VI
Effects of the Paris Agreement on Yield Spreads – Issuer-level

	(1)	(2)	(3)	(4)
After Paris × Low Env Score	0.582***	0.587***		
	(0.152)	(0.152)		
Low Env Score	0.874***			
	(0.166)			
After Paris × Top Polluter			0.586***	0.583***
			(0.171)	(0.171)
Top Polluter			0.391**	
			(0.179)	
Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.064	0.014	0.024	0.013
Obs	7,842	7,842	7,842	7,842

The table displays results from the following regression:
$Spread_{jt} = \beta_1(AfterParis_t \times EnvProfile_j) + \beta_2 TopPolluter_j + \gamma_j + \kappa_t + \epsilon_{jt}$,
where $Spread_{jt}$ is the principal-weighted average yield spread across all bond issues that issuer j has outstanding at time t. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later. $EnvProfile_j$ is either a dummy equal to one if the issuer belongs to a top polluting industry or a dummy equal to one if the issuer has a below-median environmental score. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table VII
Regulatory Risk and Effects of the Paris Agreement on Credit Ratings

	(1)	(2)	(3)	(4)
After Paris × Low Env Score × High Reg	-0.842***	-0.777***		
	(0.269)	(0.267)		
After Paris × Top Polluter × High Reg			-0.899***	-0.982***
			(0.266)	(0.248)
After Paris × Low Env Score	-0.061	-0.061		
	(0.125)	(0.125)		
After Paris × Top Polluter			-0.006	-0.030
			(0.095)	(0.087)
Low Env Score × High Reg	-1.904**			
	(0.788)			
Top Polluter × High Reg			-1.136	
			(0.923)	
After Paris × High Reg	-0.070	-0.070	-0.084	0.042
	(0.075)	(0.075)	(0.119)	(0.082)
Low Env Score	-1.185*			
	(0.603)			
Top Polluter			1.092*	
			(0.641)	
High Reg	0.924*		0.299	
	(0.548)		(0.553)	
Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.187	0.095	0.026	0.124
Obs	34,512	34,512	34,254	34,254

The table displays results from the following triple-difference regression: $Rating_{it} = \beta_1 AfterParis_t \times EnvProfile_j \times HighReg_s + \beta_2 AfterParis_t \times EnvProfile_j + \beta_3 EnvProfile_j \times HighReg_s + \beta_4 AfterParis_t \times HighReg_s + \beta_5 EnvProfile_j + \beta_6 HighReg_s + \gamma_i + \kappa_t + \epsilon_{it}$, where $Rating_{it}$ is the credit rating of bond issue i at time t and the ratings are assigned such that a higher number indicates a better rating. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later. $EnvProfile_j$ is either a dummy equal to one if the issuer belongs to a top polluting industry or a dummy equal to one if the issuer has a below-median environmental score. $HighReg_s$ is a dummy equal to one if the issuer is located in a state with above-median EPA penalties from 2012 through 2015. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table VIII
Regulatory Risk and Effects of the Paris Agreement on Yield Spreads

	(1)	(2)	(3)	(4)
After Paris × Low Env Score × High Reg	0.546**	0.546**		
	(0.254)	(0.254)		
After Paris × Top Polluter × High Reg			0.604**	0.604**
			(0.266)	(0.266)
After Paris × Low Env Score	-0.019	-0.019		
	(0.099)	(0.099)		
After Paris × Top Polluter	-0.310	-0.310	-0.033	-0.033
	(0.195)	(0.195)	(0.168)	(0.168)
Low Env Score × High Reg	0.420**			
	(0.205)			
Top Polluter × High Reg			0.581***	
			(0.218)	
After Paris × High Reg	-0.310	-0.310	-0.033	-0.033
	(0.195)	(0.195)	(0.168)	(0.168)
Low Env Score	0.007			
	(0.164)			
Top Polluter			-0.179*	
			(0.098)	
High Reg	-0.490**		-0.289*	
	(0.238)		(0.148)	
Pair-Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.111	0.037	0.145	0.079
Obs	10,608	10,608	11,520	11,520

The table displays results from the following triple-difference regression: $Spread_{it} = \beta_1 AfterParis_t \times EnvProfile_j \times HighReg_s + \beta_2 AfterParis_t \times EnvProfile_j + \beta_3 EnvProfile_j \times HighReg_s + \beta_4 AfterParis_t \times HighReg_s + \beta_5 EnvProfile_j + \beta_6 HighReg_s + \gamma_i + \kappa_t + \epsilon_{it}$, where $Spread_{jt}$ is the yield spread for bond issue i at time t. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later. $EnvProfile_j$ is either a dummy equal to one if the issuer belongs to a top polluting industry or a dummy equal to one if the issuer has a below-median environmental score. $HighReg_s$ is a dummy equal to one if the issuer is located in a state with above-median EPA penalties from 2012 through 2015. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table IX
Potential Reversals in Ratings Changes

	(1)	(2)	(3)	(4)
Panel A – 2016 Election				
After Election*Low Env Score	0.030	0.030		
	(0.029)	(0.029)		
After Election*Top Polluter			-0.029	-0.024
			(0.034)	(0.030)
Low Env Score	-2.395***			
	(0.482)			
Top Polluter			-0.006	
			(0.508)	
Adj. R^2	0.131	0.001	-0.000	0.001
Obs	22,980	22,980	23,004	23,004
Panel B – Paris Agreement Withdrawal				
After Withdraw*Low Env Score	0.077**	0.077**		
	(0.037)	(0.037)		
After Withdraw*Top Polluter			0.047	0.059*
			(0.037)	(0.033)
Low Env Score	-2.317***		0.312	
	(0.481)		(0.211)	
Top Polluter			-0.159	
			(0.497)	
Adj. R^2	0.124	0.009	0.000	0.005
Obs	23,592	23,592	23,954	23,954
Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y

The table displays results from the following regression:
$Rating_{it} = \beta AfterEvent_t \times EnvProfile_j + \gamma_i + \kappa_t + \epsilon_{it}$,
where $Rating_{it}$ is the rating for bond i at time t and the ratings are assigned such that a higher number indicates a better rating. $EnvProfile_j$ is either a dummy equal to one if issuer j has a below-median environmental score ($LowEnvScore$), or a dummy equal to one if the issuer belongs to a top polluting industry ($TopPolluter$). $AfterEvent_t$ is a dummy equal to one if the observation occurs six months following the event, which is either the 2016 U.S. Presidential election or the June 2017 announcement of the U.S. planned withdrawal from the Paris Agreement. The spread regressions include matched-pair-by-time fixed effects. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table X
Potential Reversals in Yield Spreads Changes

	(1)	(2)	(3)	(4)
Panel A – 2016 Election				
After Election*Low Env Score	-0.074	-0.074		
	(0.070)	(0.070)		
After Election*Top Polluter			-0.113**	-0.113**
			(0.044)	(0.044)
Low Env Score	0.336**			
	(0.158)			
Top Polluter			0.212**	
			(0.093)	
Adj. R^2	0.060	0.009	0.039	0.030
Obs	4,728	4,728	5,160	5,160
Panel B – Paris Agreement Withdrawal				
After Withdraw*Low Env Score	0.087	0.087		
	(0.075)	(0.075)		
After Withdraw*Top Polluter			0.009	0.009
			(0.035)	(0.035)
Low Env Score	0.312			
	(0.211)			
Top Polluter			0.051	
			(0.064)	
Adj. R^2	0.041	0.002	0.006	-0.000
Obs	4,200	4,200	4,176	4,176
Pair-Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y

The table displays results from the following regression:
$Spread_{it} = \beta AfterEvent_t \times EnvProfile_j + \gamma_i + \kappa_{tp} + \epsilon_{it}$,
where $Rating_{it}$ is the rating for bond i at time t and the ratings are assigned such that a higher number indicates a better rating. $EnvProfile_j$ is either a dummy equal to one if issuer j has a below-median environmental score ($LowEnvScore$), or a dummy equal to one if the issuer belongs to a top polluting industry ($TopPolluter$). $AfterEvent_t$ is a dummy equal to one if the observation occurs six months following the event, which is either the 2016 U.S. Presidential election or the June 2017 announcement of the U.S. planned withdrawal from the Paris Agreement. The spread regressions include matched-pair-by-time fixed effects. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Internet Appendix

Table A.1
Effect of the Paris Agreement on Yield Spreads – Unmatched sample

	(1)	(2)	(3)	(4)
After Paris × Low Env Score	0.581***	0.588***		
	(0.134)	(0.134)		
Low Env Score	0.901***			
	(0.192)			
After Paris × Top Polluter			0.489***	0.488***
			(0.122)	(0.122)
Top Polluter			0.237	
			(0.189)	
Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.080	0.021	0.017	0.015
Obs	34,734	34,734	34,734	34,734

The table displays results from the following regression:
$Spread_{it} = \beta_1 AfterParis_t \times EnvProfile_j + \beta_2 EnvProfile_j + \gamma_i + \kappa_{tp} + \epsilon_{it}$,
where $Spread_{it}$ is the yield spread for bond issue i at time t. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later. $EnvProfile_j$ is either a dummy equal to one if the issuer belongs to a top polluting industry or a dummy equal to one if the issuer has a below-median environmental score. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table A.2
Regulatory Risk and the Effects of the Paris Agreement on Ratings – Issuer level

	(1)	(2)	(3)	(4)
After Paris × Low Env Score × High Reg	-0.719***	-0.634***		
	(0.222)	(0.211)		
After Paris × Top Polluter × High Reg			-1.197***	-1.119***
			(0.231)	(0.220)
After Paris × Low Env Score	0.116	0.056		
	(0.117)	(0.102)		
After Paris × Top Polluter			0.065	0.008
			(0.105)	(0.079)
After Paris × High Reg	-0.115	-0.122	0.032	0.039
	(0.097)	(0.089)	(0.083)	(0.081)
Low Env Score × High Reg	-0.937			
	(0.650)			
Top Polluter × High Reg			-0.176	
			(0.693)	
Low Env Score	-1.463***			
	(0.457)			
Top Polluter			0.497	
			(0.483)	
High Reg	0.370		-0.525	
	(0.429)		(0.424)	
Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.129	0.061	0.026	0.129
Obs	7,786	7,786	7,786	7,786

The table displays results from the following regression:
$Rating_{jt} = \beta_1 AfterParis_t \times EnvProfile_j \times HighReg_s + \beta_2 AfterParis_t \times EnvProfile_j + \beta_3 EnvProfile_j \times HighReg_s + \beta_4 AfterParis_t \times HighReg_s + \beta_5 EnvProfile_j + \beta_6 HighReg_s + \gamma_j + \kappa_t + \epsilon_{jt}$, where $Rating_{jt}$ are principal-weighted average ratings for all issues outstanding by issuer j at time t and the ratings are assigned such that a higher number indicates a better rating. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later. $EnvProfile_j$ is either a dummy equal to one if the issuer belongs to a top polluting industry or a dummy equal to one if the issuer has a below-median environmental score. $HighReg_s$ is a dummy equal to one if the issuer is located in a state with above-median EPA penalties from 2012 through 2015. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table A.3
Regulatory Risk and the Effects of the Paris Agreement on Yield Spreads
Issuer level

	(1)	(2)	(3)	(4)
After Paris × Low Env Score × High Reg	0.775***	0.748***		
	(0.261)	(0.260)		
After Paris × Top Polluter × High Reg			1.355***	1.331***
			(0.296)	(0.295)
After Paris × Low Env Score	0.104	0.124		
	(0.110)	(0.112)		
After Paris × Top Polluter			-0.174**	-0.161*
			(0.087)	(0.089)
After Paris × High Reg	0.096	0.095	-0.030	-0.034
	(0.082)	(0.081)	(0.089)	(0.088)
Low Env Score × High Reg	0.804***			
	(0.303)			
Top Polluter × High Reg			1.023***	
			(0.327)	
Low Env Score	0.418**			
	(0.191)			
Top Polluter			-0.243	
			(0.180)	
High Reg	0.004		0.135	
	(0.175)		(0.198)	
Pair-Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.105	0.027	0.089	0.040
Obs	7,786	7,786	7,786	7,786

This table displays results from the following regression:
$Spread_{jt} = \beta_1 EnvProfile_j + \beta_2 HighReg_s + \beta_3 AfterParis_t \times EnvProfile_j + \beta_4 AfterParis_t \times HighReg_s + \beta_5 EnvProfile_j \times HighReg_s + \beta_6 EnvProfile_j \times HighReg_s \times AfterParis_t + \gamma_i + \kappa_t + \epsilon_{it}$
$Spread_{jt}$ are principal-weighted average bond spreads for all issues outstanding by issuer j at time t. $EnvProfile_j$ is either a dummy equal to one if the issuer belongs to a top polluting industry or a dummy equal to one if the issuer has a below-median environmental score. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later. $HighReg_s$ is a dummy equal to one if the issuer is located in a state with above median EPA penalties from 2012 through 2015. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.

Table A.4
Regulatory Risk and the Paris Agreement for Spreads – Unmatched Sample

	(1)	(2)	(3)	(4)
After Paris × Low Env Score × High Reg	0.777***	0.764***		
	(0.212)	(0.217)		
After Paris × Top Polluter × High Reg			0.854***	0.889***
			(0.218)	(0.216)
After Paris × Low Env Score	0.121	0.121		
	(0.077)	(0.077)		
After Paris × Top Polluter			-0.022	-0.021
			(0.054)	(0.054)
After Paris × High Reg	0.025	0.025	0.012	-0.038
	(0.050)	(0.050)	(0.066)	(0.060)
Low Env Score × High Reg	0.965***			
	(0.356)			
Top Polluter × High Reg			1.056***	
			(0.329)	
Low Env Score	0.329			
	(0.247)			
High Reg	-0.126		-0.098	
	(0.144)		(0.178)	
Top Polluter			-0.395**	
			(0.164)	
Time FE	Y	Y	Y	Y
Security FE	N	Y	N	Y
Adj. R^2	0.124	0.037	0.067	0.035
Obs	34,512	34,512	34,254	34,251

The table displays results from the following regression:
$Spread_{it} = \beta_1 AfterParis_t \times EnvProfile_j \times HighReg_s + \beta_2 AfterParis_t \times EnvProfile_j + \beta_3 EnvProfile_j \times HighReg_s + \beta_4 AfterParis_t \times HighReg_s + \beta_5 EnvProfile_j + \beta_6 HighReg_s + \gamma_i + \kappa_t + \epsilon_{it}$, where $Spread_{it}$ is the yield spread for bond issue i at time t. $AfterParis_t$ is a dummy equal to one if the observation occurs in December 2015 or later. $EnvProfile_j$ is either a dummy equal to one if the issuer belongs to a top polluting industry or a dummy equal to one if the issuer has a below-median environmental score. $HighReg_s$ is a dummy equal to one if the issuer is located in a state with above-median EPA penalties from 2012 through 2015. Standard errors, clustered at the firm level, are shown in parentheses. ***, ** and * indicate that the parameter estimate is significantly different from zero at the 1%, 5% and 10% level, respectively.