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ABSTRACT

Investor concerns about climate and other environmental regulatory risks suggest that these risks should affect corporate bond risk assessment and pricing. We test this hypothesis and find that firms with poor environmental profiles or high carbon footprints tend to have lower credit ratings and higher yield spreads, particularly when their facilities are located in states with stricter regulatory enforcement. Using the Paris Agreement as a shock to expected climate risk regulations, we provide evidence that climate regulatory risks causally affect bond credit ratings and yield spreads. Accordingly, the composition of institutional ownership also changes after the Agreement.

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1. Introduction

In recent years investors have become more concerned about the environmental and climate risks embedded in their portfolios.[1] In fact, research shows climate risk to be an important factor in institutional investors' portfolio decisions as well as corporate managers' leverage decisions, and it has been found to affect 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, 2021; Bolton and Kacperczyk, 2020, 2021; Painter, 2020). Of the three components of climate risk (physical, technological and regulatory), regulatory risk is the one that investors and others in the finance community believe has the most immediate relevance (Krüger, Sautner, and Starks, 2020; Stroebel and Wurgler, 2021). This suggests that regulation is a major channel through which climate and other types of environmental risks get embedded in security prices. In particular, environmental regulatory costs can have significant effects on firms' operating costs and cash flows (Karpoff, Lott, and Wehrly, 2005). Moreover, uncertainty about future regulation itself poses costs to firms and their investors (Pindyck, 1993).[2]

In this paper we address the issue of whether and how climate and other environmental regulatory risks affect firms' bonds. 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.[3] Thus, effects from climate risk may be more easily captured in firms' bond credit ratings and yield spreads than in their equity prices. Moreover, a firm's regulatory conditions can amplify or attenuate these risks. Consequently, we examine whether climate risks are reflected in firms' bond ratings and

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

[2] In theoretical models such as Pastor and Veronesi (2013), political uncertainty regarding climate regulations affects asset prices. Empirically, Kaviani, Kryzanowski, Maleki, and Savor (2020) find a strong relation between policy uncertainty and corporate credit spreads when they employ the Baker, Bloom, and Davis (2016) economic policy uncertainty index.

[3] Bai, Bali, and Wen (2019) show that, in the cross-section, downside risk is the strongest predictor of future bond returns.

pricing (i.e., yield spreads), and whether regulatory risks significantly influence how much firms' environmental profiles affect their bond ratings and yield spreads.

Testing these hypotheses requires measuring firms' environmental profiles as well as their regulatory risk exposures. We capture environmental profiles in two primary ways. First, we employ an assessment of the firm's environmental quality by a third-party environmental, social and governance (ESG) rating agency (Sustainalytics). Second, we construct multiple measures of firms' carbon emissions using data from CDP (formerly known as the Carbon Disclosure Project).

We estimate firms' regulatory risk exposures based on the stringency of the state environmental regulatory agencies overseeing the firms' establishments. In the United States, significant environmental legislation exists at the federal level with rule making by the EPA. However, state governments generally hold the primary responsibility for enforcing these laws and the states vary widely in their enforcement practices. Further, some states also impose additional environmental restrictions beyond those required by the EPA. To estimate a firm's aggregate regulatory risk exposure, we construct a firm-level regulatory stringency measure by aggregating across the geographical locations of the firms' establishments.[4] Thus, even when two firms have objectively similar levels of environmental quality, depending on the local regulatory conditions of their facility locations, these firms can face different degrees of regulatory risks.

In initial analyses, we examine whether bond credit ratings and yield spreads are associated with firms' environmental profiles, their aggregated regulatory risk exposures, and the interaction between the two. Employing a sample of newly-issued corporate bonds, we document important empirical relationships. First, we find a firm's environmental profile, whether measured by a third-party rating or through the firm's carbon footprint, to be unconditionally reflected in both its bond credit rating and yield spreads. Firms with a lower environmental score, higher level of carbon emissions, or higher carbon intensity,

[4]We have also constructed our tests using the state in which the firm's headquarters reside and the results hold.

i.e., carbon emissions scaled by firm revenue, exhibit lower credit ratings and higher yield spreads, on average. This echoes previous findings in the equity market that carbon risk is priced into average stock returns and the tail risk of stocks (Bolton and Kacperczyk, 2020, 2021; Ilhan, Sautner, and Vilkov, 2021). Second, and more importantly, there exists a statistically and economically significant interaction effect on credit ratings and spreads between a firm's environmental profile and its regulatory environment. The lower credit ratings (and higher yield spreads) for low environmental score firms and high-emission firms are more pronounced if they operate in states where environmental regulations are enforced more stringently. This suggests that regulatory risk is an important channel through which firms' environmental profiles affect their credit risks.

Recognizing the potential endogenous relationship between firms' environmental profiles and market participants' perceptions of the firms' risks, we consider a setting in which expectations regarding future climate regulations receive an exogenous shock, namely 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 for rating agencies and bond investors to draw was that governments—including U.S. federal and state governments—would tighten their environmental regulations related to the mitigation of climate change.[5] In fact, consistent with this presumption, at least one rating agency adjusted their baseline scenarios to include expectations of increased regulations after the Paris Agreement.[6] Survey results also suggest that firms upwardly revised their beliefs about future regulation intensity in their disclosure to the CDP around the time of the Agreement (Ramadorai and Zeni, 2021). This shock implies that U.S. firms would face greater climate regulatory risk, especially those firms more exposed to this risk

[5]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 United Nations Climate Change Conference, which began on November 30, 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 November 23, the EU's climate and energy czar warned that an agreement was far from certain.

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

because of their business activities. The importance of this event is reflected in the fact that it is the third highest spike in the Engle, Giglio, Kelly, Lee, and Stroebel (2020) climate change news index, which the authors constructed over the 1984 to 2017 period to capture innovations in climate change information.[7]

To test the hypothesis that the Paris Agreement had greater effects on the corporate bonds more exposed to climate regulatory risks, we employ difference-in-differences analyses of firms' credit ratings and yield spreads in the months around the Agreement date. The treated bonds are those issued by firms that prior to the Agreement have poor environmental scores, high carbon emissions, high carbon intensities, or that belong to a top 15 carbon-emitting industry. Using bonds issued at least twelve months prior to the Agreement and traded during the testing period, we find that after the Agreement, bonds from the treated firms experience an average decrease in credit ratings of 0.48 to 0.63 notch relative to bonds from other firms. The effect on ratings is consistent regardless of which environmental definition we employ for the treatment. 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 more problematic environmental performance, specifically including those with more significant carbon footprints. Further, our evidence suggests that credit rating analysts consider expected regulatory changes when evaluating climate risk effects on firms' default risks.

We also find that the yield spreads of treated bonds increase significantly after the Paris Agreement, suggesting that, besides credit rating analysts, bond investors also react to potential future regulatory changes. For example, yield spreads for bonds issued by firms that belong to top carbon-emitting industries increased by about 38 bps. Similarly, bonds issued by firms with high total carbon emissions, high carbon intensity, or a low environmental score also experience a significant increase in yield spreads after the Paris Agreement.

[7] See, Figure 2, p. 1193.

Given that the expected tightening of environmental regulations following the Paris Agreement would presumably be carried out under a state-enforcement regime, we hypothesize that any effects on credit ratings and yield spreads should be stronger for issuers operating in high-enforcement states. Consequently, we conduct a triple-difference analysis in which we include an indicator variable for firms operating in states with relatively more enforcement actions. The analysis indicates that following the Paris Agreement, the changes in credit ratings and yield spreads for environmentally problematic firms are more pronounced if a firm's aggregated establishment locations are in states with stricter enforcement of environmental regulations. We find the effects to be both economically and statistically significant. For example, bonds issued by firms in the top 15 carbon-emitting industries that have facilities located in the stricter states experience an additional decrease in their credit ratings of 1.09 notch.

The bond pricing results suggest that after the Paris Agreement investors should have reevaluated their holdings in bonds more exposed to climate risk. Substantial theoretical and empirical evidence provides evidence that various segments of the institutional investor population employ differing investment strategies regarding ESG risks, including climate risks.[8] Consequently, we hypothesize that after the Paris Agreement reactions should differ between the two major institutional investor types in the corporate bond market, mutual funds and insurance companies, primarily due to the variations in their typical investment horizons. Using difference-in-differences analyses with a matched sample, we find after the Paris Agreement, insurance companies, which tend toward longer investment horizons, lowered their holdings in the treated bonds. Mutual funds, which tend toward shorter investment horizons, either kept the same holdings or increased their holdings, depending on the definition of problematic environmental profile.

These results of investor holding changes along with our triple-difference analyses of

[8] See, for example, Heinkel et al. (2001); Pastor et al. (2021); Pedersen et al. (2021); Oehmke and Opp (2020); Baker et al. (2020); Goldstein et al. (2021); Dyck et al. (2019); Starks et al. (2021); Ilhan et al. (2021).

the credit ratings and bond yield spreads all support the hypothesis that the expected increases in climate regulatory requirements are associated with lower credit ratings and higher yield spreads for issuers with poor environmental profiles. A natural follow-on question is whether the changes in ratings and yield spreads subsequently reverse when the political environment changes and the market then expects climate regulatory requirements to decrease. We test this proposition through the November 2016 presidential election, with its unexpected change to a Republican administration, and the subsequent June 2017 announcement that the U.S. would withdraw from the Paris Agreement. While these events suggest that the treated firms' regulatory risks could lessen, there appears to have been more uncertainty attached to the expected regulatory outcomes of these events than to the original Paris Agreement.[9] Thus, although the outcome of the 2016 election was unexpected (Berlinger, 2016), and consequently, a shock to the regulatory setting for environmentally problematic firms, there existed uncertainty regarding the extent of the shock. Nevertheless, when we examine changes in credit ratings and yield spreads after both of these events for firms with relatively poor environmental profiles, we observe a partial rebound of these firms' yield spreads after the 2016 election. We also find suggestive evidence on a reversal in credit ratings after the withdrawal from the Paris Agreement.

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

[9] 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 these goals would be achieved was uncertain. (See, for example, Parker and Davenport (2016)). Moreover, even with the announcement, there still existed uncertainty given that the official withdrawal could not occur until the day after the November 2020 presidential election and the winner of that election could reverse the decision. After becoming the U.S. president, the winner of the 2020 election, Joseph Biden, did indeed announce that the U.S. would abide by the Paris Agreement. See `https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/20/paris-climate-agreement/`

premia in equity markets (Bolton and Kacperczyk, 2020, 2021). Further, we provide a mechanism through which climate and environmental risks affect security pricing: the regulatory risks.[10]

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, 2021; Tang and Zhang, 2020; Zerbib, 2019), and the pricing effect of ESG on sovereign bonds (Margaretic and Pouget, 2018; Capelle-Blancard et al., 2019).[11] We contribute by showing that ratings and spreads for corporate bonds as well as the institutional investor ownership of these bonds are affected by not only a firm's environmental activities but also their regulatory risk exposure.[12] Similarly, our paper is related to Jiraporn et al. (2014) and Amiraslani et al. (2021) in that we also examine the relationship between some aspect of ESG and measures of bond risk and pricing. However, these papers focus on the relation between firms' CSR/ESG ratings and either credit ratings or bond yield spreads. In contrast, our focus is on the regulatory risk aspect of the firms' environmental qualities, and how the analyst and investor perceptions of this regulatory risk are reflected in credit ratings and yield spreads. We also differ from Amiraslani et al. (2021) in that we employ the Paris Agreement as an exogenous shock that could affect bond pricing through the channel of regulatory risk, while their shock is the 2008 financial crisis, which they hypothesize makes trust more important to investors.

Several papers use political changes regarding environmental issues to examine how prospects for future governmental actions affect different aspects of firms' actions, their managers' beliefs and investor expectations. Ramadorai and Zeni (2021) employ the CDP

[10]Other research provides insights into the effects of physical climate risk such as Ginglinger and Moreau (2019), the mixed evidence on the effects of physical climate risk on real estate values (Bernstein, Gustafson, and Lewis, 2019; Murfin and Spiegel, 2020; Baldauf, Garlappi, and Yannelis, 2020) and the relationship between derivative prices and climate models (Schlenker and Taylor, 2021). Huynh and Xia (2021) examine the effect of climate news risk on corporate bond returns.

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

[12]We also contribute to the literature on bond risk and pricing. For example, Bai, Bali, and Wen (2019) and Bai, Bali, and Wen (2021) provide evidence on the relationship between bond risk and returns.

data of firms' disclosures to develop a model of managers' beliefs and actions regarding climate regulation, particularly around the Paris Agreement and test it out-of-sample with the U.S. withdrawal announcement. Our results regarding credit analysts and investors are consistent with their findings regarding firms' reactions. In terms of managerial actions, Bartram, Hou, and Kim (2021) provide evidence that differences across states in their regulatory risk can have real consequences due to firms' regulatory arbitrage and Dai, Duan, Liang, and Ng (2021) show that firms outsource their emissions due to increases in state regulatory enforcements. Ginglinger and Moreau (2019) provide evidence that firms reduced their leverage after the Paris Agreement driven by both their demand for debt and lenders' capital supply. Our paper is complementary in that we find decreased credit ratings and higher yield spreads, suggesting that the Paris Agreement increased costs of debt for the environmentally problematic firms that face more stringent regulatory oversight. Our findings using corporate bonds are consistent with those of Ramelli, Wagner, Zeckhauser, and Ziegler (2021) who examine stock market reactions to the 2016 and 2020 U.S. presidential elections, two events that reflect the changing political assessment of environmental issues in the U.S.[13]

Similarly, our paper contributes to the research showing the relation between firms' costs of debt and the liability and political uncertainty risks that they face (Gormley and Matsa, 2011; Bradley et al., 2016; Kaviani et al., 2020; Ilhan et al., 2021). Our paper is particularly complementary to that of Ilhan, Sautner, and Vilkov (2021), 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. Our study also focuses on downside risks, but our interest is in rating agencies' and bondholders' perceptions and actions, while their interest is in the equity holders' perceptions and actions. The results

[13]Our paper is also related to Child, Massoud, Schabus, and Zhou (2021) who analyze the effects of firms associated with the Republican candidate, Li, Massa, Zhang, and Zhang (2021) who examine how a change in environmental policy in China affected investor choices, and Kempf and Tsoutsoura (2021) who examine how the 2016 U.S. presidential election affected credit ratings by partisan analysts.

between the two papers support 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 credit rating analysts and bond investors respond to changes in perceptions of firms' environmental regulatory risks.

2. Data

2.1. 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.[14] 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, Sustainalytics and CDP.

We use the Mergent FISD database for characteristics of the bonds such as offering terms, maturity, the principal amount outstanding, and credit ratings (which originate from Moody's, Standard and Poor's and Fitch). We employ the Moody's ratings as the primary source of credit ratings and transform the qualitative 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

[14] 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 placements, variable rate bonds and zero coupon bonds

equivalent) receives a value of 22.[15] This approach has the advantage that when a credit rating is downgraded, the representative number is lower.

Using the Mergent FISD offering terms, we define yield spread as the difference between a bond's offering yield and the yield of a cash flow-matched synthetic Treasury bond. In this measure the discount rates of varying maturities derive from the U.S. Treasury yield curve provided by Gürkaynak et al. (2007), where the yield of the synthetic Treasury bond is inverted from its price.

We combine the Mergent FISD bond characteristics data with data on secondary market pricing for corporate bonds from the TRACE database.[16] We calculate a bond's monthly yield as the median yield on all trades of that security occurring on its last active-trading day of a given month.[17] When possible, we linearly interpolate yields for months with missing yields. We then calculate trading yield spreads and the difference between a bond's trading yield and the yield of the Treasury bond with the same maturity in that month. Data on characteristics of the issuing companies are obtained through the CRSP and Compustat databases where we use the six-digit CUSIP to link companies across databases. We drop observations for which we are unable to obtain information on either the firm's headquarters location or the SIC industry code.[18]

Our first measure of the issuing firm's environmental profile relies on Sustainalytics Environmental Scores from their ESG rating service, which during this period are based on 57 environmental indicators and range from 0-100, with a higher score indicating stronger environmental performance. We employ the summary Environmental Score, which is calculated as a weighted average of the indicators, where the weights used are industry specific

[15] 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.

[16] We adopt the procedure suggested in Dick-Nielsen (2009) to clean the TRACE data.

[17] Based on the suggestion in Edwards, Harris, and Piwowar (2007), all trades that deviate from the security daily median price by greater than 10% are dropped. Additionally, all price reversals greater than 10% are dropped.

[18] Headquarters location and SIC industry code are obtained from the Compustat. Since Compustat provides only current headquarter locations, we use historic headquarter locations provided by Gao (2020). Only 0.2% of the bonds in the sample are dropped because of missing information.

and proprietary, that is, the environmental scores are industry adjusted. We merge the corporate bond data with the Sustainalytics data at the issuer-year level using firm ticker symbols.

We derive three additional measures of a firm's environmental profile using firms' carbon emissions provided by CDP. Firms submit their carbon emissions data to CDP at the end of June each year, covering emissions for the previous year. The data includes information on Scope 1, Scope 2 and Scope 3 emissions, although not all firms that report to CDP provide the Scope 2 and Scope 3 emissions. Scope 1 emissions are direct emissions produced by the firm. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are other indirect emissions that occur due to the firm's value chain. We focus on Scope 1 emissions as the firm has the most direct control over this type of emissions, and these emissions have the most precision.[19] Using the Scope 1 emissions data, we also calculate carbon intensity by dividing carbon emissions (in tons) by firm revenue (in thousands of dollars). We employ both total carbon emissions and carbon intensity in our tests.

Because not all firms submit their carbon emissions to CDP, we identify the highest carbon emission industries in the sample and for the difference-in-differences tests we employ an additional measure according to a firm's industry. Specifically, we rank industries by total carbon emissions within our sample, and define the industries with the top 15 carbon emissions as top carbon emission industries. We employ total industry emissions for this definition because political attention for climate regulations seems to focus on the size of total emissions rather than the carbon intensity.[20]

[19] In untabulated results we examine the sum of Scope 1 and Scope 2 emissions and our results are robust to this change in variable.

[20] These industries are electricity, gas and sanitary, oil and gas extraction, transportation by air, petroleum and coal, chemical and allied products, primary metal, railroad transport, food and kindred products, paper and allied products, motor freight transportation, metal mining, general merchandise stores, stone, clay and glass, non-classifiable establishments, and transportation equipment.

2.2. *Environmental regulations data*

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

We obtain EPA enforcement data from the Integrated Compliance Information System for Federal Civil Enforcement Case Data. Employing this data we construct a measure of state-level environmental regulatory stringency that 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. Our measure, which we adopt from the political science literature (Konisky, 2007), uses the number of enforcement actions, both informal enforcement actions (notifications of violation) and formal enforcement actions resulting in a penalty for the firm (fines and administrative orders). We normalize the number of enforcement actions by the total number of facilities that are subject to EPA regulations in that state (measured in thousands), which is obtained from the Facility Registry Services (FRS).[21]

Because firms often have facilities in multiple states, we adapt the state-level EPA mea-

[21] 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.

sures to firm-specific measures to capture the regulatory environment for individual firms. In order to determine each firm's aggregate exposure to state-level EPA enforcement, we use the National Establishment Time Series Database (NETs). The NETs is produced by Wall & Associates based on the Dun & Bradstreet dollar-directory database, and provides establishment-level information on firms, which we use to calculate each firm's revenue within each state in the United States. We then define the firm-level regulatory stringency as the weighted-average state-level environmental regulatory stringency across all of a firm's establishments.[22,23]

$$RegStringency_{j,t} = \sum_{s \in S_j} \left(\frac{StateRevenue_{j,s}}{TotalRevenue_j} \times EPAEnforcements_{s,t}\right), \tag{1}$$

where $TotalRevenue_j$ is total revenue by firm j in all states, $StateRevenue_{j,s}$ are total revenue by firm j in state s and $EPAEnforcements_{s,t}$ are total EPA enforcement actions in state s scaled by the number of EPA-registered facilities (in thousands) in state s at time t. Therefore, $RegStringency_{j,t}$ captures firm j's exposure to environmental regulatory enforcement at time t across the states within which it operates.

2.3. Summary statistics

Our initial data set covers 5,548 bonds and 830 issuers contained in Mergent and TRACE databases over the 2009-2017 sample period. After merging the data with Sustainalytics, the sample size reduces to 4,235 securities from 478 firms. For the tests that employ the CDP carbon emissions data, we have 3,368 corporate bonds, corresponding to 287 firms. In Table 1 we report the sample summary statistics. Panel A contains summary statistics for the at-issue bonds. The average bond in the sample has a credit rating of about 15.3 (which is a little higher than a Baa1 rating) and an offering yield spread of

[22] For firms for which we cannot observe establishments in the NETs data, we use the total number of EPA enforcement actions for the state in which the firm's headquarters are located.

[23] The NETS data we employ are available as of 2014.

1.84%, and an average maturity of about 10 years. The average Environmental Score for the bond issuers is 60, above the halfway point of the 0-100 range. 48.7% of bond issues in the sample are from top 15 emissions industries.

The average issuing firm's carbon emissions is 6.68 million tons, but the median is only 0.44. The average carbon intensity is 0.32 tons of emissions per $1,000 in revenue, but the median is 0.01. These statistics reflect the fact that both carbon emissions and carbon intensity are highly positively skewed. Finally, the average $Reg_{j,t}$ for sample bond issuers is 0.71, indicating that, on average, 0.71 facility receives an enforcement action for every 1,000 facilities located in the same states as the issuer.

3. Credit risk, environmental profile, and regulatory stringency

3.1. Regression specifications

We first examine the relationship between bond credit risks and the issuing firms' environmental profiles, and whether that relationship is heightened by the firms' exposures to differing regulatory risks across states. In this set of analyses, we employ bond credit ratings and offering yield spreads as separate dependent variables that capture credit risk. The key independent variables in these regressions are firms' environmental profiles, the level of regulatory enforcement intensity each firm faces, and the interactions between these two variables. The specifications for bond i issued by firm j at time t are as follows:

$$Rating_{it} = \beta_1 EnvProf_{jt-1} + \beta_2 Reg_{jt-1} + \beta_3 EnvProf_{jt-1} \times Reg_{jt-1} + \beta_4 X_{jt-1} + FE + \epsilon_{it}, \tag{2}$$

$$\begin{aligned} Spread_{it} = {} & \beta_1 EnvProf_{jt-1} + \beta_2 Reg_{jt-1} + \beta_3 EnvProf_{jt-1} \times Reg_{jt-1} + \beta_4 X_{jt-1} + \beta_5 Z_{it} \\ & + FE + \epsilon_{it}, \end{aligned} \tag{3}$$

where $EnvProf_{jt-1}$ is firm j's environmental profile at time $t-1$, which we proxy for using the Sustainalytics Environmental Score, the firm's total carbon emissions (in millions of tons), or the firm's carbon intensity (tons of emissions divided by revenue in thousands of dollars). Reg_{jt-1} is the regulatory stringency for firm j at time $t-1$, proxied by the revenue-weighted average state EPA enforcement intensity. X_{jt-1} are firm j's characteristics at time $t-1$ and Z_{it} are bond i's characteristics at time t. Firm characteristics include book leverage, pre-tax interest coverage, the natural log of total assets, cash-to-assets ratio, profitability, tangibility of assets, annual stock returns and standard deviation of stock returns. In the regression on ratings, we control for a firm's weighted-average maturity of all outstanding bonds at time t. In the regression on yields, we additionally control for bond characteristics such as principal amount, time to maturity, and an indicator for callable bonds. For all specifications, time fixed effects are used to control for macroeconomic trends. In some specifications, industry fixed effects are also included to control for time-invariant industry characteristics.

In Equations (2) and (3), the primary coefficient of interest is β_3, which captures the interaction effect between firms' environmental profiles and their regulatory conditions. Based on our hypothesis that firms with poor environmental scores tend to have higher regulatory risk exposure, we expect β_3 to be positive when credit ratings are the dependent variable. That is, conditional on a certain level of regulation, higher environmental scores imply the firm should be subject to less regulatory risk, and therefore higher credit ratings. Alternatively, when we employ the carbon emission measures in Equation (2), we expect β_3 to be negative since under conditions of stricter regulatory enforcement, higher carbon emissions imply more regulatory risk exposure, and therefore, lower credit ratings.

When we employ the bond's offering yield spread as the dependent variable in Equation (3), we expect the opposite signs on β_3 because yield spreads should be decreasing in regulatory risk exposure for higher environmental profile firms and increasing for high carbon emission firms.

We are also interested in the coefficient of $EnvProf$, β_1, as it captures the unconditional effect of a firm's environmental profile on its credit risk. Recent studies have shown that carbon risk seems to command a positive risk premium in the equity market (Bolton and Kacperczyk, 2020, 2021). If bond investors also care about carbon risk, we would expect credit ratings and yield spreads to differ across issuers with different environmental profiles, even for issuers exposed to average levels of regulatory risk.

In this set of analyses, we focus on at-issue bonds to better capture the relation between environmental regulatory risk exposure and firms' costs of debt because the offering spreads reflect the costs of issuing debt. Additionally, at-issue bond spreads are less noisy than trading yields, particularly given the general illiquidity of the secondary bond market.

3.2. Results

In Table 2 Columns (1) through (3), we report the results for the regressions in which credit ratings are the dependent variables and we use time fixed effects. In column (1), using the firms' Sustainalytics environmental scores, we find that bonds issued by firms with higher environmental scores tend to have higher ratings. In particular, an increase in a firm's environmental score of one point is associated with a statistically significant 0.027 notch increase in credit rating for firm-years with an average regulatory stringency.[24] Importantly, the interaction term between a firm's environmental score and the weighted-average regulatory stringency the firm faces is positive, and both economically and statistically significant. When an increase in a firm's environmental score of one is combined with a one standard deviation increase in the firm's regulatory stringency, ratings increase by 0.047 notches ($0.027 + 0.020$). The results suggest that a firm's environmental profile affects its credit rating particularly through the channel of regulatory risks.

In the next two columns we employ the firm's carbon emissions in tons (Column (2)) and carbon intensity (Column (3)). Although we do not find a statistically significant relation

[24]The standard deviation of the environmental score is 14.1.

employing the absolute value of carbon emissions, when we use the relative measure, carbon intensity, we find a strong negative effect on the firm's credit rating. If carbon intensity increases by one (ton per $1,000 revenue), a firm's credit rating decreases by 0.514 notch. This result suggests that carbon risk is priced in corporate bond spreads unconditionally. Moreover, when combined with a one standard deviation increase in *Reg*, the same increase in carbon intensity is associated with a 0.797 notch decrease in credit ratings ($-0.514 - 0.283$).

We include industry fixed effects in the regression-specifications in columns (4) through (6) of Table 2 in order to examine whether the relationship between firm environmental profile and credit risk is also present within a given industry. Column (4), in which we use the firm's environmental score, shows results similar to column (1), an increase in a firm's environmental score of one is associated with a 0.014 notch increase in their bonds' credit ratings. Moreover, when combined with a one standard deviation increase in firms' regulatory stringency, the same magnitude increase in environmental score is associated with an even larger increase in credit ratings: a 0.033 notch increase ($0.014 + 0.019$).

In Column (5) using industry fixed effects, we now find a statistically significant positive relation between a firm's total carbon emissions and its credit ratings. In particular, a one million ton increase in a firm's credit ratings is associated with a 0.014 notch decrease in its bond ratings. Moreover, if a firm operates in states with a one standard deviation increase in regulatory stringency, the same amount of additional carbon emissions is associated with a 0.035 notch decrease ($-0.014 - 0.021$) in credit ratings. Column (6) displays results using carbon intensity. An increase in carbon intensity of one (ton per $1,000 revenue) is associated with a 0.231 decrease in credit ratings. When combined with a one standard deviation increase in *Reg*, it is instead associated with a 0.559 decrease ($-0.231 - 0.328$) in credit ratings.[25]

The results in Table 2 imply that credit rating agencies consider regulatory risk when

[25] In order to save space, we do not report the results for the case when a firm is a member of a top 15 carbon-emitting industry as the coefficient is not significantly different from zero for these tests.

evaluating how environmental concerns affect bond risk, which is consistent with rating agencies' policies. According to methodology published in 2018, credit rating analysts at Moody's consider both direct environmental implications and regulatory costs when evaluating ESG effects on credit ratings. Specifically, they state that they consider regulation more closely because forecasting is easier (Moody's, 2018). These statements are consistent with our finding that the effects of detrimental environmental activities on bond credit ratings are sensitive to the strictness of states' EPA regulation enforcement.

In Table 3, we present the regression results for the relationship between firms' offering bond spreads and their environmental risk exposures, where the regressions in columns (1) through (3) include results using only time fixed effects and columns (4) through (6) include both time and industry fixed effects. The results in column (1) indicate that a one unit increase in a firm's environmental score is associated with a 0.9 bp decrease in their bonds' offering yield spreads, holding the regulatory stringency a firm faces at the average level. Additionally, when a firm operates in states with a one standard deviation increase in EPA stringency, the same increase in environmental score is instead associated with a 1.4 bps decrease ($-0.9 - 0.5$) in offering yield spreads. Considering that the standard deviation of environmental score is 14.1, this effect is economically large. Our finding that firms with higher environmental scores have lower yield spreads is consistent with Chava (2014) who concludes that firms with higher environmental scores pay lower interest rates on their bank loans. Both our results and that of Chava (2014) imply that such firms face lower risks, which is an effect widely believed by many ESG investors.

The results in column (2) show that a one million ton increase in firm carbon emissions is associated with a 0.7 bp increase in yield spreads. When combined with a one standard deviation increase in *Reg*, the increase in emissions is associated with a 1.4 bps increase ($0.7 + 0.7$). Column (3) shows similar results when using carbon intensity as a carbon intensity increase of one (ton per \$1,000 revenue) is associated with a 16.2 bps increase in bond spreads. These results are consistent with the argument that issuers with higher carbon emissions face higher costs in raising capital.

In columns (4) through (6), we report broadly similar results when employing both time and industry fixed effects. All three columns show that when combined with an increase in environmental scores, carbon emissions or carbon intensity, the offering yield spreads become higher. For example, column (5) show that a one million ton increase in carbon emissions, is associated with 0.9 bp higher spread for firms located in states where the EPA enforcement stringency is one standard deviation higher than average.

The results in Tables 2 and 3 show that bonds from firms with poor environmental performance tend to have both lower credit ratings and higher yield spreads. These results from the corporate bond markets are consistent with findings that carbon risk is priced into equity markets (Bolton and Kacperczyk, 2020, 2021). Importantly, these findings highlight that the effect is particularly pronounced when issuing firms have establishments in states with more stringent environmental regulation enforcement. 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 credit risk.[26] The 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).

The results are also informative about the channel through which environmental regulations affect credit ratings and yield spreads. In particular, these findings show that environmental regulatory risk is related to credit ratings and yields spreads both across-industry and within-industry, which suggests that for the high carbon emission sectors, firms that operate in states with stricter regulatory enforcement likely bear even more credit risk than their counterparts in less stringent states.

[26]These results are consistent with the legal cost evidence provided by Karpoff et al. (2005). Although the authors of this article 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.

4. The Paris Agreement shock

A firm's environmental profile and its regulatory conditions may be jointly determined, thus, creating potential endogeneity issues. For example, state governments could impose stricter environmental regulations because the economic conditions in the state are favorable; these favorable economic conditions might in turn attract high carbon emission firms to locate there. To mitigate such endogeneity concerns, we exploit a shock that increases the climate regulatory risks faced by firms, while changing neither the performance nor the environmental profiles of these firms.

The setting we use in our research design is the passage of the Paris Agreement, announced on December 12, 2015. The Paris Agreement had the primary goal of limiting global temperature rise in this century to 1.5 degrees Celsius above pre-industrial levels. To achieve this goal, the Agreement calls for the signing countries to submit national action plans to reduce emissions with sufficient speed to achieve the goal. Such plans imply the development of expectations that more stringent environmental regulations are likely to be imposed in the future, since the national action plans would need to include regulatory responses to induce firms to help achieve the climate goal. We hypothesize that the Paris Agreement shock resulted in firms with poor environmental practices or high carbon footprints facing greater climate regulatory risks relative to other firms. The increased risks should then be reflected in changes in firms' bond credit ratings and spreads.

To test this hypothesis, we conduct difference-in-differences analyses so as to compare changes in the credit ratings and yield spreads of bonds from firms with problematic environmental profiles versus those from other firms, both before and after the Paris Agreement.

4.1. Descriptive evidence of changes in bond credit ratings and spreads

Before conducting formal difference-in-differences analyses, we visually inspect changes in the average credit ratings and spreads for bonds issued by firms in high carbon-emitting industries and by firms with different environmental scores. Figure 1(a) displays the average credit ratings for each of the top 15 carbon-emitting 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 some industries such as petroleum and coal products or motor freight transportation tend to be more creditworthy, on average, while other high carbon emission industries, such as stone, clay and glass or metal mining, appear to be less creditworthy, on average.

Overall, the figure demonstrates observable differences in average industry 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 high carbon emission industries. In particular, some of the high-carbon emitting industries whose ratings are most affected by the announcement of the Paris Agreement (such as primary metal and metal mining) are relatively less sensitive to oil prices, suggesting that the effect is unlikely driven by any concurrent changes in oil prices (an issue we examine in more depth later in the paper).

Figure 1(b) shows changes in yield spreads for bonds issued by firms in the top 15 carbon-emitting industries before and after the Paris Agreement. As in the case of the credit ratings, substantial differences exist across industries in the magnitude of the yield 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.

In Figures 2(a) and 2(b), we illustrate average credit ratings and yield spreads by environmental score bins for the periods before and after the Paris Agreement. We first sort bonds by their issuer's December 2014 Sustainalytics Environmental Score into eight groups and compare credit ratings and bond spreads across the environmental score bins.[27] Figure 2(a) contains the distribution of the average credit ratings according to environmental score bin from the lowest environmental scores on the left and the highest environmental scores

[27]Note the Sustaintalytics data does not include any United States firms with environmental scores below 20.

on the 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. More importantly, 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 yield spreads for bonds across the environmental score bins. 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 our sample median environmental score is 60, corporate bond issues with above-median environmental scores tend to have minimal changes in bond spreads after the Paris Agreement while those with below-median scores have increases in their spreads. These figures are consistent with our hypothesis that the Paris Agreement led to perceptions of increased regulatory risk resulting in lower credit ratings and higher bond yield spreads, on average, for firms with low environmental scores. We next conduct more formal tests of whether the Paris Agreement announcement had causal effects on the corporate bond market.

4.2. Tests for changes in credit ratings around the Paris Agreement

We first test changes in bond credit ratings in the two-year period around the December 2015 Paris Agreement through the following difference-in-differences regression:

$$Rating_{it} = \beta_1 EnvProf_j \times AfterParis_t + \gamma_i + \kappa_t + \epsilon_{it}, \tag{4}$$

where $AfterParis_t$ is an indicator variable for the months starting in December 2015 and continuing through the following 12 months. We include time fixed effects, κ_t, and in some specifications, security fixed effects, γ_i. Since the Paris Agreement is a time-series shock, our sample in these tests consists of bonds issued before the Paris Agreement in order to capture changes in ratings influenced by the Agreement.[28] 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. That is, the testing period runs from December 2014 through November 2016.

We employ four measures of a firm's environmental profile. First, we use an indicator variable equal to one if a firm has a below-median environmental score in December 2014. Second, we use an indicator variable for whether a firm is in one of the top 15 carbon-emitting industries. Third, we use an indicator variable equal to one if a firm is in the top-quartile in terms of firm-level total carbon emissions in 2014. Finally, we use an indicator variable equal to one if a firm is in the top-quartile in terms of firm-level carbon intensity in 2014.[29]

In Equation (4) β_1 captures the change in bond risk assessments around the Paris Agreement for a firm with a poor environmental profile relative to other firms, 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 4 reports the results of the difference-in-differences regressions. Column (1) shows that after the Paris Agreement, bond ratings decreased by 0.58 notch for bonds issued by firms with below-median environmental scores relative to other firms. Based on this result, the Paris Agreement led to an economically significant decrease in bond ratings for less environmentally friendly firms relative to firms that are more environmentally friendly.

In columns (2), (3) and (4), we use the CDP data to examine whether bonds issued by

[28]Specifically, the sample includes bonds issued at least one year before the Paris Agreement, i.e., in December 2014 or earlier. We also require that the bond does not mature before the end of the sample period.

[29]Below-median environmental score is based on the median environmental score for the firm-level distribution of Sustainalytics scores in December 2014, which is 55, results are similar if we instead use the sample median based on the full sample.

firms exposed to climate risk through their carbon emissions experienced ratings decreases. The results show that after the Paris Agreement, relative to other firms' bonds, the bond ratings decreased by 0.48 notch for issuing firms that belong to high emission industries, by 0.55 notch for bonds issued by firms in the top-quartile of carbon emissions and by 0.63 notch for bonds with top-quartile carbon intensity. Regardless of the measure used, corporate bond ratings decreased after the Paris Agreement for bonds issued by firms exposed to more climate risk relative to bonds from other issuers. Moreover, as shown by the results using the environmental score in the first column, bond ratings decreased after the Paris Agreement for bonds issued by firms exposed to environmental risk more generally.

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

$$Rating_{it} = \sum_{k=-11}^{11} \beta_k [\mathbb{1}(t = k) \times EnvProf_j] + \gamma_i + \kappa_t + \epsilon_{it}, \tag{5}$$

where $\mathbb{1}(t = k)$ are indicators for periods that are k months after (or before) the Paris Agreement. The time indicator variable for the first month in our sample period (December 2014) is excluded, so all treatment effects are relative to December 2014.

Figure 3 shows the results for these regressions when the outcome variable is the bond credit rating. The figure shows the treatment effect for each month in our sample, allowing us to examine the effects before and after the Agreement. Panel (a) displays the treatment effects over time for bonds issued by firms with a below-median environmental score. The solid line and dots indicate the coefficient estimates, and the dashed lines represent bands of a 95% confidence interval around these estimates. We find no significant differences in the treatment effect in the entire period before the Agreement, indicating the parallel trends assumption appears to hold. In contrast, after the Agreement, the treated firms' bonds have significantly lower credit ratings, consistent with the results reported in Table 4.

Figures 3 (b), (c) and (d) illustrate the results for Equation (5) when the treated firms are in a top 15 carbon emission industry, produced top-quartile emissions or have top-quartile carbon intensity, respectively. All of the figures show credit ratings indistinguishable from other firms' bonds before the Paris Agreement, and significantly lower credit ratings for the treatment bonds after the Paris Agreement. These charts together provide strong evidence that the parallel trends assumption is likely satisfied in addition to showing clearly observable changes in ratings for the treated bonds 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, they 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.

4.3. Tests for changes in bond yield spreads around the Paris Agreement

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

$$Spread_{it} = \beta_1 EnvProf_j \times AfterParis_t + \gamma_i + \kappa_{tp} + \epsilon_{it}, \tag{6}$$

where we measure a firm's environmental profile using the same four measures as in Equation (4). Instead of employing a time fixed effect, we include a matched-pair-by-time fixed effect κ_{tp}, where the matching procedure is described in more detail below. As a result, this test can be interpreted as comparing the change in spread for a treated security to its matched control security after the Paris Agreement, controlling for time-invariant security characteristics.

To better control for noise in spreads and to compare bonds with similar creditworthiness, we conduct a one-to-one Mahalanobis matching with replacement. The purpose of this matching approach is to identify and match every treated bond to the most similar control bond according to various covariates.[30] This distance is calculated as of year-end 2014 using the bond's credit rating, the bond principal outstanding, the bond's time to maturity, and the firm's equity oil beta.

We believe it is particularly important to match on oil beta in order to alleviate a potential concern that changes in bond pricing may be driven by concurrent movements in the oil market, particularly given the volatile changes in oil prices over this period.[31] We use the following model to calculate firms' equity oil betas:

$$R_{it} = \alpha + \beta_{market} MktRet_t + \beta_{oil} OilRet_t, \tag{7}$$

where $MktRet$ is proxied by the CRSP value-weighted index and $OilRet_t$ is the monthly return on Brent Crude Oil for month t. We calculate this value for each firm in our sample for which we observe 36 months or more of stock price data before November 2015.

We construct four matched samples, one for each of our environmental measures, the below-median environmental score, the top carbon emission industry, the top emission quartile and the top carbon intensity quartile treatments, respectively. In Table 5 we report the summary statistics for all matched samples (as of the matching date). Panels A, B, C, and D report statistics for the control and treated groups matched on the below-median environmental score indicator, the high emissions industry indicator, the top-quartile emissions indicator and the top-quartile carbon intensity indicator, respectively. The last column of each panel provides difference-in-means tests between the treated and control groups. As the differences between these two groups are generally statistically

[30]We use a caliper of 1, meaning if for a given treatment firm there does not exist a control firm whose Mahalanobis distance is 1 or less, we drop it from the sample. We further address the potential bias in continuous variable matching using the methods proposed by Abadie and Imbens (2006).

[31]Generally speaking, oil price volatility is seen as negatively predicting economic growth and aggregate equity prices, especially for the oil sector (Gao et al., 2021).

insignificant and economically small, it is reasonable to conclude the treated and control groups are observationally similar.

Table 6 reports the results from the difference-in-differences regression in which bond spread is the dependent variable. The effects of the Paris Agreement on the treated firms' spreads are both economically large and statistically significant. Column (1) indicates that after the Paris Agreement bond spreads increased by 39.4 bps for bonds issued by firms with below-median environmental scores relative to other firms. Columns (2) through (4) display results using the carbon emissions measures. Relative to other firms, corporate bond spreads increased by 38.6 bps, 30.1 bps, and 34.7 bps for bonds issued by firms in industries with high carbon emissions, by firms with top-quartile carbon emissions and by firms with top-quartile carbon intensity, respectively.[32] These results provide evidence that regardless of the specific firm environmental profile measure used, after the Paris Agreement corporate bond spreads increased for bonds issued by firms with poor environmental profiles relative to other firms.

We further provide visual evidence for the parallel trend assumption by running the following dynamic difference-in-differences regression:

$$Spread_{it} = \sum_{k=-11}^{11} \beta_k [\mathbb{1}(t = k) \times EnvProf_j] + \gamma_i + \kappa_{tp} + \epsilon_{it}. \tag{8}$$

The excluded period is December 2014. Additionally, we use security and matched-pair-by-time fixed effects.

Figure 4(a) illustrates the changes in bond spreads around the Paris Agreement using a below-median environmental score indicator as the treatment. Prior to the Paris Agreement, there does not appear to be a substantial differential increase in bond spreads for issuers with low environmental scores relative to other issuers. Additionally, right after the announcement of the Paris Agreement, there exists a significant and sizable increase in

[32] In untabulated results we also conducted the analysis using the full unmatched sample, and the results not only continue to hold, but they are also larger in magnitude.

spreads for bonds issued by firms with below-median environmental scores relative to other bonds. Similar patterns are observed when examining high carbon emission industries in Figure 4(b), high carbon emission firms in Figure 4(c), and high carbon intensity firms in Figure 4(d). These results provide some assurance that the parallel trends assumption for our difference-in-differences specifications are likely to be satisfied.

The initial increase in yield spreads for firms with low environmental profiles somewhat subsides in later months. One explanation for the partial reversals is the uncertainty surrounding what policy changes would ultimately result from the Agreement. This uncertainty arose because of the 2016 presidential election campaign and outcome as well as the subsequent June 2017 announcement that the U.S. would withdraw from the Agreement. Thus, although the Paris Agreement appears to have resulted in a persistent increase in credit ratings for treated firms as shown in Figure 3, Figure 4 suggest that the change in investors' expectations of increased climate change regulation in the United States as shown by the change in spread may have been short-lived for investors. We examine this possibility more thoroughly in section 6.

The substantial increases in bond spreads for firms with poor environmental profiles support the hypothesis that investors develop 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 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., 2021), that the Paris Agreement changed firms' leverage (Ginglinger and Moreau, 2019) and that firms revised their beliefs over the effects of climate regulation upward, sharply increasing their carbon abatement over the year from 2016 to 2017 (Ramadorai and Zeni, 2021). The result is also consistent with previous literature showing that firms' cost of debt increases with political uncertainty risk and increased liability risk (Bradley et al., 2016; Gormley and Matsa, 2011).

4.4. Triple-difference tests around the Paris Agreement

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 more affected because the regulatory environments in these states would be more likely to impose stricter regulatory requirements. To examine this hypothesis, we conduct a triple-difference regression in which we include an indicator variable for firms with stricter regulatory environments. To define the stricter regulatory environments, we sort firms by *Reg*, which is calculated as firm's revenue-weighted average environmental regulatory strigency, from 2012 through 2015 (the four years leading up to the Paris Agreement). Firms with a top-quartile *Reg* are defined as high regulatory enforcement firms.

Using these definitions, we run the following analyses:

$$\begin{aligned} Rating_{it} = {} & \gamma_i + \kappa_t + \beta_1 AfterParis_t \times EnvProf_j + \beta_2 AfterParis_t \times HighReg_j \\ & + \beta_3 EnvProf_j \times HighReg_j + \beta_4 AfterParis_t \times EnvProf_j \times HighReg_j + \epsilon_{it}, \end{aligned} \tag{9}$$

$$\begin{aligned} Spread_{it} = {} & \gamma_i + \kappa_{tp} + \beta_1 AfterParis_t \times EnvProf_j + \beta_2 AfterParis_t \times HighReg_j \\ & + \beta_3 EnvProf_j \times HighReg_j + \beta_4 AfterParis_t \times EnvProf_j \times HighReg_j + \epsilon_{it}, \end{aligned} \tag{10}$$

where $AfterParis_t$ is an indicator variable for the months starting in December 2015 and continuing through the following 12 months and $HighReg_j$ is an indicator variable for high regulatory enforcement firms.

The primary parameter of interest, β_4, captures the effects of the Paris Agreement for firms with poor environmental profiles that operate in states with strict regulatory enforcement relative to firms that operate in less stringent states. If after the Paris Agreement firms with poor environmental profiles become more exposed to climate regulatory risks in states where any potential new regulations are expected to be enforced more strictly, we expect β_4 to be negative in the credit rating regressions and positive in the yield spread regressions. Such a result would suggest that regulatory risk is the channel through which the Paris Agreement affects bond credit ratings and spreads. We again use the below-median environmental score, the high carbon emissions industry, the top-quartile firm carbon emissions and the top-quartile firm carbon intensity indicators to define treated firms.

Table 7 provides the results of the triple-difference regressions where the dependent variable is credit rating. The main parameter of interest is the coefficient for the triple-difference estimator $AfterParis_t \times EnvProf_j \times HighReg_j$. In Column (1) in which the environmental measure is the below-median environmental score indicator, the results show that after the Paris Agreement, relative to the firms located in low regulatory stringency states, firms with low environmental scores located in strict regulatory states experienced credit rating decreases of an additional 0.99 notch. Columns (2) through (4) display results using the carbon emissions data and show that after the Paris Agreement, if an issuing company is located in a high regulatory enforcement state, bond ratings decrease by an additional 1.09 notch, 1.37 notch, and 1.39 notch for bonds issued by firms in high carbon emission industries, the top-quartile of carbon emissions and the top-quartile of carbon intensity, respectively. Overall, the results imply that the decrease in corporate bond ratings following the Paris Agreement is driven by firms with operations in states that have stricter regulatory enforcement, supporting the hypothesis that climate regulatory risk is an important determinant of corporate bond ratings.

Table 8 reports the results for the triple-difference tests when bond spreads are the dependent variables. Column (1) displays results using the below-median environmental score indicator. Bond spreads increase by an additional 91.1 bps for firms with poor environmental profiles and located in stricter regulatory enforcement states, as compared with poor-environmental firms located in less strict states. Column (2) displays results for the high carbon emission industry indicator and the results are similar. Bond spreads increase by an additional 70 bps for bonds issued by firms in high carbon emission industries if the firm is located in stricter regulatory enforcement states. These results imply that changes in corporate bond spreads for firms with poor environmental profiles after the Paris Agreement are mostly driven by regulatory risk. However, the results in columns (3) and (4), which display results using the firm emissions and carbon intensity measures, are not statistically significant.

The triple-difference results indicate that most of the effect of the Paris Agreement on firms' cost of debt arises through the regulatory cost channel, which suggests that both credit rating analysts and bond investors believe that the Paris Agreement would have greater effects on the cost of debt for issuers located in high-regulation states. These results are consistent with the hypothesis that bond market participants expected the Paris Agreement to lead to increased regulations for environmentally problematic firms and that the new regulations 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 regulations e.g., Karpoff et al. (2005).

5. Changes in institutional investor bond ownership around the Paris Agreement

The bond pricing results suggest that after the Paris Agreement, investors reevaluated their corporate bond holdings more exposed to climate risk. A number of recent theory papers argue that green and brown investors view their investments from different perspectives (e.g., Heinkel, Kraus, and Zechner, 2001; Pastor, Stambaugh, and Taylor, 2021; Oehmke and Opp, 2020; Baker, Hollifield, and Osambela, 2020; Pedersen, Fitzgibbons, and Pomorski, 2021; Baker, Hollifield, and Osambela, 2020; Goldstein, Kopytov, Lin, and Xiang, 2021). In addition, empirical work shows relationships between certain types of institutional investors and their CSR or carbon risk equity portfolio holdings (Dyck, Lins, Roth, and Wagner, 2019; Ilhan, Krueger, Sautner, and Starks, 2021). Further, Starks, Venkat, and Zhu (2021) provide evidence that institutional investors with longer-term horizons have stronger preferences to invest in firms with higher ESG profiles.

Accordingly, we distinguish two classes of major investors in the corporate bond market that have been argued to have different investment horizons: insurance companies and mutual funds due to the differences in their investment strategies. In particular, insurance companies tend to hold their bonds to maturity, while mutual funds tend to trade more frequently and hence have a much shorter horizon (Massa, Yasuda, and Zhang, 2013). As long-term investors have been shown to care more about firms' environmental profiles (Starks, Venkat, and Zhu, 2021), we posit that insurance companies are more likely to reduce their holdings of corporate bonds issued by firms with poor environmental profiles after the Paris Agreement. Further, these changes should be relevant to the bond pricing changes we find because insurance companies collectively hold around 25-30% of corporate bonds and mutual funds hold around 15% of outstanding bonds.

We conduct difference-in-differences analyses using eight quarterly snapshots of institutional portfolio holdings around the Paris Agreement (from the fourth quarter of 2014 to the fourth quarter of 2016). The data consists of institutional investor holdings obtained from Refinitiv eMAXX (formerly Lipper eMAXX). Each quarter, we sum up individual bond holdings of (1) all institutional investors included in the eMAXX reporting entities, (2) all mutual funds, and (3) all insurance companies, where we scale each of the investor's bond holdings by the outstanding amount of the particular bond issue. Each treated bond is matched to a control bond using bond characteristics: issue principal size, credit rating, time to maturity and the oil beta of the firm's equity. We then regress the particular institutional ownership variable (all institutional investors, mutual funds or insurance companies) on an indicator variable indicating quarters after the Paris Agreement, an indicator variable indicating issuers with low environmental profiles and the interaction between the two variables:

$$Ownership_{it} = \beta_1 Treated_i \times AfterParis_t + \beta_2 Treated_i + BondControl + \kappa_t + \epsilon_{it}. \quad (11)$$

We define $Treated_i$ bonds in the same four way by assigning an indicator variable equal to one if the issuing firm has a below-median environmental score in December 2014, is in a top carbon emissions industry, is in the top-quartile in terms of firm-level total carbon emissions in 2014, or is in the top-quartile in terms of firm-level carbon intensity in 2014. The bond-level control variables ($BondControl$) include issuance amount, years to maturity, and bond credit rating.

Table 9 shows the results of the difference-in-differences analyses for the changes in total institutional investor ownership, mutual fund ownership, and insurance company ownership around the Paris Agreement for the treated bonds. When we define the treated bonds as bonds issued by firms belonging to the top emission industries, we find that the total institutional ownership of the treated bonds declines by 1.24 percentage points relative to control bonds that are matched on bond characteristics. When we further decompose the change in institutional ownership into ownership ratios by mutual funds and insurance companies, we find that the reduction of institutional ownership of high emissions industry bonds is entirely driven by insurance companies, whose ownership drops by 1.21 percentage points. In contrast, the ownership of these bonds by mutual funds, which typically have a relatively shorter investment horizon, is virtually unchanged around the Paris Agreement.

The other regression results reported in Table 9 are based on alternative definitions of the treated bonds. A consistent pattern emerges: the total institutional ownership either declines (in the case of below-median environmental scores) or does not change (in the case of top-quartile carbon emissions and carbon intensity). However, the ownership held by insurance companies consistently decreases by around one percentage point, while the ownership held by mutual funds consistently increases. These analyses suggest that the Paris Agreement resulted in a transfer of ownership from relatively long-term bond investors (insurance companies) to investors with typically shorter horizons (mutual funds), which is consistent with the argument that environmental and climate risks are likely to materialize in the future and investors have different considerations based on their investment horizon.[33]

6. Reversals around the 2016 U.S. Presidential election and the subsequent announcement of U.S. withdrawal from the Paris Agreement

The empirical results in the previous sections support the hypotheses that environmental regulatory risks are an important component of bond credit rating assessments and the pricing of the bonds. The results also support the hypothesis that market participants view bonds issued by firms with poor environmental performance as becoming relatively more risky after the Paris Agreement due to changed expectations regarding regulations. However, these expectations may have again changed due to subsequent U.S. political events, namely the November 2016 U.S. Presidential election and the June 2017 announcement that the U.S. would withdraw from the Paris Agreement.

After the Paris Agreement, one of the candidates in the U.S. presidential primaries,

[33]The reduction of insurance company bond ownership of high-emission firms is not driven by the occurrence of bond credit rating downgrades after the Paris Agreement. In untabulated tests, we drop all bonds that experienced a credit rating downgrade during the 12 months following the Paris Agreement. The results for the remaining bonds in the sample remain robust with a significant reduction of insurance company ownership.

Donald Trump, actively campaigned on withdrawal from the Paris Agreement.[34] Moreover, when Mr. Trump was elected President of the United States on November 8, 2016, many, including the media and betting markets appeared to view the result as a surprise.[35] Consequently, 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 interpreting the market responses to these events is that any withdrawal from the Paris Agreement could not occur before November 4, 2020.[36] Therefore, we may not observe discernible responses in credit ratings, given the documented conservatism of credit rating agencies.[37] Anecdotal evidence suggests this to be the case.[38] We also note that the climate news index of (Engle et al., 2020) has a spike in June 2017, but it is much lower than that of many other events over the authors' sample period.

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,

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

[35] 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." Further, the website PredictIt indicated a very sharp spike on election day, going from \$0.22 on November 7 to \$0.98 on November 9 (https://www.predictit.org/markets/detail/1234/Who-will-win-the-2016-US-presidential-election).

[36] 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."

[37] Evidence shows that credit rating analysts 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.

[38] 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 is too early to tell exactly what climate policy will be reversed.

even without federal regulation. In fact, upon the June 2017 announcement of the pending U.S. withdrawal from the Paris Agreement, the governors of Washington, New York and California declared that they were forming an alliance of states committed to upholding the Paris accord.[39]

To test the extent of any changes in ratings and spreads that occurred due to changed expectations around the election and the withdrawal accouncements, we conduct the following regressions:

$$Rating_{it} = \beta_1 EnvProf_j \times Event_t + \gamma_i + \kappa_t + \epsilon_{it}, \tag{12}$$

$$Spread_{it} = \beta_1 EnvProf_j \times Event_t + \gamma_i + \kappa_{tp} + \epsilon_{it}, \tag{13}$$

where $Event_t$ is an indicator variable equal to 1 for observations after the November 2016 election or the June 1, 2017 withdrawal announcement. γ_i is the security fixed effects, κ_t is the time fixed effects and κ_{tp} is the pair-time fixed effects. In each of these tests, our pre- and post-event periods are set to be 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. We limit the sample to bonds issued before December 2014 (i.e. those also used in the Paris Agreement test) and that are outstanding through the full sample period, so that we are estimating whether there exist any reversals of the changes observed following the Paris Agreement. In these specifications, β_1 can be interpreted as the change in bond credit rating or yield spread following the respective event for firms with poor environmental profiles relative to those from other firms.

The results for the changes in credit ratings after the 2016 election are displayed in Panel A of Table 10 in which columns (1) - (4) display results using the low environmental score indicator, the high carbon emissions industry indicator, the top-quartile firm carbon emissions indicator and the high carbon intensity indicator. In all four specifications the

[39]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/)

result is statistically indistinguishable from zero, thus, following the 2016 election outcome, the rating agencies did not meaningfully change ratings for bond issuers with poor environmental profiles.

Panel B reports the regression results after the June 2017 withdrawal announcement. There exists strong evidence that relative credit ratings improved for the environmentally problematic firms after the withdrawal announcement. In particular, column (1) shows that corporate bond ratings increased by 0.096 notch for bonds issued by firms with below-median environmental scores after the withdrawal announcement relative to other firms. We observe a similar increase in corporate bond ratings when examining firms with any of the high carbon emission measures. These effects can be considered partial reversals in the increase in corporate bond spreads after the Paris Agreement. The partial reversals are consistent with the argument that ratings agencies are only comfortable adjusting ratings after a clear and definitive change in climate policy.

In contrast, the evidence on bond yield spreads suggests that bond investors reacted more swiftly to these two events, as shown in Table 11, which displays the effects of the 2016 presidential election and the subsequent withdrawal announcement on bond spreads. Panel A provides the results for the changes in bond yield spreads following the 2016 election. Unlike the results on credit ratings, for all four treatments we find a substantial decrease in bond spreads following the 2016 election. In particular, Column (1) shows that after the 2016 election, bond spreads decreased by 18.8 bps for firms with low environmental scores, representing a reversal of slightly under one-half of the earlier increase in bond spreads after the Paris Agreement. Similarly, in columns (2) through (4) we find similar results using the high carbon emissions measures to define the treatment. Each of these effects represents between a one-third and one-half reversal of the effect documented in Table 6.

The evidence in Panel B of Table 11 shows no significant changes in bond spreads for firms with poor environmental profiles following the withdrawal announcement in June 2017. This result on bond spreads may be due to the response following the election.

Overall, the findings for the election and withdrawal events are consistent with ratings agencies and bond investors viewing firms with poor environmental profiles as less risky when the prospect of future environmental regulations is lessened. The results also suggest that bond investors reacted to the potential policy change affecting issuers with poor environmental profiles more swiftly (after the 2016 election), but that credit rating analysts waited for a definitive change in policy before adjusting ratings for climate regulatory risk, which is consistent with prior research on the conservatism of credit rating analysts (Altman and Rijken, 2004; Gredil et al., 2019; Löffler, 2005).

7. Conclusions

Environmental risks, including climate risks, have been receiving more focused attention from financial market participants. In this study, we provide empirical evidence that suggests uncertainty about future regulatory actions can motivate bond market participants to respond to firms' environmental performance, and particularly, changes in firms' exposures to climate risks.

We present empirical results suggesting that having poor environmental performance, including having a more significant carbon footprint, is associated in general with lower credit ratings and higher bond yield spreads, particularly for firms located in states with stricter environmental regulations. We also provide evidence of a causal component to these results by examining bond credit ratings and yield spreads for environmentally poor firms after a shock to their regulatory risk. We find that the December 2015 Paris Agreement appears to have had increased the regulatory risk for firms that are in high emissions industries or have poor environmental performance in general, resulting in negative consequences. More importantly, these effects 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.

Our results have important implications for how firms' environmental profiles are related to market participants' assessments of their corporate bonds' risks and values. 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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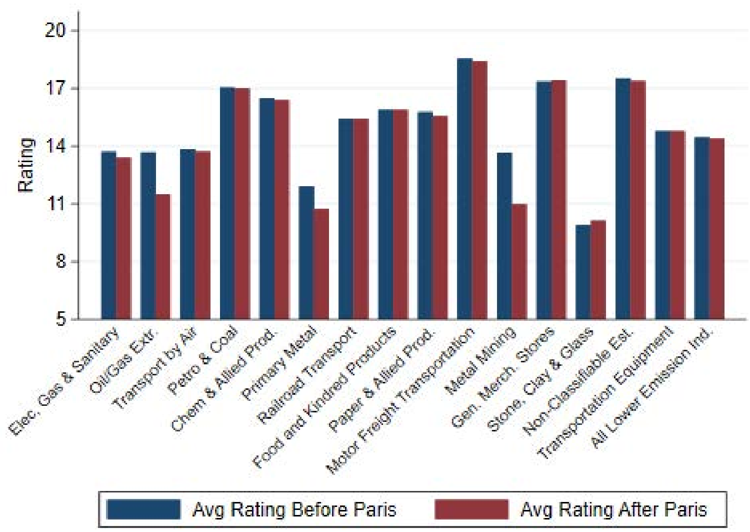
Fig. 1. Credit ratings and yield spreads of high carbon emission industries' bonds before and after the Paris Agreement.
This figure displays equal-weighted average ratings and spreads for each of the top 15 carbon-emitting industries, before and after the Paris Agreement, where the pre-period runs from December 2014 through November 2015 and the post 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) Spreads

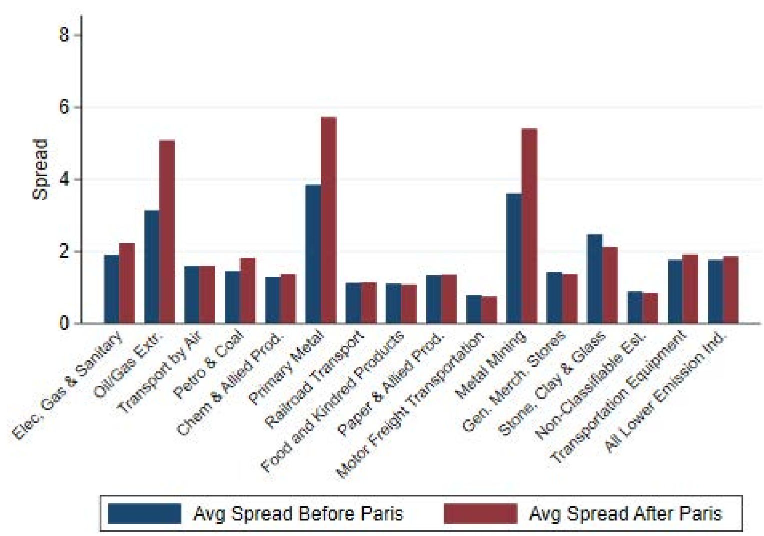
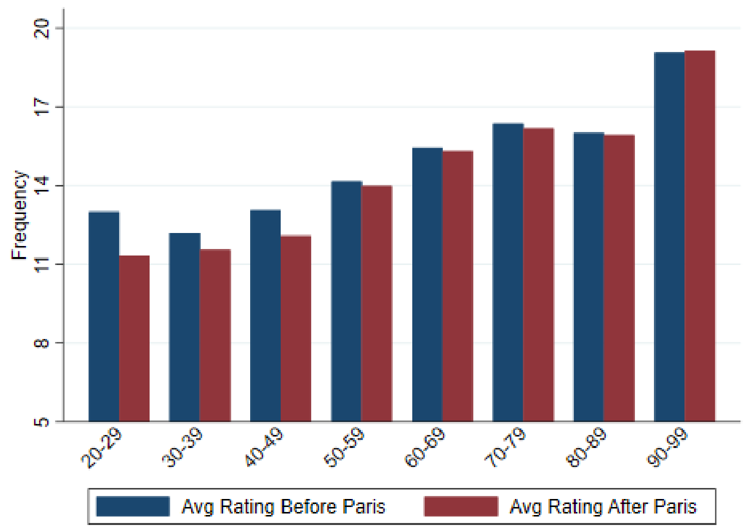


Fig. 2. Ratings and spreads by environmental scores before and after the Paris Agreement. This figure displays equal-weighted average ratings and spreads for firms divided by their levels of Sustainalytics Environmental scores, before and after the Paris Agreement, where the pre-period runs from December 2014 through November 2015 and the post 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

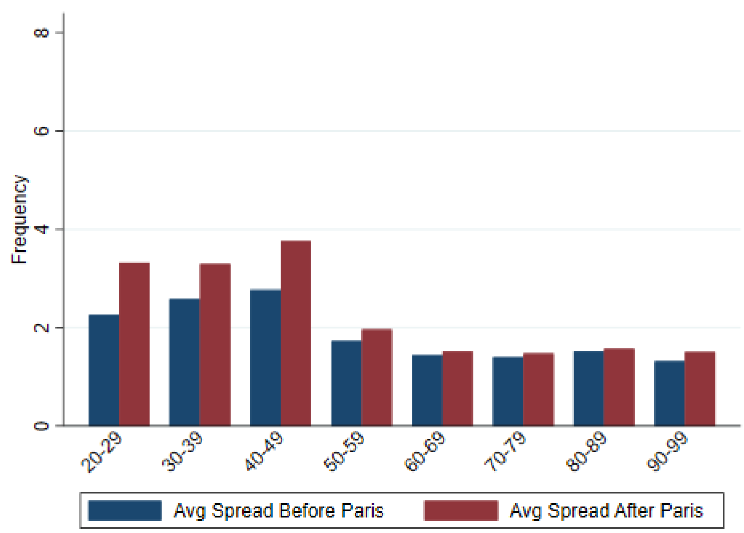
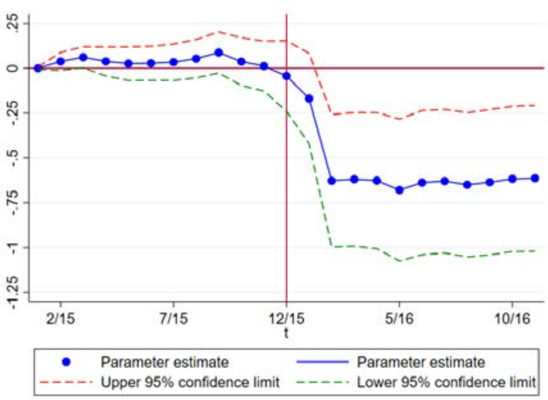
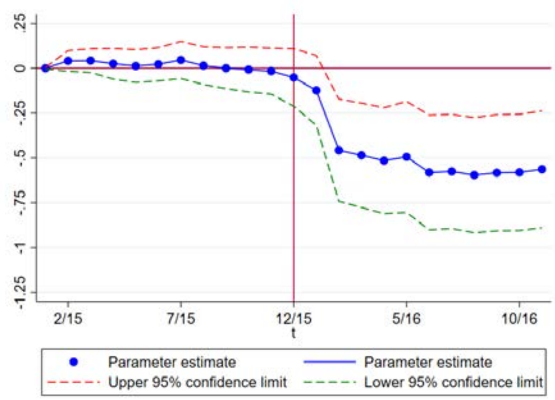


Fig. 3. Bond credit ratings around the Paris Agreement announcement.
This figure plots the coefficients from the following regression equation:
$Rating_{it} = \sum_{k=-11}^{11} \beta_k[\mathbb{1}(t = k) \times EnvProf_j] + \gamma_i + \kappa_t + \epsilon_{it}$.
$EnvProf_j$ is equal to one for treated observations, where the treatment is defined alternatively as a below-median environmental score, being in the top 15 carbon-emitting industries, being in the top-quartile of CDP emissions, or being in the top-quartile of CDP carbon intensity (tons of emissions divided by revenue in \$1,000). Control observations are all other securities. γ_i, κ_{tp} are security and matched-pair-by-time fixed effects. Pre-period runs from December 2014 through November 2015 and post-period runs December 2015 through November 2016. The chart includes all interaction terms except for December 2014, so the regression coefficient can be interpreted as the effect of being a low environmental profile firm on bond credit ratings in each period relative to December 2014. (Higher numerical scores indicate better credit ratings.)

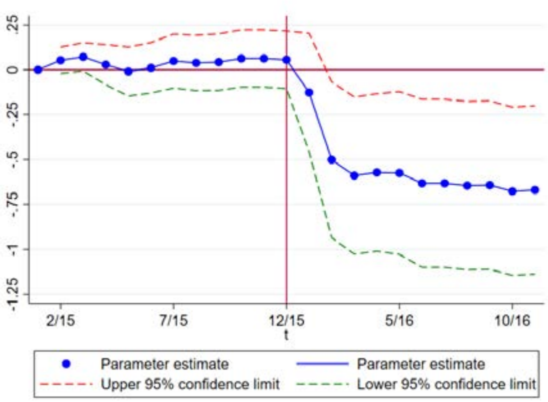
(a) $EnvProf_j = BelowMedEnv_j$



(b) $EnvProf_j = HighEmissionsInd_j$



(c) $EnvProf_j = TopQtEmissions_j$



(d) $EnvProf_j = TopQtCarbonInt._j$

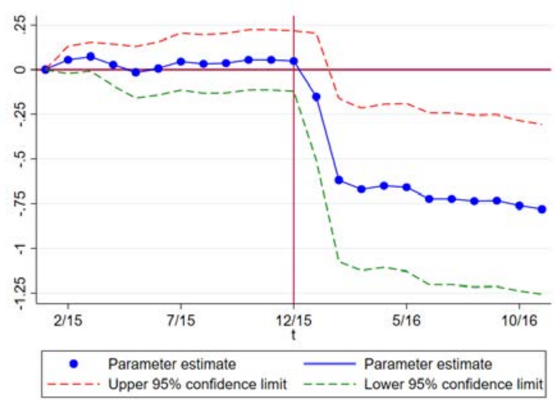
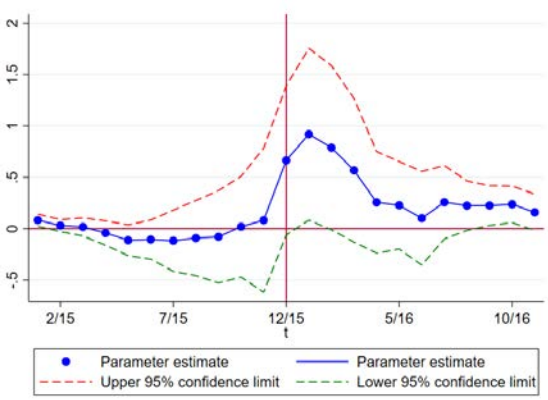
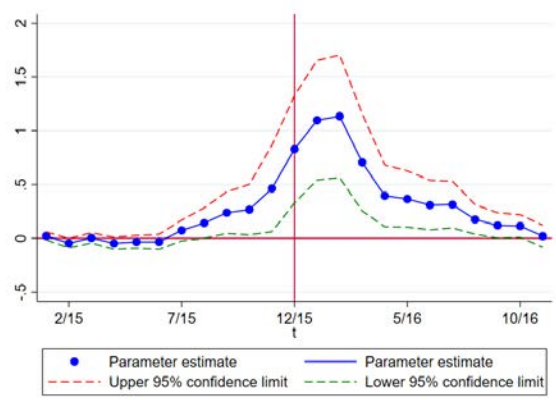


Fig. 4. Yield spreads around the Paris Agreement announcement.
This figure plots the coefficients from the following regression equation:
$Spread_{it} = \sum_{k=-11}^{11} \beta_k[\mathbb{1}(t = k) * EnvProf_j] + \gamma_i + \kappa_{tp} + \epsilon_{it}$.
$EnvProf_j$ is equal to one for treated observations, where the treatment is defined alternatively as a below-median environmental score, being in the top 15 carbon-emitting industries, being in the top-quartile of CDP emissions, or being in the top-quartile of CDP carbon intensity (tons of emissions divided by revenues in \$1,000). Control observations are selected using a one-to-one nearest neighbor matching with replacement by Mahalanobis matching with replacement procedure on rating, time to maturity, issue principal outstanding and oil beta as of year-end 2014. γ_i, κ_{tp} are security and matched-pair-by-time fixed effects. Pre-period runs from December 2014 through November 2015 and post-period runs December 2015 through November 2016. The chart includes all interaction terms except for December 2014, so the regression coefficient can be interpreted as the effect of being a low environmental profile firm on bond yield spreads in each period relative to December 2014.

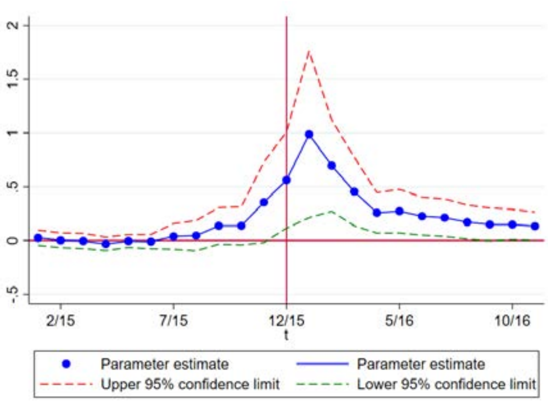
(a) $EnvProf_j = BelowMedEnv_j$



(b) $EnvProf_j = HighEmissionsInd_j$



(c) $EnvProf_j = TopQtEmissions_j$



(d) $EnvProf_j = TopQtCarbonInt._j$

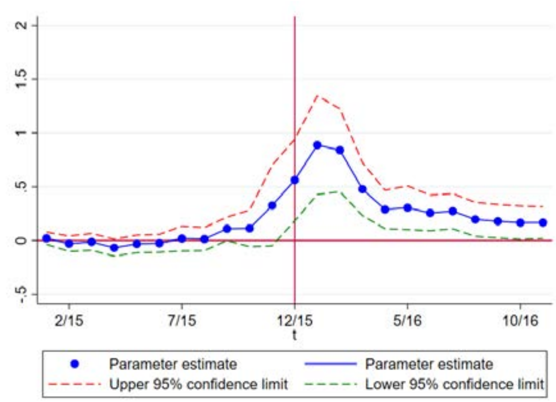


Table 1: Summary statistics.

This table reports the summary statistics for the at issue bond sample with a sample period of 2009 through 2017. Trading yield spread, yield, profitability, leverage, annual returns, ln(total assets), and cash/assets 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. Reg stringency is measured as the firm's regulatory stringency determined as the revenue-weighted average number of EPA penalties issued in a given year divided by the number of facilities (in thousands) in that state for the states the firm operates in. When this is not available, the number of EPA penalties in the state the firm's headquarters are located in divided by the number of plants regulated by the EPA in that state (in thousands). Top 15 emissions industries are defined as the top 15 carbon emissions industries based on carbon emissions using the CDP data.

Variable	Observations	Mean	Median	Std. Dev.
Credit rating	1,940	15.312	15.000	2.828
Offering spread	1,940	1.835	1.481	1.273
Firm-weighted average maturity	1,940	9.414	9.274	3.336
Environmental score	1,940	59.960	60.000	14.050
Reg Stringency	1,940	0.714	0.446	0.950
Top 15 emissions industry	1,940	0.487	0.000	0.500
Emissions (millions of ton)	1,312	6.680	0.438	19.665
Carbon intensity (ton per $1,000 revenue)	1,312	0.319	0.014	0.997
Ln(1 + Principal)	1,940	13.384	13.305	0.602
Time to maturity	1,940	9.969	10.000	7.289
Callable	1,940	0.970	1.000	0.170
Leverage	1,940	0.287	0.274	0.147
Pre-tax interest coverage	1,940	19.303	11.760	23.433
Ln(Total assets)	1,940	10.197	10.234	1.259
Cash/assets	1,940	0.118	0.072	0.131
Profitability	1,940	0.222	0.168	0.185
Tangibility	1,940	0.302	0.188	0.256
Annual stock returns	1,940	15.599	13.648	24.203
Ln(Standard deviation of returns)	1,940	2.939	2.902	0.415

Table 2: Credit ratings and regulatory stringency

This table displays results from the following panel regression:

$$Rating_{it} = \beta_1 EnvProf_{jt-1} + \beta_2 Reg_{jt-1} + \beta_3 EnvProf_{jt-1} \times Reg_{jt-1} + \beta_4 X_{jt-1} + FE + \epsilon_{it}.$$

All observations are at-issue bonds. Environmental scores, leverage, ln(total assets), profitability, annualized stock return, and the standard deviation of stock returns are winsorized at the 1% and 99% levels and are measured at the end of the previous year. Reg stringency, defined as the revenue-weighted average number of EPA penalties in a given year divided by the number of facilities in that state (for the states in which the firm operates), is also standardized by mean and scaled by standard deviation. *, ** and *** indicate 10%, 5% and 1% significance, respectively. Fixed effects are indicated in each column. Standard errors, which are clustered at the firm level, are shown in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
Environmental Score × Reg	0.020**			0.019***		
	(0.008)			(0.007)		
Emissions × Reg		-0.021			-0.021***	
		(0.013)			(0.008)	
Carbon Intensity × Reg			-0.283**			-0.328***
			(0.120)			(0.103)
Environmental Score	0.027***			0.014*		
	(0.008)			(0.007)		
Emissions		-0.013			-0.014**	
		(0.010)			(0.006)	
Carbon Intensity			-0.514***			-0.231*
			(0.141)			(0.119)
Reg	-1.031**	0.180	0.140	-0.983***	0.127	0.114
	(0.428)	(0.117)	(0.111)	(0.372)	(0.082)	(0.082)
Firm Weighted Average Maturity	0.016	-0.026	-0.035	0.041	-0.004	-0.003
	(0.031)	(0.038)	(0.038)	(0.026)	(0.029)	(0.030)
Leverage	-1.978*	-0.394	-0.221	-2.146***	-1.312	-1.299
	(1.050)	(1.272)	(1.215)	(0.812)	(1.027)	(1.035)
Pre-tax interest coverage	0.029***	0.037***	0.035***	0.021***	0.017***	0.016***
	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)
Ln(Total Assets)	0.946***	1.085***	1.033***	1.059***	1.201***	1.191***
	(0.117)	(0.133)	(0.130)	(0.111)	(0.131)	(0.129)
Cash/Assets	3.904***	5.178***	5.324***	2.501**	3.099***	3.163***
	(1.234)	(1.407)	(1.439)	(1.113)	(1.131)	(1.135)
Profitability	0.776	1.187	0.688	0.442	3.716***	3.647***
	(0.662)	(0.890)	(0.826)	(0.773)	(1.266)	(1.263)
Tangibility	-0.258	0.496	1.100*	1.679*	1.991*	2.006*
	(0.450)	(0.588)	(0.570)	(0.875)	(1.192)	(1.182)
Annual Stock Returns	-0.006**	-0.005	-0.004	-0.005**	-0.001	-0.001
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
Ln(Standard Deviation Returns)	-1.785***	-1.957***	-2.100***	-1.665***	-1.533***	-1.533***
	(0.246)	(0.334)	(0.323)	(0.209)	(0.286)	(0.286)
Time Fixed Effects	Y	Y	Y	Y	Y	Y
Industry Fixed Effects	N	N	N	Y	Y	Y
Adj. R^2	0.587	0.555	0.574	0.546	0.526	0.527
Obs	1,940	1,312	1,312	1,938	1,309	1,309

Table 3: Offering spreads and regulatory stringency.

This table displays results from the following panel regression:

$$Spread_{it} = \beta_1 EnvProf_{jt-1} + \beta_2 Reg_{jt-1} + \beta_3 EnvProf_{jt-1} \times Reg_{jt-1} + \beta_4 X_{jt-1} + \beta_5 Z_{it} + FE + \epsilon_{it}.$$

All observations are at-issue bonds. Environmental scores, coupon rate, leverage, ln(total assets), profitability, annualized stock return, and the standard deviation of stock returns are winsorized at the 1% and 99% levels. Firm characteristics are measured as of the end of the previous year. Reg stringency, defined as the revenue-weighted average number of EPA penalties in a given year divided by the number of facilities in that state (for the states in which the firm has facilities), is also standardized by mean and scaled by standard deviation. *, ** and *** indicate 10%, 5% and 1% significance, respectively. Fixed effects are indicated in each column. Standard errors, which are clustered at the firm level, are shown in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
Environmental Score × Reg	-0.005*			-0.006**		
	(0.003)			(0.003)		
Emissions × Reg		0.007*			0.009**	
		(0.004)			(0.004)	
Carbon Intensity × Reg			0.073			0.101
			(0.070)			(0.069)
Environmental Score	-0.009***			-0.004		
	(0.003)			(0.003)		
Emissions		0.007***			0.003	
		(0.003)			(0.003)	
Carbon Intensity			0.162***			0.088*
			(0.052)			(0.049)
Reg	0.225	-0.078**	-0.065*	0.333**	-0.062**	-0.054*
	(0.164)	(0.039)	(0.036)	(0.155)	(0.029)	(0.029)
Ln(1 + Principal)	0.254***	0.189***	0.216***	0.217***	0.179***	0.184***
	(0.058)	(0.057)	(0.056)	(0.045)	(0.045)	(0.045)
Time to Maturity	0.090***	0.093***	0.093***	0.091***	0.094***	0.094***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Callable	0.391*	0.296	0.275	0.058	0.033	0.022
	(0.225)	(0.183)	(0.180)	(0.155)	(0.131)	(0.131)
Leverage	1.193***	0.520	0.435	1.004***	0.582*	0.586*
	(0.416)	(0.413)	(0.391)	(0.331)	(0.331)	(0.333)
Pre-tax interest coverage	-0.007***	-0.007***	-0.006***	-0.006***	-0.005***	-0.005***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Ln(Total Assets)	-0.250***	-0.190***	-0.177***	-0.297***	-0.236***	-0.237***
	(0.036)	(0.036)	(0.034)	(0.043)	(0.042)	(0.042)
Cash/Assets	-0.473**	-0.564**	-0.635***	-0.184	-0.361	-0.368
	(0.237)	(0.231)	(0.227)	(0.244)	(0.258)	(0.262)
Profitability	-0.246	-0.211	-0.081	-0.322	-0.715	-0.685
	(0.202)	(0.151)	(0.139)	(0.374)	(0.476)	(0.474)
Tangibility	0.157	-0.291*	-0.366**	0.197	-0.530	-0.561*
	(0.151)	(0.167)	(0.153)	(0.356)	(0.329)	(0.334)
Annual Stock Returns	-0.003**	-0.003**	-0.003***	-0.003**	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Ln(Standard Deviation Returns)	1.045***	0.850***	0.878***	0.927***	0.675***	0.677***
	(0.104)	(0.125)	(0.123)	(0.094)	(0.123)	(0.122)
Time Fixed Effects	Y	Y	Y	Y	Y	Y
Industry Fixed Effects	N	N	N	Y	Y	Y
Adj. R^2	0.596	0.672	0.678	0.601	0.715	0.715
Obs	1,940	1,312	1,312	1,938	1,309	1,309

Table 4: Effects of the Paris Agreement on credit ratings.

This table displays results from the following regression:

$$Rating_{it} = \beta_1 EnvProf_j \times AfterParis_t + \gamma_i + \kappa_t + \epsilon_{it}$$

$Env.Prof_j$ is alternatively one of the following: an indicator variable equal to one if the issuing firm has a below median environmental score in December 2014 (*Low Environmental Score*), an indicator variable equal to one if the firm is in one of the top 15 carbon-emitting industries (*High Emission Industry*), an indicator variable equal to one if the firm is in the top quartile of carbon emissions in 2014 (*Top Quartile Emissions*), or an indicator variable equal to one if the firm is in the top quartile of carbon intensity (defined as tons of emissions per $1,000 in revenue) in 2014 (*Top Quartile Carbon Intensity*). $AfterParis_t$ is an indicator variable equal to one if the observation occurs in December 2015 or later. γ_i, κ_t are security and time fixed effects. Sample runs from December 2014 through November 2016. *, ** and *** indicate 10%, 5% and 1% significance, respectively. Standard errors, which are clustered at the firm level, are shown in parentheses.

	(1)	(2)	(3)	(4)
After Paris × Low Environmental Score	-0.580***			
	(0.165)			
After Paris × High Emissions Industry		-0.482***		
		(0.127)		
After Paris × Top-Quartile Emissions			-0.551***	
			(0.187)	
After Paris × Top-Quartile Carbon Intensity				-0.627***
				(0.193)
Time FE	Y	Y	Y	Y
Security FE	Y	Y	Y	Y
Adj. R^2	0.052	0.040	0.068	0.083
Obs	33,336	33,336	23,184	23,184

Table 5: Summary statistics – matched sample for yield spreads around the Paris Agreement.

This table shows summary statistics as of December 2014 (one year before the Paris Agreement)for the sample matched on the alternative environment variables. The environment variables are defined alternatively as one of the following: the firm has a below median environmental score (Panel A), the firm is in a top 15 carbon emissions industry (Panel B), the firm is in the top quartile of carbon emissions in 2014 (Panel C) and the firm is in the top quartile of carbon intensity in 2014, measured as tons of emissions divided by firm revenue in thousands of dollars (Panel D). The matched sample is formed by using one-to-one nearest neighbor Mahalanobis matching of treated bond issues to control bond issues by oil beta, issue principal outstanding, time to maturity and credit rating as of year-end 2014. Spread, profitability, leverage, tangibility, and the ln(Total Assets) are winsorized at the 1% and 99% levels. The ratings variable is assigned such that a higher number indicates a better rating. *, ** and *** indicate 10%, ** 5% and *** 1% significance respectively.

Group		**Sample**			**Control**		Diff Mean
Variable	Obs	Mean	St. Dev.	Obs	Mean	St. Dev.	
Panel A: Below Median Environmental Score							
Security-Level Variables							
Credit Rating	448	13.493	2.47	448	13.714	2.331	-0.221
Spread	448	2.011	1.283	448	2.004	1.388	0.007
Time to Maturity	448	9.46	7.447	448	9.541	7.406	-0.081
Firm Level Variables							
Profitability	129	0.233	0.196	110	0.25	0.191	-0.017
Oil Beta	129	0.011	0.032	110	0.001	0.032	0.01**
Panel B: High Carbon Emissions Industry							
Security Level Variables							
Credit Rating	646	15.265	2.761	646	15.317	2.804	-0.052
Spread	646	1.565	1.244	646	1.38	0.927	0.185***
Time to Maturity	646	11.131	8.902	646	11.219	8.924	-0.088
Firm Level Variables							
Profitability	135	0.187	0.139	114	0.288	0.22	-0.101***
Oil Beta	135	0.006	0.033	114	0.003	0.031	0.003
Panel C: Top Quartile Carbon Emissions							
Security Level Variables							
Credit Rating	252	15.905	2.47	252	15.813	2.33	0.092
Spread	252	1.292	0.787	252	1.268	0.917	0.024
Time to Maturity	252	11.937	9.504	252	12.049	9.521	-0.112
Firm Level Variables							
Profitability	39	0.161	0.121	64	0.225	0.188	-0.064*
Oil Beta	39	0.004	0.032	64	-0.001	0.029	0.005
Panel D: Top Quartile Carbon Intensity							
Security Level Variables							
Credit Rating	217	15.212	2.165	217	15.263	2.182	-0.051
Spread	217	1.413	0.83	217	1.311	0.907	0.102
Time to Maturity	217	11.791	9.412	217	11.818	9.493	-0.027
Firm Level Variables							
Profitability	38	0.134	0.09	64	0.228	0.165	-0.094***
Oil Beta	38	0.002	0.029	64	-0.004	0.025	0.006

Table 6: Effects of the Paris Agreement on yield spreads.

This table displays results from the following regression:

$$Spread_{it} = \beta_1 EnvProf_j \times AfterParis_t + \gamma_i + \kappa_{tp} + \epsilon_{it}$$

$Env.Prof_j$ is alternatively one of the following: an indicator variable equal to one if the issuing firm has a below-median environmental score (*Low Environmental Score*) in December 2014, an indicator variable equal to one if the firm is in one of the top 15 carbon-emitting industries (*High Emission Industry*), an indicator variable equal to one if the firm is in the top quartile of carbon emissions in 2014 (*Top Quartile Emission*), or an indicator variable equal to one if the firm is in the top quartile of carbon intensity (defined as tons of emissions per $1,000 in revenue) in 2014 (*Top Quartile Carbon Intensity*). $AfterParis_t$ is an indicator variable equal to one if the observation occurs in December 2015 or later. γ_i, κ_{tp} are security and matched-pair-by-time fixed effects. The sample is formed by using one-to-one nearest neighbor Mahalanobis matching of treated bond issues to control bond issues by oil beta, issue principal outstanding, time to maturity and credit rating as of year-end 2014. The sample period includes observations from December 2014 through November 2016. *, ** and *** indicate 10%, 5% and 1% significance, respectively. Standard errors, which are clustered at the firm level, are shown in parentheses.

	(1)	(2)	(3)	(4)
After Paris × Low Environmental Score	0.394***			
	(0.138)			
After Paris × High Emissions Industry		0.386***		
		(0.103)		
After Paris × Top-Quartile Emissions			0.301***	
			(0.096)	
After Paris × Top-Quartile Carbon Intensity				0.347***
				(0.088)
Pair-Time FE	Y	Y	Y	Y
Security FE	Y	Y	Y	Y
Adj. R^2	0.015	0.023	0.029	0.051
Obs	21,504	31,008	12,096	10,416

Table 7: Regulatory stringency and the effects of the Paris Agreement on credit ratings.

This table displays results from the following regression:

$$\begin{aligned} Rating_{it} &= \gamma_i + \kappa_t + \beta_1 AfterParis_t \times EnvProf_j + \beta_2 AfterParis_t \times HighReg_j \\ &+ \beta_3 EnvProf_j \times HighReg_j + \beta_4 AfterParis_t \times EnvProf_j \times HighReg_j + \epsilon_{it}. \end{aligned}$$

$EnvProf_j$ is alternatively either an indicator variable equal to one if the issuer has a below-median environmental score (*Low Environmental Score*) in December 2014, an indicator variable equal to one if the issuer is in one of the top 15 carbon-emitting industries (*High Emission Industry*), an indicator variable equal to one if a firm is in the top quartile of carbon emissions in 2014 (*Top Quartile Emission*), or an indicator variable equal to one if a firm is in the top quartile of carbon intensity (defined as tons of emissions per $1,000 in revenue) in 2014 (*Top Quartile Carbon Intensity*). $AfterParis_t$ is an indicator variable equal to one if the observation occurs in December 2015 or later. $HighReg_j$ is equal to one if the firm is in the top-quartile of exposure to EPA penalties from 2012 through 2015. γ_i, κ_t are security and time fixed effects. Sample is from December 2014 until November 2016. *, ** and *** indicate 10%, 5% and 1% significance, respectively. Standard errors, which are clustered at the firm level, are shown in parentheses.

	(1)	(2)	(3)	(4)
After Paris × Low Environmental Score × High Reg	-0.990***			
	(0.355)			
After Paris × High Emissions Industry × High Reg		-1.094***		
		(0.319)		
After Paris × Top-Quartile Emissions × High Reg			-1.371***	
			(0.446)	
After Paris × Top-Quartile Carbon Intensity × High Reg				-1.385***
				(0.411)
After Paris × Low Environmental Score	-0.100			
	(0.115)			
After Paris × High Emissions Industry		-0.111		
		(0.082)		
After Paris × Top-Quartile Emissions			-0.153	
			(0.099)	
After Paris × Top-Quartile Carbon Intensity				-0.157
				(0.102)
After Paris × High Reg	-0.121	-0.009	0.037	0.112
	(0.134)	(0.126)	(0.121)	(0.112)
Time FE	Y	Y	Y	Y
Security FE	Y	Y	Y	Y
Adj. R^2	0.126	0.134	0.182	0.189
Obs	33,336	33,336	23,184	23,184

Table 8: Regulatory stringency and effects of the Paris Agreement on yield spreads.

This table displays results from the following regression:

$$Spread_{it} = \gamma_i + \kappa_{tp} + \beta_1 AfterParis_t \times EnvProf_j + \beta_2 AfterParis_t \times HighReg_j + \beta_3 EnvProf_j \times HighReg_j + \beta_4 AfterParis_t \times EnvProf_j \times HighReg_j + \epsilon_{it}.$$

$EnvProf_j$ is alternatively one of the following: an indicator variable equal to one if the issuing firm has a below median environmental score (*Low Environmental Score*) in December 2014, an indicator variable equal to one if the firm is in one of the top 15 carbon-emitting industries (*High Emission Industry*), an indicator variable equal to one if the firm is in the top quartile of carbon emissions in 2014 (*Top Quartile Emission*), or an indicator variable equal to one if the firm is in the top quartile of carbon intensity (defined as tons of emissions per $1,000 in revenue) in 2014 (*Top Quartile Carbon Intensity*). $AfterParis_t$ is an indicator variable equal to one if the observation occurs in December 2015 or later. $HighReg_j$ is equal to one if the firm is in the top-quartile of exposure to EPA penalties from 2012 through 2015. γ_i, κ_{tp} are security and matched-pair-by-time fixed effects. The sample is formed by using one-to-one nearest neighbor Mahalanobis matching of treated bond issues to control bond issues by oil beta, issue principal outstanding, time to maturity, and credit rating as of year-end 2014. The sample period runs from December 2014 until November 2016. *, ** and *** indicate 10%, 5% and 1% significance respectively. Standard errors, which are clustered at the firm level, are shown in parentheses.

	(1)	(2)	(3)	(4)
After Paris × Low Environmental Score × High Reg	0.911**			
	(0.425)			
After Paris × High Emissions Industry × High Reg		0.700**		
		(0.336)		
After Paris × Top-Quartile Emissions × High Reg			0.199	
			(0.359)	
After Paris × Top-Quartile Carbon Intensity × High Reg				0.264
				(0.240)
After Paris × Low Environmental Score	0.033			
	(0.103)			
After Paris × High Emissions Industry		0.146**		
		(0.070)		
After Paris × Top-Quartile Emissions			0.181*	
			(0.096)	
After Paris × Top-Quartile Carbon Intensity				0.227**
				(0.111)
After Paris × High Reg	-0.169	0.083	0.340	0.125
	(0.320)	(0.160)	(0.248)	(0.127)
Pair-Time FE	Y	Y	Y	Y
Security FE	Y	Y	Y	Y
Adj. R^2	0.029	0.044	0.050	0.066
Obs	21,504	31,008	12,096	10,416

Table 9: Changes in institutional investor bond ownership around the Paris Agreement.

This table reports changes in institutional investor ownership of corporate bonds around the signing of the Paris Agreement. Quarterly observations cover the fourth quarter of 2014 through the fourth quarter of 2016. The periods after the fourth quarter of 2015 constitute the *Post Paris Agreement* periods. Treated bonds are defined in four ways: (1) the issuer company has a below-median Sustainalytics environmental score as of December 2014, (2) the issuer company belongs to a high emissions industry (one of the top 15 most carbon-emitting industries), (3) the issuer company has a top-quartile carbon emission level as of 2014 (per CDP disclosure), or (4) the issuer company has a top-quartile carbon intensity (carbon emissions scaled by revenues) as of 2014. Control bonds are one-to-one matched to treated bonds based on issue principal size, credit rating, bond time to maturity and the firm's equity oil beta. Standard errors are two-way clustered at the bond and quarter level and shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels.

Treated bond defined by:	Below-median firm environmental score			High emission industries		
Ownership (%) by	All institutions	Mutual funds	Insurance firms	All institutions	Mutual funds	Insurance firms
	(1)	(2)	(3)	(4)	(5)	(6)
Treated bonds * Post Paris Agreement	-0.426*	0.265***	-0.675**	-1.237***	-0.0333	-1.209***
	(0.221)	(0.0231)	(0.218)	(0.173)	(0.0512)	(0.215)
Treated bonds	4.759***	2.921**	1.802	0.297	0.780	-0.516
	(1.338)	(1.001)	(1.672)	(1.083)	(0.826)	(1.376)
Ln(Issue amount)	-3.633**	2.965**	-6.747***	-7.633***	1.148	-8.812***
	(1.210)	(0.983)	(1.475)	(1.007)	(0.687)	(1.241)
Years to maturity	-0.107	-0.258***	0.160	-0.00141	-0.214***	0.222**
	(0.0886)	(0.0510)	(0.103)	(0.0710)	(0.0288)	(0.0789)
Credit rating (numerical)	0.195	-1.458***	1.667***	-0.554***	-1.110***	0.563**
	(0.182)	(0.270)	(0.328)	(0.153)	(0.183)	(0.190)
Observations	7640	7640	7640	11082	11082	11082
Adjusted R^2	0.075	0.219	0.140	0.112	0.191	0.094
Time FE	Y	Y	Y	Y	Y	Y

Treated bond defined by:	Top-quartile firm carbon emission			Top-quartile firm carbon intensity		
Ownership (%) by	All institutions	Mutual funds	Insurance firms	All institutions	Mutual funds	Insurance firms
	(1)	(2)	(3)	(4)	(5)	(6)
Treated bonds * Post Paris Agreement	-0.278	0.741***	-1.022***	-0.308	0.883***	-1.230**
	(0.198)	(0.112)	(0.231)	(0.332)	(0.111)	(0.388)
Treated bonds	2.218	0.137	2.060	1.618	0.431	1.192
	(1.586)	(1.110)	(1.851)	(1.479)	(1.233)	(1.864)
Ln(Issue amount)	-8.282***	0.813	-9.118***	-6.491***	0.535	-7.045***
	(1.369)	(0.871)	(1.578)	(1.740)	(0.992)	(1.994)
Years to maturity	-0.100	-0.204***	0.114	-0.0929	-0.187***	0.103
	(0.0907)	(0.0379)	(0.0969)	(0.0947)	(0.0366)	(0.102)
Credit rating (numerical)	0.131	-0.444**	0.571**	0.235	-0.549**	0.780**
	(0.218)	(0.142)	(0.240)	(0.191)	(0.204)	(0.259)
Observations	4375	4375	4375	3742	3742	3742
Adjusted R^2	0.110	0.113	0.105	0.088	0.110	0.093
Time FE	Y	Y	Y	Y	Y	Y

Table 10: Credit ratings and events indicating potential U.S. withdrawal from the Paris Agreement

This table displays results from the following regression:

$$Rating_{it} = \beta_1 EnvProf_j \times Event_t + \gamma_i + \kappa_t + \epsilon_{it}.$$

$Env.Prof_j$ is alternatively one of the following: an indicator variable equal to one if the issuer has a below median environmental score (*Low Environmental Score*), an indicator variable equal to one if the issuer is in one of the top 15 carbon-emitting industries (*High Emission Industry*), an indicator variable equal to one if a firm is in the top quartile of carbon emissions in 2015 (*Top Quartile Emission*), or an indicator variable equal to one if a firm is in the top quartile of carbon intensity (defined as tons of emissions per $1,000 in revenue) in 2015 (*Top Quartile Carbon Intensity*). $AfterEvent_t$ is an indicator variable equal to one if the observation occurs within six months following the 2016 election (Panel A) or following the June 2017 announcement of the U.S. intention to withdraw from the Paris Agreement (Panel B). γ_i, κ_t are security and time fixed effects. The sample period runs from May 2016 until April 2017 for results on the 2016 presidential election and December 2016 until November 2017 for the results on the Paris Agreement withdrawal announcement. *, ** and *** indicate 10%, 5% and 1% significance respectively. Standard errors, which are clustered at the firm level, are shown in parentheses.

	(1)	(2)	(3)	(4)
Panel A – 2016 Election				
After Election × Low Environmental Score	0.046			
	(0.039)			
After Election × High Emissions Industry		0.014		
		(0.035)		
After Election × Top-Quartile Emissions			-0.033	
			(0.038)	
After Election × Top-Quartile Carbon Intensity				-0.056
				(0.045)
Adj. R^2	0.003	0.000	0.002	0.005
Obs	15,036	15,036	10,704	10,704
Panel B – June Withdrawal Announcement				
After Withdraw × Low Environmental Score	0.096**			
	(0.042)			
After Withdraw × High Emissions Industry		0.082**		
		(0.036)		
After Withdraw × Top-Quartile Emissions			0.084**	
			(0.038)	
After Withdraw × Top-Quartile Carbon Intensity				0.076*
				(0.042)
Adj. R^2	0.014	0.011	0.012	0.009
Obs	13,584	13,584	9,624	9,624
Time FE	Y	Y	Y	Y
Security FE	Y	Y	Y	Y

Table 11: Yield spreads and events indicating potential U.S. withdrawal from the Paris Agreement

This table displays results from the following regression:

$$Spread_{it} = \beta_1 EnvProf_j \times Event_t + \gamma_i + \kappa_{tp} + \epsilon_{it}.$$

$Env.Prof_j$ is alternatively one of the following: an indicator variable equal to one if the issuer has a below median environmental score (*Low Environmental Score*), an indicator variable equal to one if the issuer is in one of the top 15 carbon-emitting industries (*High Emission Industry*), an indicator variable equal to one if a firm is in the top quartile of carbon emissions in 2015 (*Top Quartile Emission*), or an indicator variable equal to one if a firm is in the top quartile of carbon intensity (defined as tons of emissions per $1,000 in revenue) in 2015 (*Top Quartile Carbon Intensity*). $AfterEvent_t$ is an indicator variable equal to one if the observation occurs within six months following the 2016 election (Panel A) or following the June 2017 announcement of the U.S. intention to withdraw from the Paris Agreement (Panel B). γ_i, κ_{tp} are security and matched-pair-by-time fixed effects. The sample is formed by using one-to-one nearest neighbor Mahalanobis matching of treated bond issues to control bond issues by oil beta, issue principal outstanding, time to maturity and credit rating as of year-end 2014. The sample periods include May 2016 through April 2017 for tests on the 2016 presidential election and December 2016 through November 2017 for the tests on the Paris Agreement withdrawal announcement. *, ** and *** indicate 10%, 5% and 1% significance respectively. Standard errors, which are clustered at the firm level, are shown in parentheses.

	(1)	(2)	(3)	(4)
Panel A – 2016 Election				
After Election × Low Environmental Score	-0.188*			
	(0.098)			
After Election × High Emissions Industry		-0.193**		
		(0.081)		
After Election × Top-Quartile Emissions			-0.098**	
			(0.047)	
After Election × Top-Quartile Carbon Intensity				-0.143***
				(0.045)
Adj. R^2	0.018	0.026	0.024	0.050
Obs	8,448	13,152	5,328	4,632
Panel B – June Withdrawal Announcement				
After Withdraw × Low Environmental Score	0.025			
	(0.085)			
After Withdraw × High Emissions Industry		0.015		
		(0.029)		
After Withdraw × Top-Quartile Emissions			-0.022	
			(0.033)	
After Withdraw × Top-Quartile Carbon Intensity				-0.024
				(0.029)
Adj. R^2	-0.000	-0.000	0.000	0.001
Obs	8,496	12,996	5,004	4,320
Time-by-Pair FE	Y	Y	Y	Y
Security FE	Y	Y	Y	Y