Do Firms Benefit from Carbon Risk Management: Evidence from the Credit Default Swaps Market

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Abstract

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Keywords: carbon risk management, credit risk, credit default swaps

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Abstract

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1 Introduction

Investors are increasingly concerned about the implications of climate change on the pricing of financial assets (Krueger et al., 2020). These concerns have led to investors putting significant pressure on carbon intensive firms to curb their carbon emissions (Azar et al., 2021) or divesting from carbon intensive firms altogether (Rohleder, Wilkens, and Zink, 2020). At the same time, the coalitions and initiatives such as Climate Action 100+, RE100, The Task Force on Climate-related Financial Disclosures (TCFD), United Nations Principal for Responsible Investments (UN-PRI) and Science Based Targets Initiative (SBTi) are encouraging firms' directors to invest in clean energy infrastructure and adopt management practices which can help them avoid the foreseeable and costly carbon transition risk. While the implications of carbon emission risk for corporate performance is generally well understood (Bolton and Kacperczyk, 2020a; Duan, Li, and Wen, 2020; Ilhan, Sautner, and Vilkov, 2020), there is little evidence on the benefits of proactive management of carbon emission and carbon transition risk. We fill this void in the literature by examining whether firms which are prudent in managing their carbon emissions are rewarded in the credit markets.

The U.S. credit markets provide a suitable setting to investigate the impact of firms' carbon risk management because of its active and a very large corporate debt market (USD 10.5 trillion as on December 2019), which can be critically impacted by the climate change risk. In addition, firms access debt capital significantly more than the equity market (Henderson, Jegadeesh, and Weisbach, 2006). This makes debt financing more exposed to the stakeholder activism of the socially responsible investors who can exert pressure on borrowing firms to act responsibly (Oikonomou, Brooks, and Pavelin, 2014). We specifically explore whether the credit default swap (CDS) markets favorably assess the firms which are proactive in managing their carbon risk. The advantage of using CDS based credit risk measure is that it reflects (a) forward-looking expectations of subjective or perceived credit risk, (b) better market calibration due to frequent trading (Ederington, Guan, and Yang, 2015; Ericsson, Jacobs, and Oviedo, 2009), and (c) improved standardization in terms of maturities, debt seniority levels, and restructuring events (Norden and Weber, 2009). Credit spread also represents the most informative and reliable class of financial indicators to predict future economic activity and associated idiosyncratic risk (Faust et al., 2013; Gilchrist, Sim, and Zakrajšek, 2014; Kalimipalli and Nayak, 2012).

According to Merton (1974), higher and less volatile cash flows translate into higher asset values of the firms, which results in lower probabilities of default and, thus, lower credit spreads. Carbon emission by a firm exposes it to the climate transition risk which comprises of the legal, reputational, market and technology risk which may eventually lead to solvency of the borrowing firm, making its carbon intensive assets financially stranded or non-investible, incur costly penalties (e.g., via a carbon tax, emission trading schemes or a cap-and-trade policies) or face the risk of getting excluded by the investors from their portfolios. Hence, the strongly proactive attempts by management to curb carbon emission should ideally be associated with lower carbon costs and higher expected firm value leading to positive implications on the credit risk. This conjecture of relation between the credit spread and carbon risk management also comes from the viewpoint of stakeholder theorists who suggest that the firms that are proactively environmentally and socially ethical and responsible are rewarded financially in the long term (Oikonomou et al., 2014). Our paper tests this theoretical prediction. More specifically, while analyzing the relation between the corporate carbon risk management performance and the CDS spread, we examine empirically whether firms with better carbon risk management have lower CDS spreads.

We examine the importance of carbon risk management for corporate CDS spread using a sample of 405 U.S. firms over the period August-2009 - May-2018. We use the Sustainalytics database on Environmental, Social and Governance (ESG) to assess the carbon risk management practices adopted by firms. We extract 13 firm-level indicators that focus specifically on carbon risk management out of more than 50 indictors in the wider environmental dimension of overall ESG dimensions. The carbon risk management indictors provide relative evaluation of firms' policies, programs and management system to manage their carbon risk. Some of the key practices assessed using these indicators include the transition to renewable energy, improving energy efficiency, setting of formal targets to reduce their carbon emissions, public disclosure of their emissions and practices. Each of these indicators are scored with proprietary industry adjusted weights which allows the comparison of carbon risk management practices of firms across different industries. Our key firm-level variable called as carbon risk management score (*CRMS*) is the sum of individual score of these 13 indicators.

We investigate the impact of *CRMS* primarily on the *5-year* benchmark CDS spreads of the firms which are traded more frequently as compared to the CDS of other maturities (Augustin and Izhakian, 2019; Das, Kalimipalli, and Nayak, 2014; Ericsson et al., 2009; Galil et al., 2014). We find a statistically significant and negative relation between the carbon risk management performance and the CDS spread of the firm. Our results are also economically significant. One-standard-deviation increase in a firm's *CRMS* variable decreases the *5-year* CDS spread by 73 basis points (bps) or by 32% of its standard deviation.

Furthermore, we use the Paris Agreement of December 2015 as a quasi-natural experiment to address the concerns of endogeneity and reverse causality that the firms which have better credit spread may also be the ones which are more prudent in managing their carbon risk. The Paris

Accord, the most ambitious climate agreement ever signed (Capasso, Gianfrate, and Spinelli, 2020), serves as a major exogenous shock to the significance that the financial market assigns to the firm's exposure to climate risk especially the climate transition risk or carbon risk. Hence, this exogeneous shock results in a significant change in the perception related to climate change risk materiality amongst the investor community. Using the difference-in-difference (DiD) approach, we find that the key DiD estimator is negative and statistically significant which indicates the lower market-perceived credit risk for the firms with higher carbon risk management performance. We also perform the DiD analysis on the firms with high and low CRMS values and find that the credit markets favorably assess firms that have high prudence in carbon risk management. Finally, we do a placebo test on Paris Agreement event date and redo our baseline DiD analysis with randomly picked false dates as Paris Agreement event date. The placebo test further confirms that the Paris Agreement of December 2015 is the key exogeneous event impacting the relation between carbon risk management performance and CDS spread.

Next, we examine how the effect of carbon risk management on CDS spread changes following the implementation of state-level policies pertaining to climate change. We use the adoption of the State Climate Adaptation Plan (SCAP) in 17 states over the period from 2009 to 2015 for this analysis. We find that the role of proactive carbon risk management practices becomes more critical in mitigating the credit spread if the firms are located in states which have a formalized State Climate Adaptation Plan (SCAP) in place to control the climate change risks. The staggered SCAP implementation event affects the relation between carbon risk management performance and CDS spreads similarly to the Paris Agreement. Both these events enhance the carbon transition risk for firms with poor carbon risk management as well as force the investors to be more sensitive towards the associated cost of the transition risk. This implies that the credit markets favorably assess the climate change implications on firms headquartered in those states that have adopted formal climate protection policies.

In the final set of analysis, we perform various tests to address the possibility of alternative explanations and to check the robustness of our findings. First, Ferrell, Liang, and Renneboog (2016) show that firms which are well-governed invest more in environmental and social policies. Furthermore, our *CRMS* is closely correlated (44%) with the social policies factor. Hence, it is possible that our results are driven by governance factors or are impacted by the close correlation of CRMS with factor(s) based on some firm's alternative social policies and practices. Therefore, we also control for the social and governance risk management indicators provided by the Sustainalytics to test the robustness of our results. We find that subsequent to the Paris Agreement, firms' carbon risk management measures favorably impact the CDS spreads even after controlling for governance and social risk management factors. This robustness test validates our earlier argument that the carbon risk management practices have become prominent post-Paris Climate Agreement, and have helped attenuate the credit risks for underlying firms.

Finally, we show that these results are robust when we use CDS spreads of alternative maturities (*5-, 10-,* and *30-year*), but not for 1-year maturity CDS spread. This is consistent with the perception amongst the investors that the climate change risk will impact the financial performance mainly in the longer term (Huynh and Xia, 2020). A one standard-deviation increase in CRMS reduces the quarterly spread of 10-year and 30-year maturity CDS spread by 24bps and 23bps, respectively.

Our findings contribute to the existing literature in several ways. First, we contribute to the burgeoning literature on climate finance that analyzes the relation between the climate change risk and financial markets.[1] Prior work in this emerging literature highlights the importance of carbon emissions, carbon risk factor, or hedging of climate change news in determining firm value, equity or bond returns (Bolton and Kacperczyk, 2020a; Duan et al., 2020; Engle et al., 2020; Görgen, Nerlinger, and Wilkens, 2017; Huynh and Xia, 2020; Ilhan et al., 2020; Monasterolo and de Angelis, 2020). While most of these empirical papers provide the evidence that climate risk in general and carbon emission risk in particular impacts the financial asset prices, our paper emphasizes the importance of prudent carbon emission management by a firm on its credit spread.

Next, we contribute to the broader strand of literature related to the socially responsible investment and environmental, social and governance (ESG) based investment. The impact of environmental risk on the financial performance of firms is also a closely related topic to our paper. There are several prior studies arguing that strong environmental performance is associated with improved financial performance and firm value (Bauer and Hann, 2010; Chava, 2014; King and Lenox, 2002; Klassen and McLaughlin, 1996; Konar and Cohen, 2001).

Our paper differs from the related broader ESG literature and focusses solely on the emerging climate finance literature. The total ESG score of firms does not reflect the carbon risk appropriately (that is, a high ESG risk firm may have less carbon risk and vice versa). This can be attributed to the inclusion of several variables unrelated to carbon risk in the ESG risk assessment. Hence, an overall ESG measurement may not be the right variable to proxy for climate transition risk. The growing importance of climate change in the realm of financial risk is also evident from the fact that the climate finance literature is evolving as a separate area of research, different from

[1] Climate finance is defined by the United Nations Framework Convention on Climate Change (UNFCCC) to be "local, national, or transnational financing— drawn from public, private, and alternative sources of financing—that seeks to support mitigation and adaptation actions that will address climate change."

the ESG field. Hence, we also focus only on those components of the ESG targeting the carbon transition risk.

Finally, we also contribute to the literature examining the cross-sectional determinants of the credit risk or the CDS spread specifically by showing that the carbon risk management performance adopted by firm is a novel parameter impacting the CDS spread.

The remaining paper is organized as follows. Section 2 provides the background to climate finance literature. Section 3 describes the data and key variables used in the study. Sections 4 and 5 respectively report the empirical results on the CRMS and CDS spread, and various robustness tests. Finally, Section 6 concludes.

2 Literature Review

Our study is related to rapidly growing climate finance literature that studies whether the financial markets can efficiently discount the risks emanating from the uncertain climate change scenarios (Giglio, Kelly, and Stroebel, 2020). Climate change risk can have financial implications due to the physical damages caused by the catastrophic climate events such as hurricanes, floods, and droughts (Alok, Kumar, and Wermers, 2020; Bernstein, Gustafson, and Lewis, 2019; Huynh, Nguyen, and Truong, 2020; Painter, 2020), as well as political, regulatory, market, legal and technology risks arising on account of the transition to a low-carbon economy (Azar et al., 2021; Bolton and Kacperczyk, 2020a; Görgen et al., 2017; Nguyen and Phan, 2020). The role of the financial market is critical in alleviating both the categories of climate - physical and transition - risk. Our study focusses on the climate transition risk implications on the credit markets.

The recent and vastly growing climate finance literature has considered the impact of carbon emission on the financial performance of the firms – both on equity and the fixed income markets. Krueger et al. (2020), based on their extensive survey of institutional investors, find that carbon emission risk has significant impact on the firms' financial performance and asset pricing. Andersson, Bolton, and Samama (2016) propose a long-term hedging strategy against carbon risk for passive investors. Bolton and Kacperczyk (2020a) investigate the impact of carbon emission on the cross-section of equity returns and show evidence of equity risk premium for exposure to carbon emission risk. Another study by Bolton and Kacperczyk (2020b) finds that firms across the globe are increasingly exposed to carbon-transition risk as the countries are introducing severe regulations to transition away from fossil fuels to clean energy. While Görgen et al. (2017) construct a carbon-risk factor and estimate a carbon beta for firms, Ilhan et al. (2020) argue that carbon emissions increase downside risk as reflected in out-of-the-money put option prices. Monasterolo and de Angelis (2020) explore whether investors demand higher risk premia for carbon-intensive assets following the Paris Climate agreement (COP21). Utilizing several out-of-sample performance tests, Engle et al. (2020) show that the mimicking portfolios they build can successfully hedge the innovations in climate change news. In addition, Matsumura, Prakash, and Vera-Munoz (2014) find that firms with higher carbon emission have lower market valuation, but voluntary disclosure mitigates the risk of discount in valuation. Azar et al. (2021) examine the role of the "Big 3" investors – Blackrock, Vanguard and State Street Global Advisors on corporate carbon emission and find that these investors have been able to influence their portfolio firms to curb their carbon emissions.

The above papers suggest that carbon emission risk has become a significant standalone criterion for many institutional investors to take investment decision thus reflecting the financial implication of the carbon emission risk. Furthermore, these papers are mostly focused on the equity market. There are emerging studies which examine the impact of general climate change risk and carbon risk specifically on the credit markets.

Ben-David, Kleimeier, and Viehs (2018) document that there is a significant and positive relation between the firms' carbon emission and loan spreads. Huynh and Xia (2020) use the climate change news index developed by Engle et al. (2020) to investigate whether the climate change news risk is priced in the corporate bond returns. They find that corporate bonds with a higher covariance with climate change news index earn lower future returns as implicated by the asset pricing theory. Seltzer, Starks, and Zhu (2020) find that firms with poor environmental profiles tend to have lower credit ratings and higher yield spreads, particularly when the firm is headquartered in a state with more stringent environmental regulations. Kölbel et al. (2020) use textual analytics of the firms' climate risk disclosure in their 10-K report filings to the U.S. Securities and Exchange Commission (SEC). The study finds that the disclosure about the climate transition risk increases the CDS spread, especially after the Paris Agreement of 2015 and the disclosure about physical climate risk reduces the CDS spread. Duan et al. (2020) find that bonds of firms with higher carbon emission intensity earn significantly lower returns which is contrary to the 'carbon risk premium' hypothesis as observed about stock returns by Bolton and Kacperczyk (2020a). Hence, there exists some ambiguity regarding the pricing of carbon risk by the credit markets vis-à-vis equity markets.

Our paper attempts to contribute to the climate finance literature by studying the risk mitigation impact of carbon risk management practices on firms' borrowing costs. Our study is also related to two other strands of literature focusing on the impact of (a) corporate social performance such as environmental and social practices and (b) environmental risk on the financial performance of firms. Oikonomou et al. (2014) argue that overall, corporate social performance is rewarded through lower - and corporate social transgressions are penalized through higher - corporate bond yield spreads, respectively. Barth, Hübel, and Scholz (2020) provide evidence that firms with higher overall environmental, social and governance (ESG) rating have lower credit risks as reflected in the individual firm's CDS spread. Menz (2010) finds that, *ceteris paribus*, the bond risk premium for socially responsible firms and less responsible firms are statistically similar. Several existing studies argue that strong environmental performance is associated with higher financial performance and firm value (Bauer and Hann, 2010; King and Lenox, 2002; Klassen and McLaughlin, 1996; Konar and Cohen, 2001). Bauer and Hann (2010) show that the U.S. public corporations with prudent environmental risk management are able to access corporate debt at lower rate in comparison to firms which are engaged in irresponsible environmental practices. Chava (2014) shows that firms with environmental concerns face higher implied cost of capital.

3 Data

3.1 Carbon Risk Management Score

We use the Sustainalytics database on Environmental, Social and Governance (ESG) to assess the carbon risk management practices adopted by firms. Sustainalytics is an independent research company which provides ESG assessment of firms across the globe and is among the top three companies which provide ESG research. Sustainalytics' s ESG score measures how well a company manages ESG issues that are most relevant to its operation and have been used in the extant literature (Engle et al., 2020; Görgen et al., 2017; Huynh and Xia, 2020).[2]

To assess an individual firm's carbon risk management impact on the credit spread, we use the management indicators which focus specifically on the firm's management of carbon risk

[2] Sustainalytics identifies ESG issues based on the analysis of the peer group in subindustry and its broader value chain. It assesses companies' business models and evaluates the business impact on account of inadequate management of these ESG issues. Sustainalytics collects the required data and information via firm's public disclosure, media and non-governmental organization reports. As a part of control and feedback process, Sustainalytics sends the draft ESG rating report to individual companies to gather further feedback on the accuracy of the information incorporated in the draft report. It reports ESG assessment of firms on monthly basis.

related to its own operations and exclude all other dimensions of environmental, social and governance risk management. These carbon risk management parameters are extracted from the environmental parameters within the overall ESG parameter provided by the Sustainalytics database. The environmental dimension comprises more than 50 indicators of environmental risk management practices out of which only 13 are relevant to carbon risk management which is the focus of this paper. Carbon risk management refers to various practices adopted by a firm to identify, assess, disclose, and manage its own operational energy use and carbon emissions which include Scope 1 and Scope 2 emissions and parts of Scope 3 emissions.

The carbon risk management score (*CRMS*) is evaluated through a firm's policies, programs and management system applicable to its own operations across its value chain. Some of the key practices assessed are transitioning to renewable energy, improving energy efficiency, placing greater emphasis on developing "greener" products and services in their own operations with disclosure on Scope 3 emissions. The assessment also includes the firm's track record of reducing its carbon intensity (carbon emission scaled by its total revenue) vis-à-vis its subindustry peers. Other assessment criteria include targets to reduce emissions in its products, design and development of sustainable products. Finally, the assessment also evaluates various environmental management policies and systems adopted within the firm as well as its transparency via public disclosures of its emissions and practices. These risk management practices are calibrated in absolute terms, which means that a high carbon risk management score assessment reflects a comparable degree of risk management across all the subindustries. As a result, a financial services company can be directly compared with an energy company or any other type of company. Appendix A1 provides details on these management practices which comprise our measure of carbon risk management of a firm.

[SEE Appendix A1]

Sustainalytics provides firm level score for each of the carbon risk management indicators. These scores are firm level scores but are adjusted for industry effects using proprietary weights. These weights are assigned to a subindustry depending on subindustry's exposure to individual carbon risk indicator. Our CRMS is sum of individual scores of selected indicators.

3.2 Credit Risk Measure

We investigate the impact of carbon risk management on the underlying credit spreads as captured by CDS spreads. The CDS instrument is a contingent claim that allows for a market-based proxy of the credit risk separately from other sources of uncertainty. Being a derivative instrument, it reflects forward-looking expectations of subjective and perceived risk. While credit ratings and/or credit spreads from corporate bond or loan markets can serve as credit risk proxies (Engle et al., 2020; Görgen et al., 2017; Huynh and Xia, 2020), we consider the CDS spreads because of the implicit advantages. First, CDS instruments are traded more frequently (Ederington et al., 2015; Ericsson et al., 2009; Finnerty, Miller, and Chen, 2013), and hence CDS spreads better reflect the credit risk changes than other measures (Blanco, Brennan, and Marsh, 2005; Norden and Weber, 2009). Second, CDS instruments are standardized in terms of maturities, debt seniority levels, and restructuring events enabling better comparison across firms (Norden and Weber, 2009). On the other hand, the yield spread based on corporate bond prices is affected by several individual bond characteristics such as embedded options, or specific guarantees (Zhang, Zhou, and Zhu, 2009) beyond firm characteristics. Hence, we examine the relation between the carbon risk management of the firm and the credit default swap (CDS) spreads.

We use IHS Markit database to obtain the data on single-name CDS spread across tenors of 1, 5, 10, and 30 years. The single-name CDS are the most common credit derivative contracts accounting for almost a third of the trading activity in the CDS market (Ericsson et al., 2009). We use single-name CDS spread data of the firms headquartered in the U.S. during the period between August 2009 and May 2018. The beginning of the period is determined by the availability of the CRMS data from the Sustainalytics. We use the average of daily CDS spread in a quarter as the frequency of the time-series of the sample is quarterly based on frequency of the firm level control variables.

3.3 Control Variables

In order to isolate the impact of the CRMS on the credit spread, we select several macro-economic and firm-specific control variables that have been found to impact the credit spread of a firm in the prior literature (Appendix A2). Following the structural credit risk models especially by Merton (1974), we include the theoretical determinants of the credit spread such as asset value, asset volatility and leverage of the firm. Asset value is the total assets of the firm reported quarterly. We use the natural logarithm of asset value and denote it as *SIZE* in our analysis. We use the standard deviation of daily excess returns, computed as the difference between a firm's stock return and the CRSP value-weighted return over the past 180 days as a measure of idiosyncratic volatility (*IVOL*) following Kaviani et al. (2020) and Campbell and Taksler (2003). The average book value of the leverage of the firm is total of the short and long-term debts divided by the total assets of the firm (Kaviani et al., 2020).

We also control for various firm-level fundamental determinants of credit spread following Bharath and Shumway (2008) and Bai and Wu (2016). These control variables include the return on assets (*ROA*) to capture the profitability of the firm, cash and cash equivalent scaled by total assets (*CASH*) to capture the liquidity of the firm, revenue or the turnover of the firm scaled by total assets (*TURNOVER*), capital expenditure scaled by the total assets (*CAPEX*) and property, plant and equipment scaled by the assets (*PPE*) to capture the tangibility of the firm. We obtain the data of all these variables from the Compustat-North America quarterly database.

Finally, we use excess market return (*MktRET*), one-year U.S. treasury rates (*Yield1Yr*) and the government treasury yield curve (*YieldCurve*) as the macroeconomic and market level control factors which we expect to be impacting the CDS spreads as per Zhang et al. (2009). We obtain the excess market return from the Kenneth French data library. The one-year U.S. treasury rate and the yield curve slope, which is the difference between 10-year and 2-year U.S. treasury rate, are obtained from the U.S. Federal Reserve website. Appendix A2 provides further the description, and data sources for all the variables.

3.4 Sample Construction

We follow prior studies (Bai and Wu, 2016; Ericsson et al., 2009; Griffin, Hong, and Kim, 2016) to clean the CDS data. Specifically, we (1) remove CDS which are denominated in currencies other than the U.S. dollar; (2) keep only the senior unsecured obligations as they are the most liquid trading CDS contracts; (3) keep only those CDS contracts which have modified restructuring (MR) documentation clause prior to April 2009 ("CDS Big Bang") and no restructuring clause afterwards; (4) exclude CDS contracts which have spread more than 10,000 bps to minimize any measurement errors as such contracts are mostly illiquid due to bilateral arrangements for up-front payments; (5) remove CDS entry which does not have any observation for CDS spread for any of the tenor. The final CDS data consists of 483 unique single-name or firm level daily CDS spreads distributed across *1-, 5-, 10- and 30-year* tenors.

In the next step, we merge the CDS spread data with the CRMS data from the Sustainalytics database and firm level control variables data from the Compustat database. We calculate the daily average of the CDS spread in each quarter of a particular year for each firm. Similarly, we also aggregate monthly averages of CRMS for each quarter of a year for each firm. Then, we merge the three datasets across common firms and corresponding quarters of a particular year using common identifiers such as GVKey and REDCODE.[3] We remove all observations where the value of the asset of any firm is less than zero or missing.

The final sample consists of 405 unique firms with a quarterly frequency starting from August-2009 to May-2018 leading to total of 9,407 firm-quarter observations. The sample size is similar to prior papers on the climate change and ESG risk implication on CDS spread (Barth et al., 2020; Kölbel et al., 2020). Finally, all continuous variables are winsorized at 1st and 99th percentile to mitigate the effect of data errors.

3.5 Descriptive Statistics

We present summary statistics on all the main variables used in the analysis in Table 1. The CDS spreads which are transformed in logarithmic scale in the regression analysis are reported in the real values in the table to facilitate interpretation. The median of 5-year CDS spread is 90.53 basis points (bps), which is consistent with prior papers such as Barth et al. (2020); Augustin and Izhakian (2019) and Kölbel et al. (2020). Firms in our sample have median size of USD16.78 billion (total assets). Our descriptive statistics of key variables in the sample, such as median leverage of 29.4% and median idiosyncratic volatility of 1.19%, are similar to those in recent papers (Barth et al., 2020; Kaviani et al., 2020; Kölbel et al., 2020) focusing on CDS spreads.

[INSERT Table 1 HERE]

Table 2 shows pooled quarterly correlations among all the key variables. Correlations between the CDS spread of all the maturities and carbon risk management score (*CRMS*) are negative and statistically significant. This finding provides some early indication of a negative relation between

[3] In cases, where the common identifiers are not available, we apply the fuzzy-logic method using Python programming to match the firm names and importing corresponding identifiers.

CRMS and CDS spreads. The correlation of the CDS spread with the other control variable is as similar to that established in previous literature and theory. For instance, the correlations of *5-year* CDS spread with idiosyncratic volatility and leverage are 60% and 32%, respectively in our sample which are very close to the ones observed in sample used by Ericsson et al. (2009) and Augustin and Izhakian (2019).

[INSERT Table 2 HERE]

4 Empirical Analysis

4.1 Carbon Risk Management and CDS Spread

We analyze how the carbon risk management practices of a firm impact the CDS spreads. We use the following general model specification to test the relation between the one quarter ahead CDS spreads and carbon risk management score:

$$\ln(CDS_{i,t+1}^{m}) = \alpha + \beta^{CRMS} CRMS_{i,t} + \beta^{X} X_{i,t} + \beta^{Y} Y_{t} + \epsilon_{i,t+1} , \quad (1)$$

where $\ln(CDS_{i,t+1}^{m})$ denotes next quarter's natural logarithm of the firm *i's* daily average of CDS *m*-year spread. The CRMS represents the carbon risk management score of the firm in the current quarter. $X_{i,t}$ and Y_t are the firm specific and macro-economic control vectors, respectively. We opt for quarterly frequency based on the frequency of the reporting of the financial statements. We control all the panel regression models for quarter-year fixed effect and industry fixed effects. The use of fixed effects ensures capturing of cross-sectional differences in the estimated coefficients as well as low-frequency changes in the coefficients over time (Patton and Verardo, 2012). Since macroeconomic control variables take the same value for all firms in the same quarter of the same year, these variables get absorbed when we use model specification with quarter-year fixed effect. Thus, we estimate specifications with and without time fixed effects in our analysis. We do not use firm level fixed effect due to the persistence of the key carbon risk management score variable.

The industry fixed effects are based on the industry classification provided by the Sustainalytics.[4] The industry fixed effect is used to absorb industry effects specifically as the Sustainalytics calculates the management scores using proprietary industry weights to create parity amongst sectors ensuring standardized comparisons. The carbon risk management practices could concentrate across firms and in time, hence, we cluster standard errors at the firm and the quarter-year level to account for the cross-sectional and serial correlation in the error terms (Cameron and Miller, 2015; Petersen, 2009).

The coefficient estimates for β^{CRMS} capture the impact of carbon risk management on the CDS spread of the firm. We expect that the carbon risk management practices should have a risk mitigation impact on the credit spread of the firm. This means, a more negative β^{CRMS} would provide an empirical evidence that the firms which are prudent in managing their firm level carbon risk are rewarded with a lower credit spread as reflected via the CDS spread.

4.2 Baseline regression results

We investigate the impact of carbon risk management on the *5-year* CDS spread as it is the most liquid and traded CDS instrument. Table 3 reports the main regression results examining the impact of carbon risk management on the *5-year* CDS spread in Model 1 (without time fixed effect) and Model 2 (with time fixed effects). We observe a significant and negative relation between the carbon risk management score and the *5-year* CDS spread in these two models. We include several firm-characteristics and macro-economic variables as additional control variables in Model 3 which is without time fixed effect and Model 4 which is with the time fixed effect. We observe a

[4] In unreported tests, we also estimate specifications with industry fixed effect based on the 2-digit Standard Industrial Classification (SIC2) which is slightly less coarse than the Sustainalytics based industry classification. In our sample, there are 41 industries based on Sustainalytics and 55 industries based on SIC2 classification. Our results are qualitatively similar when we use SIC2 industry classification.

significant and negative relation between *CRMS* and *5-year* CDS spreads, implying that carbon risk management practices have a risk mitigation impact on firms' credit risk.

Our results are also economically significant. We assess the economic significance[5] of these findings by estimating the expected change in the CDS spread due to a one-standard deviation change in the CRMS. We calculate that one standard deviation (27. 3%) increase in the CRMS (see Table 1) reduce the *5-year* CDS spread by ~73 bps in a quarter which is 32% of the standard deviation of *5-year* CDS spread. Column 4 shows estimation without the time fixed effect and similar results. Hence, the regression results support our hypothesis that the carbon risk management performance is associated with significantly lower CDS spreads.[6]

With regards to the control variables, we find that CDS spreads are higher for firms with higher leverage (*LEVERAGE*) and volatility (*IVOL*) and lower for larger firms (*SIZE)*. The results are consistent with the credit risk structural models and associated theories (Ericsson et al., 2009; Merton, 1974). The other firm level determinants of credit spreads such as *ROA*, and *PPE* also show the similar relation with the CDS spread as established in the related literature (Bai and Wu, 2016; Ericsson et al., 2009). The explanatory power of regressions for 5-year CDS spread levels is up to 65%, in terms of adjusted R^2. The prior papers on the pricing of CDS spread reports a similar explanatory power (Augustin and Izhakian, 2019; Ericsson et al., 2009).

A few of our control variable especially the macro-economic variable gets absorbed by the time fixed effect dummy variable due to the perfect collinearity. As time fixed effect is supposed to capture most of the influence of aggregate time-series trends (including trend in the macro-

[5] Economic significance is calculated by multiplying the coefficient and the standard deviation of the key independent variable. In our case, we first take the anti-log of the coefficient of the *CRMS* variable as the dependent variable i.e. CDS spread is in natural logarithm form. We then proceed with the multiplication of resultant coefficient and the standard deviation of the *CRMS*.

[6] We obtain consistent results when we exclude financial firms from our sample. We report the results including the financial firms as these firms are equally exposed and under pressure to act against carbon transition risk.

economic control variables), we use Model 4 as our main specification baseline model for subsequent analysis and do not report the specifications without the time fixed effect estimation. However, all our unreported estimations without the time-fixed effect are similar qualitatively.

[INSERT Table 3 HERE]

4.3 Endogeneity and Reverse Causality: The Impact of the Paris Agreement

Our baseline regression results show that firms with better carbon risk management have lower CDS spread. However, there may be an endogeneity concern as firms that perform better financially may also be the ones which are more prudent in managing their carbon risk. To alleviate this concern, we use the Paris Agreement[7] as a quasi-natural experiment to examine how the CDS spread change after a potentially exogeneous shock to the value of CRMS. Bolton and Kacperczyk (2020a); and Delis, de Greiff, and Ongena (2019) state that the Paris Agreement of 2015 is considered as a most significant event in climate finance history. It is primarily after the Paris Agreement that the discussion about the climate change became prominent amongst the investor community. The Paris accord was an inflexion point after which climate change became risk and return relevant. The December-2015 Paris-Agreement, the most ambitious climate agreement ever signed (Capasso et al., 2020), serves as a major exogenous shock to the firms' exposure to climate risk, especially the climate transition risk or carbon risk. Therefore, if the Paris Agreement strengthens the effect of carbon risk on firm's default risk, the costs of issuing new bonds or borrowing from banks or the probability of default or the credit spread of the carbon-intensive firms should be higher following this event. The same argument suggests that firms with better and proactive carbon risk management practices should be in a better position to mitigate the credit

[7] The Paris Climate Agreement is officially known as the COP21. It was the twenty-first session of the Conference of the Parties (COP) hosted by the United Nations which took place from November 30th to December 11th, in Paris, France. It is also referred as Paris Climate Accord or Paris Agreement on Climate Change.

spread risk of the firm after the Paris Agreement. As such, the influence of carbon risk management on CDS spread should be more pronounced after the Paris Agreement.

To test for this conjecture, we estimate the following regression model:

$$\ln(CDS_{i,t+1}^{m}) = \alpha + \beta^{CRMS} CRMS_{i,t} + \beta^{POST} POST_t + \beta^{CRMS*POST} CRMS_{i,t} * POST_t + \beta^{X} X_{i,t} + \beta^{Y} Y_t + \epsilon_{i,t+1}, \quad (2)$$

where '*POST'* is a binary dummy variable which takes value of '1' for all the quarters after the Paris Agreement i.e. after December 2015 and '0' for the quarters before the event. The key coefficient in Equation (2) is $\beta^{CRMS*POST}$. The coefficient captures the sensitivity of the CDS spread to an exogeneous shock across the firms with varying CRMS. It describes the change in the CDS spread due to the change in the CRMS around the Paris Agreement. If the estimated coefficient is negative and significant, it would indicate that a better carbon risk management score of a firm helps in mitigating its credit risk. Since, the dummy variable '*POST'* is highly correlated with the time fixed effect dummy variable, we do not include the *POST* variable in our regression model with time fixed-effect specifications.

We present the results in Model 1 of Table 4. We observe a negative and significant relation between *CRMS* and CDS spreads. The results suggest that CDS markets incorporate the carbon risk management exposure in credit spreads and confirms our baseline results that carbon risk management performance mitigates the credit spread of a firm.[8] More importantly, the coefficient estimates for the interaction term, $\beta^{CRMS*POST}$, is negative and significant (p-value < 0.05). This finding indicates that the effect of carbon risk management on CDS spread becomes stronger after the December-2015 Paris Agreement. We perform a similar analysis in Model 2 with the exception

[8] When we split our sample into the pre-Paris Agreement and post-Paris Agreement period, we find that the relevance of carbon risk management for credit risk has indeed became significant only after the Paris climate event.

that we exclude time fixed effects and include macroeconomic variables. Consistent with the results in Model 1, we still observe a negative and significant coefficient estimates for the interaction term *CRMS* x *POST*.

Next, we perform the difference-in-difference analysis to compare changes in the CDS spread of firms with prudent carbon risk management versus those with poor carbon risk management. To conduct our analysis, we sperate the firms into those with high (*TREAT*) versus low (*CONTROL*) CRMS and apply the following model specification:

$$\ln(CDS_{i}^{m}{}_{,t+1}) = \alpha + \beta^{TREAT} TREAT_{i,t} + \beta^{POST} POST_{t} + \beta^{TREAT*POST} TREAT_{i,t} * POST_{t} + \beta^{X} X_{i,t} + \beta^{Y} Y_{t} + \epsilon_{i,t+1} , \quad (3)$$

where $TREAT_{i,t}$ is an indicator variable which equals to one for the treatment firms and zero otherwise; *'POST'* is an indicator variable which equals to one for the year after the Paris Agreement of December 2015 and zero otherwise. Other variables are as defined in Equation (1). We divide the firms into quintiles based on their CRMS in the year 2014 (one year before the Paris Agreement) to mitigate the effect of the possible anticipation of the outcome of the Paris Agreement planned in December 2015.[9] We only keep the firms within the top and bottom quintile CRMS values obtained in the year 2014 and classify those in the top quintile as treatment firms (*TREAT*) and those in the bottom quintile as control firms (*CONTROL*). The results in Models (3) and (4) of Table 4 show that the 5-year CDS spread is lower for treatment firms compared to control firms. The coefficient estimates for the interaction term *TREAT* x *POST* is negative and significant in both models with or without time fixed effects. These results imply that the Paris Agreement led CDS markets to view firms with high carbon risk management performance more

[9] We find similar results in case of dividing the sample to into High and Low *CRMS* firms based on decile scores of *CRMS*.

positively. It also implies that investors started giving more attention to the climate risk mostly after the Paris Agreement created an environment of strong action by governments against the climate risk.

[INSERT Table 4 HERE]

Finally, to further allay the possibility of finding significant results due to random chance, we run a placebo or falsification test on the Paris Agreement event. We first randomly pick pseudo Paris Agreement dates instead of the actual date of December 2015 and re-do our analysis based on Equation (2). We randomly select the pseudo dates as March-2012, June-2012, September-2013 and December-2013 for the Paris Agreement event. We remove all the observations after March 2015 to eliminate the effect of the actual Paris Agreement event on the CDS-CRMS relation. The results in the

Table ***5*** show that the resulting DiD coefficient estimates (CRMS x POST_Mar12; CRMS x POST_Jun12; CRMS x POST_Sep2013; CRMS x POST_Dec2013) are insignificant. This finding supports our assertion that the Paris Agreement is the major catalyst event impacting the relation between the CDS spread and carbon risk management performance of the firm.

[INSERT Table 5 HERE]

4.4 Firms Headquartered in States with Climate Adaptation Plans

The states in the U.S. face a diverse set of climate change related challenges due to geographical dispersion. In any given year in the U.S., some states face drought-related issues while others grapple with catastrophes caused by hurricanes and floods. This heterogeneity in climate challenges and insufficient support at the federal level has forced several states in the U.S. to pass their own State Climate Adaptation Plans (SCAPs) that vary in the scope, goals, and strategies. However, all of them share a common goal of combating the climate change risk and making their respective state more resilient and better prepared to mitigate the disastrous effect of climate change. To date 17 states have finalized the climate adaptation policies (Appendix A3). Most of these 17 states adopted their first SCAP before 2015 but in staggered dates. The SCAPs include a mixture of legislative actions, executive orders by the governors, and engagements with all the stakeholders. The new resultant regulations and their post-implementation monitoring can have a wide-ranging direct and indirect effect on how firms do their business and leading to higher cost of compliance. The SCAP implementation can lead to higher carbon transition risk for firms operating in such states. Hence, SCAP implementation provides a similar setting as the Paris Agreement to assess the impact of higher regulatory regime leading to higher carbon transition risk on the relation between the carbon risk management practices and credit spread.

The credit markets are particularly sensitive to the carbon emission activities of the firms which are headquartered in states with formal plans against climate change activities because of firms' higher susceptibility to climate change regulatory violations and the associated costs. At the same time, through encouraging and facilitating prudent carbon risk management practices, climate adaptation plans, and initiatives of a state may increase the value of firms' assets (Chen, 2008; Konar and Cohen, 2001; Porter and Van der Linde, 1995a; Porter and Van der Linde, 1995b) thus reducing the credit risk of those firms. Ex-ante, we expect that the effect of carbon risk management on corporate credit spread becomes stronger in states which have adopted SCAP.

To test this hypothesis, we use a difference-in-difference framework to find the evidence of the prediction that the carbon risk management practices of firms become more important and significant in states which have adopted state climate adaptation plans. We extend the panel regression model in Equation (1) with an interaction variable that combine our measure of carbon risk management performance (*CRMS*) with an indicator variable, *POST_SCAP*. This indicator variable takes the value of one if a firm (*treatment firms*) is headquartered in a state with SCAP implemented and in the years post the implementation of SCAP; and takes the value of zero if a firm (*control firms*) is either in a state without any SCAP or in the state with SCAP but in the years before the SCAP got implemented in that state. Our key variable of interest, *POST_SCAP×CRMS*, captures the heterogeneous effect of the carbon risk management performance on the credit spread of the treatment firms vis-à-vis control firms.

The results in Table 6 show that the 5-year CDS spreads are particularly sensitive to the carbon risk management performance of the treatment firms. The coefficients on the interaction variable *POST_SCAP×CRMS* are negative and statistically significant, which implies that the carbon risk management performance improve the credit standing of the firms which are headquartered in states that are more concerned about climate change risk. The results also show that the staggered event of adoption of climate initiative plans by certain states in the U.S. enhance the importance of carbon risk management practices by mitigating the credit spread of the firms even before the exogeneous event of the Paris Agreement. While the results are relatively weaker than those observed in case of Paris Agreement, they indicate that credit markets have been sensitive to climate regulatory regimes where firms operate.

[INSERT Table 6 HERE]

5 Alternative Explanations and Robustness Checks

5.1 Impact of Governance and Social Factors on CDS Spread

The focus of this paper is to understand the impact of climate change related risk management or more precisely carbon risk management practices in mitigating the credit spread of the firm. However, it is plausible that our results are driven by firm-level corporate governance as firms that are well-governed invest more in environmental and social policies (Ferrell et al., 2016). As carbon risk management is one of the many ESG practices, it is pertinent to exclude the governance effect, if any, in order to show that carbon risk management practices are not driven due by implicit governance quality. In addition, we also control for the social factor as social issues are also correlated (44%) with carbon risk management practices.

We use the Social (S) and Governance (G) risk management score provided by Sustainalytics for the robustness test. Sustainalytics evaluates firms' social and governance risk management under several dimensions. For instance, some of the dimensions to evaluate social risk management include firms' policy on freedom of association, human capital development, data privacy and security, human rights, and product responsibility. The governance risk management include dimensions such as management quality, board structure, remuneration, business ethics, shareholder governance among many other dimensions. Similar to our main measure, carbon risk management score, the social and governance management scores are also adjusted for respective industries to allow for comparison across the firms in different industries.

The results in Table 7 highlight that the carbon risk management scores become insignificant after we control for the governance and social scores. However, post Paris Agreement event, the carbon risk management practices start to prominently mitigate the CDS spread as an independent parameter even after controlling for governance and social effect. These findings show that carbon risk management practices have a bearing on firms' credit risks mainly after the 2015 Paris agreement.[10] This robustness check further validates our argument that the relevance of carbon risk management has increased over recent years as a result of the growing pressure on companies about climate change and investors' awareness and concern.

[10] We repeat the difference-in-differences panel regression using the 2015 Paris Agreement as the exogeneous shock event with social and the governance factor as additional control variables. Our unreported results provide further evidence that carbon risk management helps to mitigate the credit risk even after controlling for governance and social factors.

[INSERT Table 7 HERE]

5.2 *Impact of Carbon Risk Management on CDS of Different Maturities*

We use the *5-year* CDS spread in our main analysis. There are single-name CDS of various maturities which trade in capital markets but with lower frequency as compared to the CDS of five-year maturity. We expect that all the CDS spreads across maturities especially the longer maturity CDS spread should decrease with a higher carbon risk management score. As a robustness check, we use CDS spreads of *1-year*, *10-year* and *30-year* single-name CDS of the firms in the sample as alternative dependent variables. We repeat our analysis of Table 3 to understand if the risk mitigation impact of carbon risk management performance is consistent across CDS of other maturities.[11] Consistent with our baseline results, we observe a negative relation between CRMS and CDS spreads of *1-year*, *10-year* and *30-year* single-name CDS in Table 8. In terms of economic significance, one standard deviation (~27%) increase in the CRMS (Table 1) reduces the quarterly spread of 10-year and 30-year maturity CDS spread by 24bps and 23bps, respectively. The influence of CRMS on CDS spreads also become stronger after the Paris Agreement. We therefore conclude that our findings are robust when we use alternative measures of CDS spread.

[INSERT Table 8 HERE]

The climate change risk is generally considered as a risk which will affect the firm's financial performance in the longer term (Huynh and Xia, 2020). Therefore, the management of this risk should have risk mitigation impact on longer maturity CDS. As a further robustness check, we repeat the analysis on the impact of the 2015 Paris Agreement on CDS spreads of other maturities. The results presented in Table 9 shows that the key variable of interest i.e. *CRMS* x *POST* is significant and negatively related to *10-year* and *30-year* CDS spreads but not to *1-year*

[11] The CDS-CRMS relationship for other maturities holds even after controlling for social and governance factors. However, the relationship is significant only after the Paris Agreement of Dec-2015.

CDS spreads. This suggests that the carbon risk management helps in mitigating the longer-term credit risk of a firm but does not show similar mitigation effect on short term credit risk which is consistent with our ex-ante conjecture.

[INSERT Table 9 HERE]

5.3 Impact of High versus Low Carbon Risk Management on CDS Spreads

We next evaluate how the variation in Carbon Risk Management across firms can impact the underlying credit risk. Does being a superior Carbon Risk Management firm compared to rest of the industry help lower its credit risk valuation? In order to evaluate this, we reconsider Table 3 regressions and implement them for different CDS maturities separately for high or low CRMS portfolio firms, based on above or below median values of carbon risk management practices. Firms lying above (below) median carbon risk management are interpreted to be those with superior (inferior) management practices compared to rest of the peer firms. Results are tabulated in Table 10. We observe that the CRMS and CDS relationship is primarily found in the weakly managed (i.e. below mean) firms based on models 5 to 8. We further drill down the effects based on the implementation of the 2015 Paris Agreement, a Quasi-exogenous event. We capture the results for low CRMS (i.e. below mean) sub–samples separately for pre–Paris Agreement (Models 9 to 12), and Post–Paris Agreement (Models 13–16). We find that the significant negative relationship between CRMS and CDS spreads among the weakly managed firms becomes more reinforced in the Post-Paris Agreement phase. The significant CRMS coefficients become more negative in the Post-Paris Accord period, ranging from 30% to 85% of the pre- Paris Accord values, and are particularly strong for the 5– and 10– year CDS contracts. Our findings collectively imply that firms with weaker Carbon Risk Management practices, and lying below the industry averages, are more severely penalized with higher credit risks in the Post-Paris Accord period.

[INSERT Table 10 HERE]

5.4 Evaluating Alternative Channels for the Relationship Between CRMS and CDS Spreads

We finally examine possible channels inducing the relationship between CRMS and CDS spreads. We tackle this question in multiple ways. *Firstly*, we examine how the variation of Carbon risk Management can predictively explain the key financial variables. We consider several financial variables such as profitability (ROA), growth options (Tobin's Q) liquidity (cash to assets) and leverage (long-term debt to assets). We consider panel regressions similar to Table 3, with the dependent variable being defined as one of the chosen financial variables. Table 11, Panel A, presents the results. Dependent variables in Models (1) to (3) represent one-quarter ahead financial variables, while those in Models (4) to (5) capture leading five-year averages of the dependent financial variables. We use 5-year ahead averages to proxy for the 5-year horizons underlying the most liquid 5-year CDS contracts. We only report the CRMS variable for brevity. We observe that more prudent (or better Carbon managed) firms have higher subsequent growth options and liquidity reserves more so over the longer five-year horizon. The effect of ROA is however not prominent.

Secondly, we consider CDS regressions and examine the differential effect of high versus low financial variables on the relationship between CRMS and CDS spreads. Panel B, Table 11, presents the effects of CRMS on one-quarter ahead 5-year CDS spreads interacted with top versus bottom quartile (Models (1) to (3)) or a high vs low leverage dummy, identified using a median value (Models (4) to (6)). We find that better carbon managed firms with higher than industry median leverage have lower subsequent credit risk valuations in the Post-Paris Agreement period. This implies that better managed carbon firms despite loading up their capital structure with higher debt may not necessarily be experiencing higher default risk; the fact that this effect is mainly observed in the Post Paris Accord implies that enforcement of carbon risk management can have enhanced firm value for more carbon prudent firms. We next evaluate the effect of profitability on the credit risk sensitivity to CRMS. Panel C presents the effects of CRMS on one-quarter ahead 5-year CDS spreads interacted with High ROA - a high vs low profitability dummy. We observe that better carbon managed firms that are more profitable within the industry have significantly lower subsequent credit risks. However, such effects are reversed in the Post-Paris Agreement period implying that higher profitability per se does not favorably influence how a better carbon managed firm is assessed in the credit market.[12]

[INSERT Table 11 HERE]

6 Conclusion

We document that a proactive carbon transition risk engagement of firms is associated with a lower CDS spread. Our results are robust when we control for established credit risk determinants and industry- and time-level unobservable heterogeneity. The importance of carbon risk management performance has gained importance in recent years especially after increase in the investors' awareness post the Paris Climate agreement of December 2015. We also find that carbon risk management practices play greater role in credit risk mitigation if the firm is headquartered in states which have implemented state climate adaptation plans. These findings suggest that the enhanced regulatory regime against the carbon emission force the investors to price the firms' carbon risk management judiciously while investing. Further analysis shows that the influence of carbon risk management performance on CDS spreads is not driven by the role of governance or social factors, especially in the period after the Paris Agreement. Weaker carbon risk managed firms, and those operating below the industry risk management levels, are more severely penalized

[12] We also consider Table 11 regressions with asset tangibility (Property, Plant and Equipment as ratio of assets), leverage and idiosyncratic volatility but find no effects. Results are not tabulated for brevity.

with higher credit risks in the Post-Paris Accord period. Similarly, better carbon managed firms with higher than industry leverage or profitability have lower subsequent credit risk valuations.

Overall, our findings extend prior research by demonstrating that the credit market does not only respond to the carbon emission risk, but also prices the carbon risk management of firms to avoid the anticipated cost of the carbon transition risk. Our findings have implications for corporates, investors and credit rating agencies. Specifically, the firms can be motivated to adopt and enhance their carbon risk management to help mitigate their credit risks. In addition, long-term investors may beneficially adjust their portfolios based on firms' adequacy of carbon risk management. Moreover, given that carbon risk management can potentially lower firms' credit risks, the credit rating agencies may consider the firms' carbon risk management performance in their credit risk rating assessment. Providing direct evidence on these implications is an important and interesting question for future research.

Appendix A1: Measurement of Carbon Risk Management Performance

This table lists 13 indicators which we use to measure the carbon risk management practices adopted by the firms. The information on these qualitative and quantitative indicators is collected from the *Environmental* dimension in the Sustainalytics ESG database. The *Environmental* dimension comprise more than 50 indicators of environmental risk management practices out of which only 13 are relevant to carbon risk which is the focus of this paper. Sustainalytics provides firm level score for each of these indicators. These scores are industry adjusted weighted scores where the weights are proprietary and assigned to a subindustry depending on subindustry's exposure to individual carbon risk indicator. Our Carbon Risk Management Score (*CRMS*) is sum of individual scores of selected indicators.

Carbon Risk Management Performance Indicators, *CRMS*

Component of Carbon Risk Management	**Key Criteria Used for Evaluation by Sustainalytics**
Formal Environmental Policy	This includes formal policy commitment to reduce emissions, energy efficiency practices, commitment to environmental protection and regular public disclosure of environmental issues.
Environmental Management System (EMS)	The formal management system should include programs to measure and manage emissions. The responsibilities and corresponding accountability of such programs should be delegated to management or board level members.
External Certification of EMS	There should be an audit of firm's EMS by an independent third part agencies which can certify whether the environmental management system adopted by the firm is appropriate.
Participation in Carbon Disclosure Project (CDP)	This relates to transparency of a firm's on its progress on carbon emission reduction programs by responding to CDP's questionnaire on carbon emission
Scope of Corporate Reporting on GHG Emissions	This criterion evaluates whether the company reports on Scope 1 & 2 and discloses relevant information on Scope 3 GHG emissions
Programs and Targets to Reduce Greenhouse Gas (GHG) Emissions from own operations	The evaluation is based on policy commitment to reduce GHG emissions, initiatives to reduce GHG emissions, GHG reduction targets with deadlines, GHG emissions monitoring and measurement with regular GHG audits or verification.
Programs and Targets to Increase Renewable Energy Use	It assesses the commitment of the firm to transition its energy usage to renewable energy in its operations. There must be formal programs within the firm to ensure such a transition.
Carbon Intensity	It is the relative performance of the firm with its peers on carbon intensity
Carbon Intensity Trend	It evaluates carbon intensity trend of the firm in past three years.
% Primary Energy Use from Renewables	It measures the percentage of total energy consumption from renewable energy.
Programs and Targets to Reduce GHG Emissions from Outsourced Logistics Services	This criterion evaluates the Scope 3 emission reduction programs and target of a firm by assessing its broader value chain.
Revenue from Clean Technology or Climate Friendly Products	This criterion evaluates the material impact of firm's transition to clean energy technologies and usage of climate friendly products by calculating the revenue generated from such a transition.
Carbon Intensity of Energy Mix	This is an additional criterion which assess the carbon intensity of the firm across its value chain and wider energy usage mix.

Appendix A2: Variable Description

This table describes the variables that we use in our analysis. Column 1 reports the variable names. Column 2 provides the description of the variables and column 3 provides the data sources.

Variable	Description	Source
	Panel A: Carbon Risk Management Measure	
CRMS (Carbon Risk Management Score)	A sum of weighted score of management indicators focusing specifically on firm's management of carbon risk related to its own operations. These carbon risk management parameters are extracted from the long list of parameters of environmental parameter within the overall ESG parameter provided by the Sustainalytics database.	Sustainalytics
	Panel B: CDS Spread	
CDSX	Spread on CDS with maturity X years	IHS Markit
	Panel C: Firm-level variables	
LEVERAGE	Total debt (DLTTQ + DLCQ) divided by total assets (ATQ).	Compustat
IVOL (Idiosyncratic volatility)	Standard deviation of daily excess returns, computed as the difference between a firm's stock return and the CRSP value-weighted return over the past 180 days.	CRSP
SIZE	Total asset value (ATQ)	Compustat
ROA (Return on Assets)	Income after taxes scaled by average total assets over the quarter	Compustat
CASH	Cash (CHQ) & Short-Term Investments (CHEQ) scaled by Total Assets (ATQ)	Compustat
TURNOVER	Total revenues (REVTQ) scaled by total assets (ATQ)	Compustat
PPE (Property, Plant and Equipment)	Gross Property, Plant and Equipment less accumulated reserves for depreciation, depletion and amortization (PPEGTQ) scaled by Total Assets (ATQ)	Compustat
CAPEX	Capital expenditures representing the funds used to acquire fixed assets (CAPXY) scaled by Total Assets (ATQ)	Compustat
	Panel D: Macroeconomic and Market Variables	
Yield1Yr	1-year U.S. Treasury rate	Federal Reserve Board
YieldCurve	The difference in the yields of ten- and two-year Treasury bonds	Federal Reserve Board
MktRET	Monthly excess return of the market factor	K. French data library
	Panel E: Other Variables	
Governance Score	Sum of the weighted scores of the governance risk management performance of a firm.	Sustainalytics
Social Score	Sum of the weighted scores of the social risk management performance of a firm.	Sustainalytics

Appendix A3: State Climate Adoption Plan by the various states in the U.S.

The information on state climate adaptation plans is compiled by the Georgetown Climate Center at https://www.georgetownclimate.org/adaptation/plans.html. The dates mentioned in the table is the first time when an individual state adopted the SCAP till year 2020. These states keep updating these policies.

State	Date Finalized
Alaska	January-2010
California	September-2009
Colorado	November-2011
Connecticut	July-2013
Delaware	March-2015
Florida	October-2008
Maine	February-2010
Maryland	July-2008
Massachusetts	September-2011
New Hampshire	March-2009
New York	November-2010
North Carolina	June-2020
Oregon	December-2010
Pennsylvania	January-2011
Rhode Island	July-2018
Virginia	December-2008
Washington	April-2012

Table 1: Descriptive Statistics

This table provides the summary statistics of the test variables for a sample of 405 single–CDS of firms in the U.S. for a period from August–2009 to May–2018. Note that the log–transformed CDS spread, and *SIZE* are reported in real values and expressed in basis points (bps) and billion dollars, respectively. *CDS1*, *CDS5*, *CDS10* and *CDS30* are the daily averages of CDS spread across 1–, 5–, 10– and 30–year tenor in each quarter. *CRMS* denotes the sum of the scores of each of the carbon risk management practices adopted by a firm. *LEVERAGE* is the ratio of total liabilities to total assets. *IVOL* is the idiosyncratic volatility of a firm. It is the standard deviation of daily excess returns, computed as the difference between a firm's stock return and the CRSP value–weighted return over the past 180 days. *SIZE* is the firm's size measure by the total assets (log–transformed). *ROA* is the return on assets, *PPE* is the property plant and equipment scaled by the total assets of the firm and *CAPEX* is the capital expenditure scaled by total assets. *CASH* and *TURNOVER* are the cash and cash equivalent and revenue of the firm both scaled by the total assets of the firm, respectively. *Yield1Yr* is the 1–year U.S. Treasury rate and *YieldCurve* is the difference between 10–year and 2–year U.S. Treasury rate. *MktRET* is the quarterly excess return of the market. The details of these variables are provided in Appendix A2. All continuous variables are winsorized at the 1st and 99th percentile.

	Obs.	Mean	Median	min	p5	p95	max	Std. Dev.
CDS Spread across Tenors								
CDS1	9,407	59.38	22.93	1.94	5.114	196.84	7,842.56	212.96
CDS5	9,407	148.78	90.53	11.80	28.085	447.10	6,565.96	223.82
CDS10	9,407	184.67	127.92	28.44	52.396	505.10	6,032.69	211.40
CDS30	9,407	195.03	141.73	31.55	61.630	513.37	5,410.63	197.16
Carbon Risk Management Score								
CRMS	9,407	3.71	3.40	0.00	0.000	8.76	16.00	2.73
Firm Level Variables								
LEVERAGE	8,716	0.312	0.29	0.02	0.067	0.61	0.87	0.17
IVOL (%)	9,407	0.014	0.01	0.01	0.007	0.03	0.14	0.01
SIZE (in billion $)	9,407	55.86	16.78	2.26	3.463	235.50	841.37	130.82
ROA	9,403	0.01	0.01	–0.06	–0.010	0.04	0.05	0.02
CASH	9,407	0.09	0.06	0.00	0.005	0.28	0.49	0.09
TURNOVER	9,359	0.19	0.15	0.01	0.025	0.54	0.92	0.17
PPE	8,625	0.31	0.22	0.00	0.009	0.81	0.88	0.26
CAPEX	9,397	0.03	0.01	0.00	0.000	0.09	0.17	0.03
Macroeconomic Variables								
Yield1Yr (%)	9,407	0.45	0.26	0.10	0.100	1.70	2.27	0.47
YieldCurve (%)	9,407	1.72	1.70	0.47	0.560	2.72	2.77	0.65
MktRET (%)	9,407	1.13	0.78	–7.59	–5.570	6.96	9.54	3.47

Table 2: Correlation Matrix

This table shows pooled Pearson correlations for major variables used in our empirical analyses. All variables are explained in detail in Appendix A1. The sample includes 405 firms located in the U.S. from August 2009 to May 2018. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively.

	CDS1	CDS5	CDS10	CDS30	CRMS	YieldCurve	Yield1Yr	MktRET	LEVERAGE	IVOL
CDS1	1.00									
CDS5	0.89*	1.00								
CDS10	0.80*	0.98*	1.00							
CDS30	0.77*	0.96*	0.99*	1.00						
CRMS	–0.22*	–0.25*	–0.25*	–0.24*	1.00					
YieldCurve	0.23*	0.11*	0.04*	0.01	0.09*	1.00				
Yield1Yr	–0.18*	–0.13*	–0.09*	–0.07*	–0.06*	–0.67*	1.00			
MktRET	0.02	0.00	–0.03	–0.04*	0.02	0.14*	–0.05*	1.00		
LEVERAGE	0.19*	0.32*	0.36*	0.37*	–0.09*	–0.10*	0.08*	–0.02	1.00	
IVOL	0.53*	0.60*	0.60*	0.59*	–0.07*	0.00	0.00	0.04*	0.20*	1.00

Table 3: The Relation between CRMS and 5–Year CDS Spread

This table presents the results from the panel regression of the natural logarithm of daily average of 5–year senior unsecured CDS spread level (*CDS5*) in a quarter on the carbon risk management score, structural variables such as leverage (*LEVERAGE*), idiosyncratic volatility (*IVOL*), Excess Market Return (*MktRET*), and other control variables. All variables are explained in detail in Appendix A2. The sample includes 405 firms located in the U.S. from August 2009 to May 2018. The model includes the industry fixed effect (based on Sustainalytics Industry Classification). The standard errors are clustered by firm and by time. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively. The values in the parentheses are the standard errors of the estimated coefficients.

	CDS5 (1)	CDS5 (2)	CDS5 (3)	CDS5 (4)
CRMS	–0.059***	–0.067***	–0.026**	–0.027***
	(0.020)	(0.019)	(0.010)	(0.010)
LEVERAGE			1.305***	1.352***
			(0.170)	(0.166)
IVOL			47.620***	48.117***
			(5.122)	(4.726)
SIZE			–0.178***	–0.165***
			(0.025)	(0.025)
ROA			–7.996***	–8.485***
			(1.231)	(1.218)
CASH			–0.240	–0.308
			(0.221)	(0.223)
TURNOVER			0.127	0.091
			(0.165)	(0.163)
PPE			–0.558***	–0.588***
			(0.195)	(0.196)
CAPEX			0.380	0.746
			(0.717)	(0.672)
Yield1Yr			–15.259**	
			(6.843)	
YieldCurve			10.739*	
			(5.788)	
MktRET			–0.560	
			(0.882)	
Industry FE	Yes	Yes	Yes	Yes
Quarter–Year FE	No	Yes	No	Yes
Observations	9,407	9,407	8,350	8,350
Adj.R^2	0.181	0.261	0.614	0.658

Table 4: The Impact of the Paris Agreement on the CRMS–CDS Spread Relation

This table shows the results of the difference–in–difference model using Paris Agreement of December-2015 as the exogeneous shock event. The dependent variable is the natural logarithm of the daily average of *5–year* CDS spread level (*CDS5*) in a quarter. To measure the impact of the Paris Agreement, we use a dummy variable '*POST*' which takes value of '1' for the period after December 2015 and '0' otherwise. The key variable in the model (Columns 1 and 2) is '*CRMS* x *POST*' which is an interaction term of '*CRMS*' and '*Post*'. The key variable in the model (Columns 3 and 4) is '*TREAT* x *POST*' which is an interaction term of '*TREAT*' and '*POST*'. '*TREAT'* takes the value of '1' if a firm's *CRMS* is in the top quintile in the year 2014; and '0' otherwise. All variables are explained in detail in Appendix A2. The model includes the industry fixed effect (Sustainalytics Industry Classification). The standard errors are clustered by firm and by time. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively. The values in the parentheses are the standard errors of the estimated coefficients.

	CDS5 (1)	CDS5 (2)	CDS5 (3)	CDS5 (4)
CRMS x POST	–0.023**	–0.020**		
	(0.010)	(0.009)		
TREAT x POST			–0.228**	–0.219**
			(0.090)	(0.088)
CRMS	–0.022**	–0.022**		
	(0.010)	(0.011)		
TREAT			–0.251*	–0.246*
			(0.131)	(0.128)
POST		–0.109		–0.091
		(0.088)		(0.104)
LEVERAGE	1.364***	1.325***	1.805***	1.743***
	(0.167)	(0.171)	(0.214)	(0.212)
IVOL	47.952***	47.970***	40.274***	42.373***
	(4.730)	(5.104)	(4.672)	(5.161)
SIZE	–0.164***	–0.175***	–0.194***	–0.197***
	(0.025)	(0.025)	(0.037)	(0.038)
ROA	–8.496***	–7.972***	–5.939***	–4.877***
	(1.195)	(1.216)	(1.805)	(1.731)
CASH	–0.285	–0.223	–0.372	–0.334
	(0.225)	(0.222)	(0.307)	(0.301)
TURNOVER	0.092	0.125	0.488	0.478
	(0.163)	(0.165)	(0.317)	(0.318)
PPE	–0.589***	–0.558***	0.020	–0.045
	(0.196)	(0.194)	(0.317)	(0.313)
CAPEX	0.768	0.373	–0.409	–0.568
	(0.670)	(0.708)	(1.180)	(1.153)
Yield1Yr		–5.874		–5.323
		(5.068)		(5.829)
YieldCurve		5.579		4.499
		(6.907)		(7.890)
MktRET		–0.459		–0.393
		(0.858)		(0.976)
Industry FE	Yes	Yes	Yes	Yes
Quarter–Year FE	Yes	No	Yes	No
Observations	8,350	8,350	2,544	2,547
Adj.R^2	0.659	0.617	0.751	0.714

Table 5: Placebo Test for Paris Agreement

This table presents the results of the placebo test to ascertain the impact of Paris Agreement of December-2015. The dependent variable *CDS5* is the natural logarithm of the daily average of 5–year CDS spread (*CDS5*) in a quarter. We use dummy variable (*POST_FalseDate*) to present Paris Agreement on random false dates such as March–2012, June–2012, September–2013 and December–2013. The '*POST_FalseDate*' takes value of '1' for the period after the false dates and '0' otherwise. The key variable in the model is '*CRMS* x *POST_FalseDate*' which is an interaction term of '*CRMS*' and '*POST_FalseDate*'. All variables are explained in detail in Appendix A2. The model includes the industry fixed effect (Sustainalytics Industry Classification) and quarter–year fixed effects. The standard errors are clustered by firm and by time. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively. The values in the parentheses are the standard errors of the estimated coefficients.

	CDS5 (1)	CDS5 (2)	CDS5 (3)	CDS5 (4)
CRMS	–0.010	–0.009	–0.012	–0.013
	(0.011)	(0.011)	(0.01)	(0.010)
POST_Mar12				
CRMSxPOST_Mar12	–0.012			
	(0.009)			
POST_Jun12				
CRMSxPOST_Jun12		–0.015		
		(0.009)		
POST_Sep13				
CRMSxPOST_Sep2013			–0.016	
			(0.01)	
POST_Dec13				
CRMSxPOST_Dec2013				–0.016
				(0.010)
Control Variables	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Quarter–Year FE	Yes	Yes	Yes	Yes
Observations	5,560	5,560	5,560	5,560
Adj. R^2	0.666	0.684	0.684	0.684

Table 6: The Impact of the State Climate Adaptation Plan on the CRMS–CDS Spread Relation

This table reports the impact of state climate adaptation plans (SCAP) on the relation between firm's carbon risk management performance and CDS spreads during the years after the SCAP got implemented. *POSTSCAP* is a combined indicator variable for the treatment firms headquartered in states that finalize the SCAP and during the post SCAP implementation years. The firms in the control group are either the ones which are headquartered in states without SCAP or the ones which are headquartered in states with SCAP but before the implementation of SCAP. *POSTSCAP* equals '1' if a firm operates in a state with SCAP and during the years after the implementation of SCAP; and '0' otherwise. The dependent variable is the natural logarithm of the daily average of *5–year* CDS spread level (*CDS5*) in a quarter. We regress the *CDS5* on carbon risk management score (*CRMS*) and respective interaction term (*POSTSCAP*x*CRMS*) while controlling for specific control variables. All variables are explained in detail in Appendix A2. All the models include the industry fixed effect (Sustainalytics Industry Classification), time fixed effect and state fixed effects. The standard errors are clustered by firm and by time. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively. The values in the parentheses are the standard errors of the estimated coefficients.

	CDS5 (1)	CDS5 (2)
CRMS	–0.041**	–0.012
	(0.020)	(0.011)
POSTSCAPxCRMS	–0.025*	–0.025**
	(0.014)	(0.011)
POSTSCAP	0.140*	0.156***
	(0.074)	(0.058)
Control Variables	No	Yes
Industry FE	Yes	Yes
Quarter–Year FE	Yes	Yes
State FE	Yes	Yes
Observations	9,406	8,349
Adj.R^2	0.313	0.668

Table 7: The Relation between CRMS and 5–Year CDS Spread, Controlling for Governance and Social Scores

This table shows the effect of carbon risk management practices of the firm on credit risk over different time period after controlling for the Governance and Social factors. The results are shown for the panel regressions done on full–sample (Panel A), sub–sample pre–Paris Agreement (Panel B) and Paris Agreement onwards (Panel C). The dependent variable is the natural logarithm of the daily average of 5–year CDS spread in a quarter. All variables are explained in detail in Appendix A2. All the models include the industry fixed effect (Sustainalytics Industry Classification). The results in Columns 1,3 and 5 are with quarter–year fixed effects and the ones in columns 2,4 and 6 are presented without Quarter–Year fixed effect. The standard errors are clustered by firm and by time. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively. The values in the parentheses are the standard errors of the estimated coefficients. The values in the parentheses are the standard errors of the estimated coefficients.

	A. Full Sample	B. Pre–Paris Agreement	C. Post–Paris Agreement
	CDS5	CDS5	CDS5
	(1)	(2)	(3)
CRMS	–0.015	–0.007	–0.040***
	(0.010)	(0.010)	(0.014)
Governance Score	–0.006**	–0.004	–0.009*
	(0.003)	(0.003)	(0.004)
Social Score	–0.005**	–0.005**	–0.005
	(0.002)	(0.002)	(0.003)
LEVERAGE	1.329***	1.474***	0.991***
	(0.165)	(0.170)	(0.247)
IVOL	47.222***	51.573***	40.434***
	(4.685)	(4.683)	(7.544)
SIZE	–0.165***	–0.158***	–0.181***
	(0.025)	(0.025)	(0.033)
ROA	–8.485***	–9.943***	–5.346***
	(1.202)	(1.155)	(1.571)
CASH	–0.302	–0.215	–0.360
	(0.219)	(0.226)	(0.270)
TURNOVER	0.091	0.202	–0.373*
	(0.161)	(0.158)	(0.198)
PPE	–0.583***	–0.581***	–0.589**
	(0.195)	(0.180)	(0.275)
CAPEX	0.639	–0.020	2.788***
	(0.684)	(0.697)	(0.941)
Industry FE	Yes	Yes	Yes
Quarter–Year FE	Yes	Yes	Yes
Observations	8,348	5,826	2,522
Adj. R^2	0.662	0.687	0.639

Table 8: Robustness Checks using CDS Spreads of Different Maturities

This table shows the effect of carbon risk management practices of the firm on credit risk over different time period after controlling for the Governance and Social factors. The results are shown for the panel regressions done on full sample (Column 1–3), sub–sample pre–Paris Agreement (Column 4–6) and sub–sample Post–Paris Agreement (Column 7–9). The dependent variable is the natural logarithm of the daily average of CDS spreads of 1–year, 10–year and 30–year maturities in a quarter. All variables are explained in detail in Appendix A2. All the models include the industry fixed effect (Sustainalytics Industry Classification) and time fixed effects. The standard errors are clustered by firm and by time. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively. The values in the parentheses are the standard errors of the estimated coefficients.

	A. Full Sample			B. Pre–Paris Agreement			C. Post–Paris Agreement		
	CDS1	CDS10	CDS30	CDS1	CDS10	CDS30	CDS1	CDS10	CDS30
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CRMS	–0.045***	–0.019**	–0.017**	–0.036**	–0.012	–0.011	–0.070***	–0.043***	–0.039***
	(0.015)	(0.008)	(0.008)	(0.015)	(0.009)	(0.008)	(0.020)	(0.011)	(0.010)
LEVERAGE	1.256***	1.230***	1.167***	1.351***	1.334***	1.247***	0.942***	0.985***	0.960***
	(0.218)	(0.138)	(0.128)	(0.232)	(0.142)	(0.134)	(0.312)	(0.202)	(0.183)
IVOL	54.797***	40.966***	38.224***	58.551***	45.314***	42.599***	47.821***	34.839***	32.479***
	(5.362)	(3.959)	(3.727)	(6.090)	(3.897)	(3.760)	(7.838)	(6.148)	(5.609)
SIZE	–0.214***	–0.119***	–0.103***	–0.218***	–0.114***	–0.103***	–0.214***	–0.128***	–0.100***
	(0.035)	(0.020)	(0.019)	(0.036)	(0.021)	(0.020)	(0.044)	(0.027)	(0.025)
ROA	–9.601***	–7.040***	–6.548***	–11.916***	–8.364***	–7.909***	–5.379**	–4.394***	–3.927***
	(1.650)	(0.991)	(0.918)	(1.602)	(0.962)	(0.905)	(2.200)	(1.326)	(1.182)
CASH	0.118	–0.339*	–0.308*	0.221	–0.241	–0.210	0.065	–0.422*	–0.405**
	(0.333)	(0.188)	(0.174)	(0.343)	(0.199)	(0.188)	(0.415)	(0.221)	(0.198)
TURNOVER	–0.287	0.177	0.201	–0.165	0.253*	0.261*	–0.786***	–0.115	–0.046
	(0.211)	(0.138)	(0.129)	(0.206)	(0.138)	(0.132)	(0.283)	(0.162)	(0.147)
PPE	–0.651***	–0.475***	–0.442***	–0.789***	–0.429***	–0.387**	–0.249	–0.550**	–0.513**
	(0.223)	(0.168)	(0.160)	(0.212)	(0.156)	(0.151)	(0.317)	(0.233)	(0.214)
CAPEX	0.284	0.587	0.491	–0.235	–0.064	–0.174	2.147*	2.409***	2.290***
	(0.749)	(0.569)	(0.535)	(0.802)	(0.581)	(0.549)	(1.096)	(0.781)	(0.719)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter–Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,350	8,350	8,350	5,826	5,826	5,826	2,524	2,524	2,524
Adj. R^2	0.630	0.653	0.639	0.663	0.679	0.667	0.523	0.640	0.627

Table 9: The Impact of the Paris Agreement on the CRMS–CDS Spread (1-, 10-, 30–year maturity) Relation

This table shows the results of the difference–in–difference model using Paris Agreement of December-2015 as the exogeneous shock event. The dependent variable is the natural logarithm of the daily average of *1–year*, *10–year* and *30–year* CDS spread in a quarter. To measure the impact of the Paris Agreement, we use a dummy variable '*POST*' which takes value of '1' for the period after December 2015 and '0' otherwise. The key variable in the model is '*CRMS* x *Post*' which is an interaction term of '*CRMS'* and '*POST*'. All variables are explained in detail in Appendix A2. The sample includes 405 firms located in the U.S. from August 2009 to May 2018. All the models include the industry fixed effect (based on Sustainalytics Industry Classification). The standard errors are clustered by firm and by time. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively. The values in the parentheses are the standard errors of the estimated coefficients.

	CDS1	CDS10	CDS30
	(1)	(2)	(3)
CRMS	–0.042***	–0.015*	–0.014
	(0.015)	(0.009)	(0.008)
POST			
CRMSxPOST	–0.011	–0.019**	–0.016**
	(0.012)	(0.008)	(0.007)
LEVERAGE	1.262***	1.240***	1.175***
	(0.220)	(0.139)	(0.128)
IVOL	54.718***	40.833***	38.112***
	(5.369)	(3.963)	(3.729)
SIZE	–0.213***	–0.118***	–0.102***
	(0.035)	(0.020)	(0.019)
ROA	–9.606***	–7.048***	–6.555***
	(1.639)	(0.972)	(0.903)
CASH	0.130	–0.320*	–0.293*
	(0.334)	(0.189)	(0.175)
TURNOVER	–0.286	0.179	0.202
	(0.211)	(0.138)	(0.129)
PPE	–0.651***	–0.476***	–0.443***
	(0.223)	(0.168)	(0.160)
CAPEX	0.295	0.605	0.506
	(0.749)	(0.568)	(0.534)
Industry FE	Yes	Yes	Yes
Quarter–Year FE	Yes	Yes	Yes
Observations	8,350	8,350	8,350
Adj.R^2	0.630	0.654	0.640

Table 10: Robustness Checks Using High versus Low CRMS Firms

This table implements Table 3 regressions for high or low portfolios based on high or low median of carbon risk management practices of the firm. The results are shown for the panel regressions done separately on high CRMS sample (Models 1–4), low CRMS sample (Models 5–8), and further, low CRMS sub–samples implemented separately for pre–Paris Agreement (Models 9–12) and Post–Paris Agreement (Models 13–16). The dependent variable is the natural logarithm of the daily average of CDS spreads of 1–year, 10–year and 30–year maturities in a quarter. All variables are explained in detail in Appendix A2. All the models include the industry fixed effect (Sustainalytics Industry Classification) and time fixed effects. The standard errors are clustered by firm and by time. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively. The values in the parentheses are the standard errors of the estimated coefficients.

	HIGH CRMS				LOW CRMS			
	CDS1	CDS5	CDS10	CDS30	CDS1	CDS5	CDS10	CDS30
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CRMS	–0.017	–0.007	–0.002	–0.001	–0.148***	–0.085***	–0.064***	–0.060***
	(0.020)	(0.012)	(0.010)	(0.009)	(0.037)	(0.028)	(0.023)	(0.022)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter–Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,545	4,545	4,545	4,545	3,804	3,804	3,804	3,804.000
Adj.R^2	0.653	0.702	0.708	0.697	0.586	0.582	0.578	0.566

	PRE–PARIS LOW CRMS				POST–PARIS LOW CRMS			
	CDS1	CDS5	CDS10	CDS30	CDS1	CDS5	CDS10	CDS30
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
CRMS	–0.131***	–0.068**	–0.051**	–0.050**	–0.171***	–0.124***	–0.095***	–0.084***
	(0.039)	(0.027)	(0.022)	(0.020)	(0.051)	(0.038)	(0.032)	(0.030)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter–Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,657	2,657	2,657	2,657	1,147	1,147	1,147	1,147
Adj.R^2	0.603	0.601	0.598	0.590	0.533	0.620	0.624	0.615

Table 11: Exploring Alternative Channels for CRMS and CDS Spread Relationship

This table presents the results on verification of alternative channels inducing the relationship between CRMS and CDS spreads. Panel A presents the Table 3 type regressions with the dependent variable now being one of the following financial variables: profitability (ROA), growth options (Tobin's Q) and liquidity (cash to assets). Models (1) to (3) use one–quarter ahead financial variables, while Models (4) to (5) use leading five–year averages of the dependent variables. Only CRMS variable is presented for brevity. Panel B presents the effects of CRMS on one–quarter ahead 5–year CDS spreads interacted with *HighLeverage* – a high vs low leverage dummy, and Post, the Paris Agreement dummy. The key variables are '*CRMS* x *HighLeverage*' (interacting '*CRMS*' and '*HighLeverage'* dummy) and '*CRMS* x *Post* x *Highleverage*' (interacting '*CRMS*', 'Post' and '*HighLeverage'* dummy). Models (1) to (3) use dummy (*'HighLeverage'*) classified using highest versus lowest leverage quartile portfolios, while Models (4) to (6) use dummy (*'HighLeverage'*) based on above versus below median leverage firms. Finally, Panel C presents the effects of CRMS on one–quarter ahead 5–year CDS spreads interacted with '*HighROA*' – a high vs low profitability dummy, and Post, the Paris Agreement dummy. The key variables are '*CRMS* x *HighROA*' (interacting '*CRMS*' and '*HighROA*' *dummy*') and 'CRMS x *Post* x *HighROA*' (interacting '*CRMS*', "Post" and '*HighROA*' dummy). Models (1) to (3) use dummy (*'HighROA'*) classified using highest versus lowest *ROA* quartile portfolios, while Models (4) to (6) use dummy (*'HighROA'*) based on above versus below median ROA firms. All variables are explained in detail in Appendix A2. The model includes the industry fixed effect (Sustainalytics Industry Classification). The standard errors are clustered by firm and by time. By ***, ** and *, we indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively. The values in the parentheses are the standard errors of the estimated coefficients.

Panel A

	F_ROA	F_TOBINQ	F_CASH	ROA_5Y	TOBINQ_5Y	CASH_5Y
	(1)	(2)	(3)	(4)	(5)	(6)
CRMS	–0.0004215**	0.022**	0.003**	–0.0000549	0.032***	0.005***
	(0.000)	(0.009)	(0.001)	(0.000)	(0.012)	(0.001)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter–Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,317	8,317	8,319	8,328	8,327	8,327
Adj.R^2	0.431	0.556	0.421	0.610	0.536	0.475

Panel B

	Quartile based Sample			Median based Sample		
	CDS5	CDS5	CDS5	CDS5	CDS5	CDS5
	(1)	(2)	(3)	(4)	(5)	(6)
CRMS	0.003	0.007	0.002	–0.022**	–0.021*	–0.022**
	(0.017)	(0.017)	(0.017)	(0.011)	(0.011)	(0.011)
HighLeverage	0.580***	0.601***	0.543***	0.302***	0.316***	0.308***
	(0.118)	(0.117)	(0.118)	(0.080)	(0.080)	(0.088)
CRMSxHighLeverage	–0.016	–0.010	–0.001	–0.010	–0.004	–0.003
	(0.024)	(0.023)	(0.023)	(0.015)	(0.015)	(0.017)
Post		0.000	0.000		0.000	0.000
		(0.000)	(0.000)		(0.000)	(0.000)
CRMSxPost		–0.014	0.005		–0.001	0.001
		(0.016)	(0.019)		(0.010)	(0.013)
CRMSxPostxHighLeverage		–0.039**	–0.077***		–0.036***	–0.041**
		(0.015)	(0.025)		(0.010)	(0.017)
HighLeveragexPost			0.208*			0.028
			(0.121)			(0.084)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter–Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,023	4,023	4,023	8,350	8,350	8,350
Adj.R^2	0.681	0.684	0.685	0.632	0.634	0.634

Panel C

	Quartile Sample			Median based Sample		
	CDS5	CDS5	CDS5	CDS5	CDS5	CDS5
	(1)	(2)	(3)	(4)	(5)	(6)
CRMS	–0.008	0.004	0.003	–0.014	–0.007	–0.010
	(0.013)	(0.013)	(0.013)	(0.012)	(0.012)	(0.013)
HighROA	–0.376***	–0.395***	–0.406***	–0.168***	–0.175***	–0.211***
	(0.084)	(0.083)	(0.089)	(0.054)	(0.054)	(0.059)
CRMSxHighROA	–0.034**	–0.042***	–0.040***	–0.024**	–0.028**	–0.022*
	(0.014)	(0.014)	(0.015)	(0.011)	(0.011)	(0.012)
Post		0.000	0.000		0.000	0.000
		(0.000)	(0.000)		(0.000)	(0.000)
CRMSxPost		–0.060***	–0.057***		–0.037***	–0.026*
		(0.013)	(0.013)		(0.011)	(0.014)
CRMSxPostxHighROA		0.048***	0.042**		0.024***	0.001
		(0.011)	(0.018)		(0.008)	(0.015)
HighROAxPost			0.037			0.127*
			(0.093)			(0.069)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter–Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,080	4,080	4,080	8,350	8,350	8,350
Adj.R^2	0.723	0.727	0.727	0.656	0.657	0.658

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