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Does Climate Change Exposure Matter to Stakeholders? Evidence from the Costs of High Leverage

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ABSTRACT

This work adds to climate finance research by studying stakeholder reactions to climate change exposure in the context of capital structure and product market interactions. We use a sample of 2,547 U.S. firms from 2004 to 2020, and find that climate change exposure intensifies stakeholder-driven costs of high leverage. The impact is stronger for firms headquartered in Democratic-leaning states, after the–Paris Agreement, in industries with more physical exposure, and among firms with more sensitive stakeholder responses. Overall, our results suggest that highly leveraged firms are vulnerable to climate change shocks and undergo stricter scrutiny from their stakeholders. Our study has several implications for climate finance research.

Keywords: Climate exposure, capital structure, product market performance, stakeholders

JEL Codes: Q54, G32, G33

1 Introduction

Climate finance is a rapidly expanding field of study in finance research. Researchers have used a variety of venues to examine: how climate change

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affects equity prices and return (Choi *et al.*, 2020; Bolton and Kacperczyk, 2021; Pástor *et al.*, 2021, 2022); commercial loans (Javadi and Masum, 2021; Huang *et al.*, 2021); corporate and government bonds and access to financing (Zerbib, 2016; Huynh and Xia, 2021; Painter, 2020; Tang and Zhang, 2020; Kling *et al.*, 2021); real estate (Baldauf *et al.*, 2020; Murfin and Spiegel, 2020; Nguyen *et al.*, 2022); institutional funds (Ceccarelli *et al.*, 2023; Kuang and Liang, 2023; Liang *et al.*, 2022); firm financial decisions (Ginglinger and Moreau, 2022; Heo, 2021).[1]

However, to the best of our knowledge, no climate finance study to date has investigated the nexus between climate change exposure and the costs of high leverage. Addressing this research gap, we aim to study the impact of climate change exposure on the costs of high leverage. The high leverage costs literature emphasizes the agency problem between a firm and its stakeholders, such as customers, competitors, employees, and investors (Titman, 1984). Therefore, it allows us to provide a wider perspective on different stakeholders' reactions to climate change exposure, which is noticeably absent from the extant climate finance literature.

The high leverage costs arise when heavily indebted firms pose threats to their stakeholders, triggering their adverse reactions (Maksimovic and Titman, 1991; Opler and Titman, 1994; Bae *et al.*, 2019). The costs manifest in various ways. For example, customers may choose to stop purchasing products or services from the firm, leading to potential revenue loss. Employees might decide to change jobs, seeking more stable or secure employment opportunities. Additionally, the company's high leverage can leave it vulnerable to competitive attacks, as rivals may perceive its weakened financial position as an opportunity to gain market share or advantage (Bolton and Scharfstein, 1990; Chevalier, 1995; Campello, 2006).

Typically, firms are exposed to two types of climate change risk: physical and transition. Physical risk exposure is closely related to a firm's exposure and vulnerability to climate-related hazards such as sea level rise or extreme weather. Transition risk exposure refers to a firm's readiness to transit its business model to align with a low-carbon, climate-friendly framework. We argue that firms' high leverage costs are exacerbated by their exposure to climate change mainly through four channels: consumer behavior changes, operational disruptions, higher financing costs, and potential revenue disruptions. First, as consumer awareness and preferences shift towards sustainable businesses, firms that are slow to adapt face increasing scrutiny (Pankratz and Schiller, 2022). Second, physical risks from climate hazards could disrupt operations, which would especially impact highly leveraged firms. Third, climate change exposure raises financing costs and restricts access to funding (Bolton and Kacperczyk, 2021;

[1]See Giglio *et al.* (2021) for a recent review of the literature on the pricing of climate risk in financial markets.

Huynh and Xia, 2021; Painter, 2020; Kling *et al.*, 2021; Ginglinger and Moreau, 2022). Fourth, policy challenges like carbon pricing proposals can disrupt revenue (Heo, 2021). In general, we expect the high leverage costs to be more pronounced in firms with high climate change exposure.

To test this idea, we quantify firm-level climate change exposure utilizing data from Sautner *et al.* (2023). They use machine learning algorithms to measure time-varying climate change exposure at a firm level from firms' quarterly earnings conference call transcripts. Specifically, they develop three sets of self-learning bigrams to measure firm-level climate change exposure along three dimensions: opportunity exposure, regulatory exposure, and physical exposure.[2] Opportunity exposure captures firms' business and innovation opportunities in transitioning their business to a more climate-friendly model. Regulatory exposure captures firms' climate change transition risk especially that related to policy shocks like carbon tax or emission caps. Physical exposure covers climate change physical risk related to extreme weather or climate hazards. Sautner *et al.* (2023) validate the robustness of their methodology through a variety of methods. They show that their measures are consistent with previous research and effectively capture climate change shocks.

Our study yields several interesting findings. First, we document that climate change exposure significantly raises high leverage costs. Specifically, a one-standard-deviation increase in the industry-adjusted measure of climate change exposure reduces highly leveraged firms' relative-to-industry sales growth by 1.38% in two years. This result is robust after adjusting for time, industry, and firm heterogeneity. More importantly, it holds after adding corporate social responsibility (CSR) measures as controls, suggesting that climate change exposure stands independently from CSR. This finding aligns with Kuang and Liang (2023), who report a low correlation between climate change risk and environmental, social, and governance (ESG) risk.

Second, we find that stakeholders' attitudes toward climate change differ significantly based on political affiliation. For example, the negative effects of climate change exposure on highly leveraged firms exist only in the subsample of firms headquartered in Democrat-leaning states. The results are not significant in the subsample of firms headquartered in Republican-leaning states. This finding is consistent with the pattern observed by academic studies and survey data showing that liberal-leaning individuals are more likely to care about climate change and support policy interventions than conservative-leaning individuals.

Third, we document that climate awareness plays a vital role in affecting stakeholders' actions. Climate change exposure negatively affects highly leveraged firms' sales growth only after 2015, that is, after the 2015 Paris Agreement. This finding is consistent with previous studies that demonstrate

[2] Sautner *et al.* (2023) list the top bigrams used in their three sets of measures in the appendix of their paper.

that the Paris Agreement enhanced global recognition of the need for action on climate change (Choi *et al.*, 2023; Ginglinger and Moreau, 2022; Ehlers *et al.*, 2022).

Fourth, we explicate how climate change exposure has distinct impacts on firms. We show that highly leveraged firms in manufacturing and retail industries are adversely affected by both physical exposure and transition exposure, while those in high-tech industries are only negatively affected by transition exposure.

Fifth, we find that the influence of climate exposure operates through multiple stakeholder types. More adverse reactions from stakeholders lead to greater leverage costs if customers purchase products that are closely tied to the company's fate, if competitors display stronger predation actions, and if employees are locked into more labor-intensive fields. In addition, debtholders are reluctant to provide more capital for highly leveraged firms, consistent with the notion of debt overhang (Myers, 1977).

Our research contributes to the existing literature in several key ways. First, our study builds on the rapidly growing field of climate finance. An extensive body of literature has been developed to investigate how capital markets and investors react to climate change exposure. Heo (2021) finds that climate change exposure affects firms' cash-holding decisions, while Ginglinger and Moreau (2022) document a negative relation between climate change exposure and firm leverage. However, we have limited understanding of how a firm's non-financial stakeholders react to its exposure to climate change, both as a rational economic decision and as a social preference decision.

Our study identifies a unique channel through which climate change exposure affects firm value: We show that highly leveraged firms face more adverse behavior from customers, competitors, and employees when exposed to climate change risk.

Second, our paper contributes to the line of work that investigates the determinants of high leverage costs. Bae *et al.* (2019) show that CSR, including the environmental component, significantly reduces customer dissatisfaction and competitor predation for highly leveraged firms. Relatedly, we find that environment-related factors such as climate change exposure influence stakeholders' responses to high leverage. Importantly, our paper additionally shows that climate change exposure goes beyond CSR practices in impacting stakeholder behavior. In other words, climate change exposure is not just related to a component of CSR. Several other studies have found that high leverage costs are driven by collectivism culture, creditor rights, debt heterogeneity, and executive characteristics (El Ghoul *et al.*, 2019, 2021, 2022). Our work adds to these studies by presenting another influencing factor: climate change exposure.

Third, our study emphasizes the ongoing importance of increasing climate change awareness among the general public and highlights the significance of analyzing various channels of climate change exposure. We demonstrate that the heterogeneity in partisan ideology and climate awareness significantly influences individuals' perceptions of the urgency of climate change and impacts their assessment of firms' climate behavior. This underscores the need for a more concerted effort to push for consensus in our society regarding climate actions. Furthermore, the current research in climate finance predominantly focuses on transition risks associated with carbon emissions. Scholars have increasingly emphasized the importance of examining the impact of physical risks in finance and business (Fiedler *et al.*, 2021; Bressan *et al.*, 2022; Ranger *et al.*, 2022). By utilizing Sautner *et al.*'s (2023) comprehensive measure of climate change exposure, we are able to shed light on how different channels of climate change exposure affect firms across diverse industries. Our findings indicate that while investors express general concerns about firms' transition risk exposure across industries, companies with greater reliance on physical facilities are particularly vulnerable to physical risk exposure. This discovery provides valuable insights into stakeholders' responses to various manifestations of climate change exposure.

The remainder of our paper is structured as follows. In Section 2, we develop our hypotheses. We provide detailed research methodology, sample selection, and variable constructions in Section 3. Section 4 presents our baseline results, the findings related to the Paris Agreement, political stands, and industry characteristics, and Section 5 investigates the influencing channels based on stakeholder reactions. Section 6 discusses the robustness tests. Section 7 concludes.

2 Hypothesis Development

2.1 Climate Exposure

The latest Assessment Report (AR6) of the Intergovernmental Panel on Climate Change warns of the increasing urgency to address climate change, particularly reducing greenhouse gas emissions and mitigating the impacts of global warming. The report states that climate change is accelerating at an alarming rate due to positive feedback loops, and has already had severe impacts on society.[3] The 27th Conference of the Parties (COP27) to the UN Framework Convention on Climate Change reaffirmed the goal of limiting global temperature rise to 1.5 degrees Celsius above pre-industrial levels. It calls on all countries to take rapid and comprehensive action.[4] Extreme weather events associated with climate change have dramatically disrupted and damaged business operations. In 2018, California wildfires caused a total economic loss of nearly $150 billion,

[3]Sixth Assessment Report, https://www.ipcc.ch/assessment-report/ar6/.

[4]Decisions taken at the Sharm El-Sheikh Climate Change Conference, https://unfccc.int/cop27.

and led many businesses to shut down permanently (Wang *et al.*, 2021). In 2021, Texas experienced a large-scale power outage due to an unprecedented winter storm. Hundreds of residents froze to death, and businesses such as Dell, Samsung, and Toyota halted production. This crisis caused $195 billion in damage.[5] 2022 saw 18 extreme weather and climate disaster events in the U.S., with losses exceeding $1 billion.[6] The World Economic Forum issued a global risk assessment report predicting that around 2% of global financial assets (or up to 10% in the worst-case scenario) will be put at risk by climate change by 2100.[7]

2.2 Main Hypotheses

High leverage costs are driven by various stakeholders (Bae *et al.*, 2019; El Ghoul *et al.*, 2019, 2021, 2022). Customer-driven high leverage costs are built on the agency cost theory. Agency problems can arise in a firm with interconnecting contracts among customers, employees, investors, and suppliers (Coase, 1937). Firm managers could dispossess the residual claims of these stakeholders without their consent (Jensen and Meckling, 1976). This agency problem becomes especially severe for firms that take high leverage. Further, high-leverage firms tend to retain cash flows in an effort to avoid bankruptcy, which can lead to dishonoring warranties and producing low-quality merchandise (Maksimovic and Titman, 1991). As a response, customers may stop buying products from the highly leveraged firm (Opler and Titman, 1994), resulting in the customer-driven costs of high leverage (Titman, 1984; Matsa, 2011; Phillips and Sertsios, 2013; Kini *et al.*, 2017). Since employees and investors also form implicit contracts with highly leveraged firms, they also contribute to high leverage costs.

Competitor-driven high leverage costs are built on the predation theory (Telser, 1966; Bolton and Scharfstein, 1990; Chevalier, 1995; El Ghoul *et al.*, 2019). This theory suggests that, due to capital market frictions, highly leveraged firms face reduced access to capital as well as higher costs of capital, thereby becoming less competitive. This provides an opportunity for financially healthy competitors to benefit by lowering prices and intensively advertising their products in an effort to attract customers away from highly leveraged firms. According to the literature on capital structure and product market performance (Campello, 2003, 2006; Opler and Titman, 1994; Titman, 1984),

[5]2021 Texas power crisis report, https://energy.utexas.edu/sites/default/files/UTAustin%20%282021%29%20EventsFebruary2021TexasBlackout%2020210714.pdf.

[6]Billion-Dollar weather and climate disasters, https://www.ncei.noaa.gov/access/billions/#:~:text=In%202022%2C%20there%20were%2018,and%201%20winter%20storm%20event.

[7]The Global Risks Report 2020, World Economic Forum, http://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf.

stakeholders show negative behavioral changes in the product market toward firms taking high leverage.

Firms face new levels of uncertainty and increased costs when exposed to climate change risk, and we identify four channels through which such exposure may influence the high leverage costs. First, consumers' behavior is influenced by social factors. As awareness of climate change urgency increases, and social preferences shift toward more sustainable and climate-friendly businesses, firms that are slow to adapt will be subject to increased scrutiny from consumers and other stakeholders. As pointed out by Pankratz and Schiller (2022), unexpected climate shocks increase the likelihood that customers terminate their relationships with existing suppliers. Thus, the costs of high leverage will be intensified by greater climate change exposure.

Second, firms face potential financial and operating disruptions from physical risk exposure. Extreme weather or climate hazards may cause direct damage to assets, upending firms' daily operations or disrupting supply chains.[8] McKinsey Global Institute issued a report in 2020 highlighting the threats of physical hazards caused by climate change.[9] Highly leveraged firms are especially vulnerable to these negative shocks. They could further increase firms' liquidation risk, and damage their credibility with stakeholders in terms of providing continuous high-quality service.

Third, climate change exposure increases firms' financing costs and limits access to financing. Researchers show that investors demand a higher return to compensate for climate change risk. Bolton and Kacperczyk (2021) show that institutional investors implement stricter screening based on firms' emission intensity. Bolton *et al.* (2022) further document that corporate carbon emissions are linked to price-earnings discount. Huynh and Xia (2021) document that investors favor more environment-friendly bonds and are willing to pay a higher price for them. Moreover, Painter (2020) shows that municipal bonds issued by counties with more climate change exposure sustain higher bond yield and underwriting fees. Kling *et al.* (2021) show that climate vulnerability increases the costs of capital and restrains access to financing. Ginglinger and Moreau (2022) show that higher physical risk exposure may lead firms to lower their leverage. High leverage already puts a substantial financing burden on firms. Thus, rising financing costs may further weaken highly levered firms' competitive positions.

Fourth, transition risk exposes firms to potential revenue disruption. Firms are facing increasing policy and regulatory challenges. Policymakers in the

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[8]For example, the summer 2022 heat wave in China caused factories to halt operations in response to government demand to save energy, leading to major disruptions to supply chains worldwide.

[9]McKinsey Global Institute Climate risk and response: Physical hazards and socioeconomic impacts, https://www.mckinsey.com/capabilities/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts.

U.S. are contemplating raising the fees for carbon emissions or implementing a direct carbon tax, which could negatively impact firms' revenue. According to a report from the Center for Climate and Energy Solutions, members of the 117^{th} Congress have introduced five carbon pricing proposals.[10] Several states are also moving promisingly to introduce a state tax on carbon emissions.[11] Heo (2021) finds that firms are forced to hold more cash when their climate change exposure increases. More highly leveraged firms are subject to greater lender discretion and are more vulnerable to abrupt revenue disruption. Taken together, the arguments above suggest:

Hypothesis 1. *Ceteris paribus, firms with higher climate change exposure are associated with greater costs of high leverage.*

Previous studies have found robust associations between political affiliation and attitudes towards climate change. According to the Pew Research Center, there is a stark partisan divide between Democrats and Republicans regarding climate change issues. Typically, Democrats are more concerned about climate change and more likely to endorse government action in response to climate issues.[12] This trend is further substantiated by academic research, which indicates that individuals who plan to vote for more liberal political parties are more inclined to believe in climate change than those who identify with conservative political parties (Druckman and McGrath, 2019; Hoffman, 2011; Hazlett and Mildenberger, 2020; Hornsey *et al.*, 2016; McCright and Dunlap, 2011). Baldauf *et al.* (2020) demonstrate that perceptions of the urgency of climate change are linked to political party affiliation and, in turn, influence the value of properties at risk of being flooded. Therefore, we test the following hypothesis:

Hypothesis 2. *Ceteris paribus, the relation between climate change exposure and the high leverage costs is stronger for firms headquartered in democratic states.*

The 2015 Paris Agreement played a critical role in enhancing awareness and comprehension of climate issues and promoting a collaborative global initiative to combat climate change. Research suggests that the Agreement raised awareness in investors and managers about climate change issues, influencing their business decision-making. For example, Choi *et al.* (2023) indicate that institutional shareholders have started to divest from high–carbon risk companies since the adoption of the Paris Agreement. Ehlers *et al.* (2022) document that banks began to charge a carbon premium on commercial loans

[10] Details are available at https://www.c2es.org/content/carbon-tax-basics/.

[11] For additional details, please refer to the report available at https://www.carbontax.org/ctc-state-by-state-report-2017/.

[12] Pew Research Center, https://www.pewresearch.org/science/2019/11/25/u-s-public-views-on-climate-and-energy/.

after 2015. Additionally, Ginglinger and Moreau (2022) report that firms with high exposure to physical climate change risks tend to have lower leverage ratios post-2015. Formally, we test the following hypothesis:

Hypothesis 3. *Ceteris paribus, the relation between climate change exposure and the high leverage costs is stronger after the 2015 Paris Agreement.*

As we discussed earlier, firms face both physical and transitional risks related to climate change, and the effects of these risks vary across industries. For instance, businesses operating in the manufacturing and retail sectors are highly dependent on physical facilities, making them susceptible to severe weather events. Additionally, these firms are typically involved in global supply chains, meaning that disruptions in one location can have knock-on effects on other companies. In a 2021 report, Moody's estimated that "The manufacturing industry has the largest proportion of assets exposed to physical climate hazards."[13]

Hypothesis 4. *Ceteris paribus, the relation between climate change exposure and the high leverage costs is stronger for industries (e.g., manufacturing and retail) more vulnerable to physical exposure.*

Our theoretical arguments suggest that climate exposure influences high leverage costs via a wide set of stakeholders. Specifically, we consider the reactions from customers, competitors, employees, and investors. Our analyses are built on two main underlying theories. First, firms form implicit contracts with multiple stakeholders, such as customers, employees, and investors (Coase, 1937). Second, liquidation can impose costs on customers, employees, suppliers, etc. Titman (1984). Since our theoretical motivation suggests that climate exposure is associated with breaking the implicit contracts and an increased chance of liquidation, we expect it to increase the costs of high leverage driven by various stakeholders. To test this idea, we build the following hypothesis:

Hypothesis 5. *Ceteris paribus, the relation between climate change exposure and the high leverage costs is stronger when stakeholders are highly sensitive to firm leverage.*

3 Sample, Methodology, and Summary Statistics

3.1 Sample Construction

We begin with all firms listed in Compustat (North America) from 2004 to 2020. We exclude financial firms (SIC codes 6000–6999) and utility firms

[13] https://assets.website-files.com/5df9172583d7eec04960799a/618872a58d35f2643cbcaef2_BX9770_ESG_Critical%20industries%20have%20substantial%20exposure_7Nov2021.pdf.

(SIC 4900–4999) because regulatory restrictions may affect their product market performance. We merge these files with the firm-level climate change exposure data from Sautner *et al.* (2023). We further require each firm-year observation to have positive values on total assets and sales, non-missing equity, and variables in our baseline regression. To control for outliers, we exclude firm-year observations with assets or sales growth greater than 200%. These filters result in a sample of 20,038 firm-year observations for 2,547 unique firms.

3.2 Measuring Climate Change Exposure

Our main objective is to examine the interaction between high leverage costs and firms' exposure to climate change risk. We borrow from Sautner *et al.* (2023), and construct firm-level climate change exposure and also include their transition and physical risk exposure measures. Specifically, to capture a firm's transition risk exposure to climate change, we use $CCEXPOSURE^{reg}$ (henceforth, $REGEXPO$), of which the initial bigrams include keywords associated with climate-related regulatory interventions. To capture a firm's physical risk exposure to climate change, we use $CCEXPOSURE^{phy}$ (henceforth, $PHYEXPO$), of which the initial bigrams include keywords associated with climate-related physical hazards.[14] In our main tests, we combine regulatory and physical exposure into a single variable, $CCEXPOSURE$ (henceforth, $CCEXPO$), by averaging $REGEXPO$ and $PHYEXPO$ to measure a firm's overall exposure to climate change risk.

3.3 Measuring High Leverage Costs

Building on the framework of the high leverage cost literature (Bae *et al.*, 2019; El Ghoul *et al.*, 2019, 2021, 2022), we employ the following model:

$$\begin{aligned} SALES\_G_{i,t} = a + \lambda_1 HLEV_{i,t-2} + \lambda_2 SIZE_{i,t} + \sum_{k=1}^{2} \lambda_{3k} PROFIT_{i,t-k} \\ + \sum_{k=1}^{2} \lambda_{4k} INVESTMENT_{i,t-k} \\ + \sum_{k=1}^{2} \lambda_{5k} SELLEXP_{i,t-k} + +\mu_i + \mu_t + \varepsilon_{i,t}, \end{aligned} \tag{1}$$

[14]Sautner *et al.* (2023) also measure a firm's exposure to climate change opportunities related to climate innovation. We argue that this measure is not suitable in our empirical analysis because we focus on how risk exposure negatively affects the costs of high leverage. In untabulated tests, we add the opportunity exposure measure. The coefficient estimates on the opportunity exposure measure are not significant. All test results are available upon request.

where i indicates firm and t represents year. We include firm and year fixed effects to account for the unobserved firm-specific factors that do not change across time, and we exclude any time variations. $SALES\_G$ is sales growth, a measure to capture stakeholders' actions in the product market. We should observe reduced sales growth in the presence of customer dissatisfaction and competitor predation.

$HLEV$ is a high-leverage dummy variable that equals 1 if the long-term debt ratio of a firm is in the top three deciles of the country in which the firm is headquartered in a given year. The use of long-term rather than total debt mitigates the endogeneity problem because long-term debt is less likely to be adjusted in response to short-term performance (see Campello, 2006). In addition, we follow the literature, and employ a two-year lag between the high leverage dummy and sales growth (Campello, 2006). This practice helps minimize any reverse causality concerns. Note that a negative coefficient on $HLEV$ represents higher costs of high leverage, and more negative reactions from stakeholders.

To replicate the model in Bae *et al.* (2019), we control for four firm-level characteristics correlated with the dependent variable $SALES\_G$ and the key independent variable *HLEV*. Firm size, *SIZE*, is the natural logarithm of total assets. Large firms grow less due to their maturity. Firm profitability, *PROFIT*, is represented by operating earnings plus depreciation over total assets. Leverage could play a disciplined role in increasing profitability and improving sales growth. Capital investment, *INVESTMENT*, is capital expenditures over total assets. Firms could take on more debt to increase capital investment. Higher investment leads to more products and higher sales growth. Sell expenses, *SELLEXP*, is the ratio of advertising and selling expenses to total sales. Firms' attention to selling comes with expenses and contributes to future sales.

Note that all firm-level variables in Equation (1) are mean-adjusted based on industry years, following this line of literature (Campello, 2003, 2006; Opler and Titman, 1994; Bae *et al.*, 2019; Bae *et al.*, 2019; El Ghoul *et al.*, 2019, 2021, 2022). The relative measurement approach further strengthens exogeneity because a firm's performance is relative to peers, and thus is less likely to be influenced by the focal firm.

3.4 Measuring CSR Performance

Previous research shows that firms' CSR performance may mitigate the negative effect of high leverage on product market performance (Bae *et al.*, 2019). To distinguish a firm's climate change exposure from the traditional CSR performance measure, we follow El Ghoul *et al.* (2011), Jiao (2010), and Bae *et al.* (2019, 2021). We measure a firm's CSR performance from MSCI ESG STATS (formerly known as Kinder, Lydenberg, and Domini Research &

Analytics; KLD), which tracks seven areas: community, diversity, employee relations, environment, human rights, product characteristics, and corporate governance. For each firm-year, we calculate a firm's dimensional scores by subtracting the number of concerns from the number of strengths. We then obtain the firm's raw CSR score, *CSR*, by summing the scores across all areas except corporate governance. In the robustness tests, we replace the CSR measure with measures from other source and the main results remain robust.

3.5 Descriptive Statistics

Table 1 presents the sample distribution by industry and year. Panel A shows the distribution using the Fama–French 48-industry classification. The Business Services (14.13%), Retail (8.30%), and Electronic Equipment (7.94%) industries encompass the most firms in our sample. We note that the number of sample firms remains steady overall from 2005 to 2020. The changes in the early years are due to increased coverage of firms' conference call transcripts.

Table 2 presents the descriptive statistics for our main variables (before an industry-year adjustment). Approximately 33% of firm-years in our sample are highly leveraged, which is consistent with our definition of $HLEV$. On average, the annual sales growth rate is 7% with a standard deviation of 0.21. The average level of climate change exposure, combining both regulatory and physical risks, is 0.26 with a standard deviation of 1.16. Specifically, the average regulatory risk exposure alone is 0.37 with a standard deviation of 2.01, while the average physical risk exposure alone is 0.14 with a standard deviation of 1.05. In the summary statistics, we amplify the climate change exposure variables by a factor of 10,000.[15] For our control variables, the average ratios of profit, investment, selling expenses, and cost of goods sold are all positive. Chircop *et al.* (2023) demonstrate a positive relation between climate change exposure and environmental violations. To address the possibility that regulation violation penalties could be a confounding factor in our results, we include firms' regulation violation penalty from Violation Tracker as a control variable. The average natural logarithm of firms' regulation violation penalty is 3.21 with a standard deviation of 5.44. Additionally, we control for industry competition as the market share of the four largest firms in a certain industry. Finally, the average corporate social responsibility score is −2.55, with a standard deviation of 13.47.

Table 3 illustrates the correlation matrix among key variables over the sample period. The results show that the correlation coefficients are low, suggesting that multicollinearity is unlikely to be driving our results.[16]

[15] In the regression analysis, the climate change exposure variables are standardized.

[16] High correlations are expected between control variables and their own lagging variables. For example, the correlation between $INVESTMENT_{t-1}$ and $INVESTMENT_{t-2}$ is 0.85. However, correlations between different variables are generally low.

Table 1: Sample distribution by industry and year.

Panel A. Sample distribution by industry

#	Industry	*N*	%
1	Agriculture	37	0.18
2	Food products	441	2.20
3	Candy & soda	30	0.15
4	Beer & liquor	90	0.45
5	Tobacco products	38	0.19
6	Recreation	126	0.63
7	Entertainment	299	1.49
8	Printing & publishing	168	0.84
9	Consumer goods	388	1.94
10	Apparel	400	2.00
11	Healthcare	317	1.58
12	Medical equipment	780	3.89
13	Pharmaceutical products	791	3.95
14	Chemicals	627	3.13
15	Rubber & plastic products	163	0.81
16	Textile	65	0.32
17	Construction materials	498	2.49
18	Construction	449	2.24
19	Steel works	327	1.63
20	Fabricated products	40	0.20
21	Machinery	992	4.95
22	Electrical equipment	339	1.69
23	Automobiles & truck	447	2.23
24	Aircraft	203	1.01
25	Shipbuilding & industrial metal mining	81	0.40
26	Defense	26	0.13
27	Precious metals	47	0.23
28	Non-metallic & industrial metal mining	125	0.62
29	Coal	71	0.35
30	Petroleum & natural gas	992	4.95
32	Communication	599	2.99
33	Personal services	329	1.64
34	Business services	2832	14.13
35	Computers	862	4.30
36	Electronic equipment	1591	7.94
37	Measuring & control equipment	563	2.81
38	Business supplies	318	1.59
39	Shipping containers	137	0.68
40	Transportation	425	2.12
41	Wholesale	865	4.32
42	Retail	1664	8.30
43	Restaurants, hotels & motels	437	2.18
46	Real estate	19	0.09
	Total	20,038	100.00

Table 1: Continued.

Panel B. Sample distribution by year		
Year	N	%
2004	446	2.23
2005	1,059	5.28
2006	1,105	5.51
2007	1,110	5.54
2008	1,177	5.87
2009	1,254	6.26
2010	1,315	6.56
2011	1,324	6.61
2012	1,369	6.83
2013	1,332	6.65
2014	1,349	6.73
2015	1,213	6.05
2016	1,204	6.01
2017	1,146	5.72
2018	1,139	5.68
2019	1,163	5.80
2020	1,333	6.65
Total	20,038	100.00

Note: This table presents the Fama–French (1997) 48-industry and fiscal year distributions for our sample of 20,038 firm-year observations representing 2,547 unique firms.

Table 2: Descriptive statistics.

	N	*Mean*	*SD*	Minimum	Q1	Median	Q3	Maximum
$SALES\_G_t$	20,038	0.07	0.21	−0.94	−0.02	0.06	0.15	1.94
CSR_{t-2}	20,038	−2.55	13.47	−33.00	−15.00	−1.00	11.00	28.00
$REGEXPO_{t-2}$	20,038	0.37	2.01	0.00	0.00	0.00	0.00	87.11
$PHYEXPO_{t-2}$	20,038	0.14	1.05	0.00	0.00	0.00	0.00	59.77
$CCEXPO_{t-2}$	20,038	0.26	1.16	0.00	0.00	0.00	0.00	43.56
$HLEV_{t-2}$	20,038	0.33	0.47	0.00	0.00	0.00	1.00	1.00
$SIZE_t$	20,038	7.49	1.59	1.07	6.36	7.40	8.48	13.22
$COMPETITION_t$	20,038	0.48	0.14	0.23	0.37	0.45	0.55	1.00
$PROFIT_{t-1}$	20,038	0.07	0.13	−3.72	0.05	0.09	0.13	0.38
$PROFIT_{t-2}$	20,038	0.08	0.12	−3.11	0.05	0.09	0.13	0.38
$INVESTMENT_{t-1}$	20,038	0.05	0.05	0.00	0.02	0.03	0.06	0.38
$INVESTMENT_{t-2}$	20,038	0.05	0.06	0.00	0.02	0.03	0.06	0.38
$SELLEXP_{t-1}$	20,038	0.30	0.40	0.02	0.12	0.23	0.38	18.02
$SELLEXP_{t-2}$	20,038	0.30	0.39	0.02	0.12	0.23	0.38	18.02
$COGS_{t-1}$	20,038	0.56	0.33	0.00	0.26	0.53	0.92	1.00
$COGS_{t-2}$	20,038	0.56	0.33	0.00	0.27	0.54	0.93	1.00
$PENALTY_{t-1}$	20,038	3.21	5.44	0.00	0.00	0.00	8.84	22.69
$PENALTY_{t-2}$	20,038	3.16	5.40	0.00	0.00	0.00	8.76	22.69

Note: This table reports the descriptive statistics for the key variables (before industry-year adjustments) used in Equations (1) and (2).

Table 3: Correlation matrix.

	$SALES\_G_t$	CSR_{t-2}	$REGEXPO_{t-2}$	$PHYEXPO_{t-2}$	$CCEXPO_{t-2}$	$HLEV_{t-2}$	$SIZE_t$	$COMPETITION_t$
$SALES\_G_t$	1.000							
CSR_{t-2}	0.018	1.000						
$REGEXPO_{t-2}$	−0.005	0.006	1.000					
$PHYEXPO_{t-2}$	−0.010	−0.005	0.045	1.000				
$CCEXPO_{t-2}$	−0.009	0.003	0.890	0.495	1.000			
$HLEV_{t-2}$	−0.034	−0.102	−0.009	0.024	0.003	1.000		
$SIZE_t$	0.008	0.028	−0.034	−0.011	−0.035	0.199	1.000	
$COMPETITION_t$	−0.024	−0.034	0.011	−0.018	0.001	0.047	0.147	1.000
$PROFIT_{t-1}$	0.048	0.019	−0.038	0.009	−0.029	−0.052	0.189	0.019
$PROFIT_{t-2}$	−0.053	0.019	−0.044	0.008	−0.034	−0.097	0.169	0.019
$INVESTMENT_{t-1}$	−0.010	0.004	−0.003	−0.004	−0.004	0.053	0.041	0.075
$INVESTMENT_{t-2}$	0.004	0.010	−0.004	−0.004	−0.006	0.068	0.039	0.071
$SELLEXP_{t-1}$	0.095	0.023	−0.057	−0.038	−0.067	−0.145	−0.260	−0.066
$SELLEXP_{t-2}$	0.103	0.024	−0.051	−0.036	−0.061	−0.146	−0.261	−0.066
$COGS_{t-1}$	−0.133	−0.016	0.038	0.036	0.050	−0.093	−0.163	−0.083
$COGS_{t-2}$	−0.091	−0.017	0.035	0.034	0.046	−0.096	−0.148	−0.077
$PENALTY_{t-1}$	−0.033	−0.010	0.015	0.013	0.019	0.094	0.474	0.070
$PENALTY_{t-2}$	−0.040	−0.018	0.013	0.007	0.014	0.095	0.474	0.071

Table 3: Continued.

	$PROFIT_{t-1}$	$PROFIT_{t-2}$	$INVESTMENT_{t-1}$	$INVESTMENT_{t-2}$	$SELL\ EXP_{t-1}$	$SELL\ EXP_{t-2}$	$COGS_{t-1}$	$COGS_{t-2}$	$Penalty_{t-1}$	$Penalty_{t-2}$
$SALES\_G_t$										
CSR_{t-2}										
$REGEXPO_{t-2}$										
$PHYEXPO_{t-2}$										
$CCEXPO_{t-2}$										
$HLEV_{t-2}$										
$SIZE_t$										
$COMPETITION_t$										
$PROFIT_{t-1}$	1.000									
$PROFIT_{t-2}$	0.549	1.000								
$INVESTMENT_{t-1}$	0.118	0.181	1.000							
$INVESTMENT_{t-2}$	0.101	0.141	0.851	1.000						
$SELLEXP_{t-1}$	−0.289	−0.255	−0.175	−0.166	1.000					
$SELLEXP_{t-2}$	−0.258	−0.300	−0.178	−0.170	0.936	1.000				
$COGS_{t-1}$	0.033	0.052	−0.026	−0.041	−0.436	−0.432	1.000			
$COGS_{t-2}$	0.074	0.049	−0.037	−0.030	−0.436	−0.441	0.968	1.000		
$PENALTY_{t-1}$	0.088	0.083	0.054	0.049	−0.240	−0.241	0.130	0.136	1.000	
$PENALTY_{t-2}$	0.080	0.078	0.050	0.044	−0.238	−0.239	0.127	0.134	0.600	1.000

Note: This table reports the correlation matrix among key variables (before industry-year adjustments) used in Equations (1) and (2).

4 Empirical Results

4.1 Main Evidence

We begin by analyzing the relation between climate change exposure and the costs of high leverage. Specifically, we augment the model of high leverage costs (Equation (1)) by adding a proxy for climate change exposure and its interaction with *HLEV*. Our baseline model is:

$$\begin{aligned} SALES\_G_{i,t} = b &+ \beta_1 CCEXPO_{i,t-2} \times HLEV_{i,t-2} \\ &+ \beta_2 CCEXPO_{i,t-2} + \beta_3 CSR_{i,t-2} \times HLEV_{i,t-2} \\ &+ \beta_4 CSR_{i,t-2} + \beta_5 HLEV_{i,t-2} + \beta_6 SIZE_{i,t} \\ &+ \beta_7 COMPETITION_{i,t} + \sum_{k=1}^{2} \beta_{8k} PROFIT_{i,t-k} \\ &+ \sum_{k=1}^{2} \beta_{9k} INVESTMENT_{i,t-k} + \sum_{k=1}^{2} \beta_{10k} SELLEXP_{i,t-k} \\ &+ \sum_{k=1}^{2} \beta_{11k} COGS_{i,t-k} + \sum_{k=1}^{2} \beta_{12k} PENALTY_{i,t-k} + \varepsilon_{i,t}. \end{aligned} \quad (2)$$

Our focus in Equation (2) is the interaction term between climate change exposure and the high leverage indicator. A negative β_1 suggests that climate change exposure intensifies the costs of high leverage.

Table 4 reports the results of the effect of climate exposure on the costs of high leverage using different specifications. Models 1 and 2 employ the fixed effect regressions with firm and year fixed effects. Model 1 (Model 2) excludes (includes) CSR and its interactions with the high leverage variable. We find a significantly negative coefficient estimate on *CCEXPO* × *HLEV* in both models, consistent with our expectation that climate change exposure intensifies high leverage costs. Models 3 and 4 replicate the existing two models by replacing year fixed effects with year × industry fixed effects. Model 4 is our baseline model. The coefficient estimates on *CCEXPO* × *HLEV* is −0.0138, significant at the 1% level.

Economically speaking, a one-standard-deviation increase in the industry-adjusted firm-level climate change exposure reduces highly leveraged firms' relative-to-industry sales growth by 1.38% in two years. We observe that CSR mitigates high leverage costs, as described by Bae *et al.* (2019). Importantly, *CCEXPO* × *HLEV* continues to load negatively in all specifications with comparable magnitudes, regardless of whether CSR components are included. This implies that climate change exposure stands independently from a firm's CSR performance.

Table 4: Climate change exposure and the costs of high leverage.

	(1)	(2)	(3)	(4)
$CCEXPO_{t-2} \times HLEV_{t-2}$	-0.0132^{***}	-0.0131^{***}	-0.0138^{***}	-0.0138^{***}
	(−3.21)	(−3.20)	(−3.18)	(−3.18)
$CCEXPO_{t-2}$	0.0082^{***}	0.0082^{***}	0.0085^{***}	0.0086^{***}
	(3.21)	(3.21)	(3.18)	(3.19)
$CSR_{t-2} \times HLEV_{t-2}$		0.0077^{**}		0.0055^{*}
		(2.52)		(1.81)
CSR_{t-2}		-0.0099^{***}		-0.0084^{***}
		(−4.70)		(−4.10)
$HLEV_{t-2}$	-0.0183^{***}	-0.0188^{***}	-0.0203^{***}	-0.0205^{***}
	(−3.81)	(−3.88)	(−4.18)	(−4.20)
$SIZE_t$	0.0371^{***}	0.0374^{***}	0.0533^{***}	0.0536^{***}
	(7.30)	(7.40)	(8.58)	(8.64)
$COMPETITION_t$	0.0868^{**}	0.0867^{**}	0.1292	0.1426
	(1.97)	(1.97)	(0.84)	(0.94)
$PROFIT_{t-1}$	-0.0907^{***}	-0.0908^{***}	-0.0852^{***}	-0.0857^{***}
	(−4.22)	(−4.23)	(−2.96)	(−2.96)
$PROFIT_{t-2}$	−0.0306	−0.0308	-0.0543^{*}	-0.0551^{*}
	(−1.45)	(−1.46)	(−1.89)	(−1.92)
$INVESTMENT_{t-1}$	0.1429^{*}	0.1394^{*}	0.0739	0.0716
	(1.84)	(1.80)	(1.04)	(1.01)
$INVESTMENT_{t-2}$	−0.0899	−0.0895	−0.0136	−0.0137
	(−1.12)	(−1.12)	(−0.19)	(−0.19)
$SELLEXP_{t-1}$	−0.0018	−0.0020	0.0501	0.0501
	(−0.13)	(−0.15)	(1.33)	(1.33)
$SELLEXP_{t-2}$	0.0220^{*}	0.0219^{*}	0.0190	0.0190
	(1.71)	(1.70)	(0.63)	(0.63)
$COGS_{t-1}$	-0.3550^{***}	-0.3566^{***}	-0.3415^{***}	-0.3427^{***}
	(−13.03)	(−13.11)	(−11.90)	(−11.95)
$COGS_{t-2}$	0.1607^{***}	0.1581^{***}	0.1753^{***}	0.1732^{***}
	(6.37)	(6.28)	(6.52)	(6.45)
$PENALTY_{t-1}$	-0.0006^{*}	-0.0006^{*}	-0.0009^{**}	-0.0009^{***}
	(−1.77)	(−1.81)	(−2.56)	(−2.61)
$PENALTY_{t-2}$	-0.0010^{***}	-0.0010^{***}	-0.0011^{***}	-0.0011^{***}
	(−2.93)	(−2.86)	(−3.39)	(−3.34)
CONSTANT	-0.0512^{**}	-0.0552^{**}	0.0008	−0.0041
	(−2.24)	(−2.42)	(0.01)	(−0.05)
N	20,038	20,038	20,038	20,038
R-squared	5.12%	5.26%	18.53%	18.62%
Firm F.E.	Y	Y	Y	Y
Firm F.E.	Y	Y		
Year × Industry F.E.			Y	Y

Note: This table reports the results of the effect of climate exposure on high leverage costs using a firm fixed effects regression model. Models 1 and 2 employ the fixed effect regressions with firm and year fixed effects. Models 3 and 4 replace year fixed effects with year × industry fixed effects. The dependent variable is industry-adjusted sales growth ($SALES\_G$). The main variable of interest is the interaction term between industry-adjusted climate change exposure ($CCEXPO$) and a dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample ($HLEV$). Additional variable definitions are in the Appendix. All control variables are adjusted to their industry-year means and are winsorized at the 1st and 99th percentiles. Further, we require that each industry-year contains at least four firms to be qualified in the analysis so that the industry-year mean is not biased toward outliers. The sample period is 2004–2020. The t-statistics based on heteroskedasticity-robust standard errors and clustered at the firm level are reported in parentheses. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level.

Interestingly, we find a negative relation between the standalone *CSR* variable and sales growth. Following Bae *et al.* (2019), we consider the results as supporting the notion that CSR investment functions similarly to an insurance product. Companies make CSR investments as a form of insurance premium when they are financially stable; in return, they reap the advantages of CSR as a protective measure during times of financial difficulty. On the other hand, the relation between the standalone *CCEXPO* variable and sales growth is positive but only among low leverage firms. In the subsequent analysis, we further observe that this positive correlation is also observed only prior to the 2015 Paris Agreement. We interpret these results as suggesting the important role of public scrutiny in shaping firm behaviors. Firms with low leverage are less likely to face extensive scrutiny from stakeholders compared to highly leveraged firms. In addition, before the 2015 Paris Agreement, public awareness of climate change was limited. The lack of concern about climate change provides firms with an opportunity to prioritize growth without giving much thought to environmental considerations, particularly in relation to climate issues.

Overall, our findings suggest that stakeholder-driven highly leveraged costs become more pronounced for firms that are more exposed to climate change.

4.2 Effect of Climate Change Exposure on High Leverage Costs: Political Affiliation Variations

Following prior research (Bae *et al.*, 2021; Bhandari and Golden, 2021; Dunbar *et al.*, 2020; Hutton *et al.*, 2014), we classify a state as "blue" if it voted for the Democratic Party in the most recent presidential election and "red" if it supported the Republican Party. We then distinguish between companies headquartered in blue and red states and investigate the impact of climate exposure on the high leverage costs in states with distinct political affiliations. In Table 5, Models 1 and 2 report the regression results from the sample in blue states, while Models 3 and 4 report the regression results from the sample in red states. We incorporate firm and year $\times$ industry fixed effects into all models. We observe that the coefficient estimates on $CCEXPO \times HLEV$ are negative and significant, but only in the subset of firms headquartered in blue states. This finding is consistent with our assumption that Democrats tend to be more concerned about climate change and more supportive of government actions.

The coefficient estimate on $CCEXPO \times HLEV$ in Model 2 is -0.0085, significant at the 5% level. In terms of economic significance, a one-standard-deviation increase in the industry-adjusted firm-level climate change exposure measure decreases highly leveraged firms' relative-to-industry sales growth by 0.85% in two years. Another interesting finding is that the mitigation effects of CSR on high leverage costs also only exist in blue states. This is

Table 5: Climate change exposure and the costs of high leverage: Political affiliation.

	Blue States		Red States	
	(1)	(2)	(3)	(4)
$CCEXPO_{t-2} \times HLEV_{t-2}$	-0.0086^{**}	-0.0085^{**}	-0.0030	-0.0024
	(-2.19)	(-2.21)	(-0.29)	(-0.23)
$CCEXPO_{t-2}$	0.0050	0.0049	0.0092	0.0086
	(1.47)	(1.48)	(1.24)	(1.18)
$CSR_{t-2} \times HLEV_{t-2}$		0.0075^{*}		0.0077
		(1.89)		(1.15)
CSR_{t-2}		-0.0098^{***}		-0.0081
		(-3.79)		(-1.62)
$HLEV_{t-2}$	-0.0183^{***}	-0.0194^{***}	-0.0170	-0.0168
	(-2.95)	(-3.05)	(-1.53)	(-1.51)
$SIZE_t$	0.0648^{***}	0.0657^{***}	0.0914^{***}	0.0910^{***}
	(6.59)	(6.68)	(6.76)	(6.73)
$COMPETITION_t$	-0.0519	-0.0359	0.3359	0.3429
	(-0.24)	(-0.17)	(0.93)	(0.95)
$PROFIT_{t-1}$	-0.0707^{**}	-0.0720^{**}	-0.1179^{*}	-0.1188^{*}
	(-2.17)	(-2.21)	(-1.94)	(-1.95)
$PROFIT_{t-2}$	-0.0575	-0.0589	-0.0367	-0.0365
	(-1.48)	(-1.52)	(-0.71)	(-0.70)
$INVESTMENT_{t-1}$	-0.0229	-0.0297	0.1420	0.1415
	(-0.21)	(-0.27)	(1.05)	(1.04)
$INVESTMENT_{t-2}$	-0.1000	-0.1025	-0.2534^{*}	-0.2524^{*}
	(-1.04)	(-1.07)	(-1.75)	(-1.74)
$SELLEXP_{t-1}$	0.0541	0.0537	-0.0298	-0.0308
	(0.61)	(0.60)	(-0.47)	(-0.49)
$SELLEXP_{t-2}$	0.0306	0.0317	0.0654	0.0639
	(0.52)	(0.54)	(1.24)	(1.21)
$COGS_{t-1}$	-0.4116^{***}	-0.4120^{***}	-0.3085^{***}	-0.3119^{***}
	(-9.50)	(-9.47)	(-5.84)	(-5.92)
$COGS_{t-2}$	0.2259^{***}	0.2229^{***}	0.0878^{*}	0.0862^{*}
	(6.12)	(6.04)	(1.79)	(1.76)
$PENALTY_{t-1}$	-0.0006	-0.0006	-0.0013^{*}	-0.0013^{ast}
	(-1.35)	(-1.37)	(-1.71)	(-1.74)
$PENALTY_{t-2}$	-0.0013^{***}	-0.0012^{***}	-0.0000	-0.0001
	(-3.08)	(-3.03)	(-0.06)	(-0.08)
$CONSTANT$	-0.0818	-0.0937	-0.4597^{*}	-0.4636^{*}
	(-0.71)	(-0.82)	(-1.93)	(-1.94)
N	9,950	9,950	5,008	5,008
R-squared	16.52%	16.69%	35.51%	35.57%
Firm F.E.	Y	Y	Y	Y
Year × Industry F.E.	Y	Y	Y	Y

Note: This table reports the results of the effect of climate exposure on high leverage costs in states with Democratic or Republican affiliation. Models 1 and 2 report regression results for the subsample with firms headquartered in blue states; Models 3 and 4 report regression results for the subsample with firms headquartered in red states. We classify a state as blue if it voted Democratic and red if it voted Republican in the last presidential election. The dependent variable is industry-adjusted sales growth ($SALES\_G$). The main variable of interest is the interaction term between industry-adjusted climate change exposure ($CCEXPO$) and a dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample ($HLEV$). Additional variable definitions are in the Appendix. All control variables are adjusted to their industry-year means and are winsorized at the 1st and 99th percentiles. Further, we require that each industry-year contains at least four firms to be qualified in the analysis so that the industry-year mean is not biased toward outliers. The sample period is 2004–2020. The t-statistics based on heteroskedasticity-robust standard errors and clustered at the firm level are reported in parentheses. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level.

consistent with other researchers' findings that political affiliation correlates with attitudes toward social issues. We again observe that the impact of climate change exposure is independent of firms' CSR performance.

4.3 Effect of Climate Change Exposure on High Leverage Costs: Climate Change Awareness Variations

To investigate the potential influence of increased awareness of climate change on our analysis, we partition our dataset into two distinct periods: before and after the 2015 Paris Agreement. Subsequently, we conduct the regression analysis described in Equation (2) on each subsample.

Table 6 reports the regression results. Models 1 and 2 present the findings from the pre-2015 Paris Agreement period, whereas Models 3 and 4 outline the post-Agreement period results. We incorporate firm and year × industry fixed effects into all models. Our results align with prior research, indicating that the detrimental consequences of climate change exposure on high leverage costs only emerge in the sub-period after the 2015 Paris Agreement. The coefficient estimates on $CCEXPO \times HLEV$ are negative and significant at the 10% level in Models 3 and 4.

4.4 Effect of Climate Change Exposure on High Leverage Costs: Industry Variations

To further investigate how industry variation in climate change exposure may impact our analyses, we construct two additional subsample tests. Following McGurr and DeVaney (1998) and Ho *et al.* (2005), and Kile and Phillips (2009), we identify firms with 3-digit SIC codes of 283, 357, 366, 367, 382, 384, 481, 482, 489, 737, and 873 as high-tech firms; firms with 2-digit SIC codes ranging from 20 to 39 (excluding those classified as high-tech) as manufacturing firms; and firms with 4-digit SIC codes ranging from 5200 to 5999 as retail firms. We then conduct the regression analysis described in Equation (2) on each subsample.

Table 7, Panel A, reports the results of the combined climate change exposure. Models 1 and 2 present the results for a sample of firms in the high-tech sector; Models 3 and 4 present results for a sample of firms in the manufacturing and retail sectors. The coefficient estimates on $CCEXPO \times HLEV$ are negative and significant at the 10% level in the high-tech sector, and negative and significant at the 1% level in the manufacturing and retail sectors. Next, we replace the combined climate exposure measure, $CCEXPO$, with regulatory exposure measure ($REGEXPO$) and physical exposure measure ($PHYEXPO$), respectively.

Table 7, Panel B, reports the regression results. Models 1 and 3 report the results of regulatory exposure. The coefficient estimates of $REGEXPO \times HLEV$

Table 6: Climate change exposure and the costs of high leverage: Paris Agreement.

	Before Paris Agreement		After Paris Agreement	
	(1)	(2)	(3)	(4)
$CCEXPO_{t-2} \times HLEV_{t-2}$	-0.0087	-0.0089	-0.0079^{*}	-0.0076^{*}
	(-1.35)	(-1.37)	(-1.77)	(-1.71)
$CCEXPO_{t-2}$	0.0108^{***}	0.0109^{***}	0.0027	0.0027
	(3.37)	(3.41)	(0.41)	(0.41)
$CSR_{t-2} \times HLEV_{t-2}$		0.0091^{**}		0.0043
		(2.45)		(0.72)
CSR_{t-2}		-0.0096^{***}		-0.0056
		(-4.16)		(-1.03)
$HLEV_{t-2}$	-0.0238^{***}	-0.0242^{***}	0.0045	0.0041
	(-3.98)	(-4.05)	(0.41)	(0.37)
$SIZE_{t}$	0.0660^{***}	0.0661^{***}	0.2220^{***}	0.2231^{***}
	(8.18)	(8.24)	(10.57)	(10.68)
$COMPETITION_{t}$	0.1963	0.2073	0.0263	0.0004
	(1.23)	(1.30)	(0.04)	(0.00)
$PROFIT_{t-1}$	-0.0995^{***}	-0.1002^{***}	-0.2158^{***}	-0.2144^{***}
	(-3.28)	(-3.30)	(-2.74)	(-2.72)
$PROFIT_{t-2}$	-0.0960^{***}	-0.0970^{***}	-0.0125	-0.0113
	(-2.99)	(-3.03)	(-0.17)	(-0.15)
$INVESTMENT_{t-1}$	0.0539	0.0523	0.0859	0.0787
	(0.71)	(0.69)	(0.36)	(0.33)
$INVESTMENT_{t-2}$	-0.0224	-0.0220	0.0412	0.0371
	(-0.28)	(-0.28)	(0.18)	(0.17)
$SELLEXP_{t-1}$	0.0914^{**}	0.0912^{**}	0.2130^{*}	0.2139^{*}
	(2.36)	(2.35)	(1.75)	(1.75)
$SELLEXP_{t-2}$	0.0293	0.0287	0.0353	0.0381
	(0.94)	(0.92)	(0.52)	(0.56)
$COGS_{t-1}$	-0.3420^{***}	-0.3438^{***}	-0.4536^{***}	-0.4538^{***}
	(-10.42)	(-10.51)	(-6.57)	(-6.57)
$COGS_{t-2}$	0.1754^{***}	0.1730^{***}	0.1358^{**}	0.1352^{**}
	(5.80)	(5.72)	(2.32)	(2.31)
$PENALTY_{t-1}$	-0.0010^{**}	-0.0010^{**}	-0.0006	-0.0006
	(-2.51)	(-2.52)	(-0.85)	(-0.89)
$PENALTY_{t-2}$	-0.0010^{**}	-0.0009^{**}	-0.0012^{*}	-0.0012^{*}
	(-2.48)	(-2.41)	(-1.84)	(-1.86)
$CONSTANT$	0.0286	0.0263	-0.1029	-0.0916
	(0.31)	(0.28)	(-0.30)	(-0.27)
N	15,257	15,257	4,781	4,781
R-squared	21.05%	21.16%	19.29%	19.33%
Firm F.E.	Y	Y	Y	Y
Year × Industry F.E.	Y	Y	Y	Y

Note: This table reports the results of the effect of climate exposure on high leverage costs before and after the 2015 Paris Agreement. Models 1 and 2 report the regression results for the pre-Agreement sample; Models 3 and 4 report regression the results for the post-Agreement sample. The dependent variable is industry-adjusted sales growth ($SALES\_G$). The main variable of interest is the interaction term between industry-adjusted climate change exposure ($CCEXPO$) and a dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample ($HLEV$). Additional variable definitions are in the Appendix. All control variables are adjusted to their industry-year means and are winsorized at the 1st and 99th percentiles. Further, we require that each industry-year contains at least four firms to be qualified in the analysis so that the industry-year mean is not biased toward outliers. The sample period is 2004–2020. The t-statistics based on heteroskedasticity-robust standard errors and clustered at the firm level are reported in parentheses. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level.

Table 7: Climate change exposure and the costs of high leverage: High-tech vs. manufacturing and retail industries.

Panel A

	High-tech Industry		Manufacturing and Retail Industries	
	(1)	(2)	(3)	(4)
$CCEXPO_{t-2} \times HLEV_{t-2}$	-0.0313^{*}	-0.0324^{*}	-0.0131^{***}	-0.0130^{***}
	(−1.82)	(−1.79)	(−2.93)	(−2.92)
$CCEXPO_{t-2}$	0.0093	0.0098	0.0048	0.0048
	(1.14)	(1.22)	(1.50)	(1.49)
$CSR_{t-2} \times HLEV_{t-2}$		0.0013		0.0053
		(0.22)		(1.38)
CSR_{t-2}		-0.0101^{***}		-0.0063^{**}
		(−2.93)		(−2.27)
$HLEV_{t-2}$	−0.0124	−0.0124	-0.0171^{***}	-0.0172^{***}
	(−1.34)	(−1.31)	(−2.61)	(−2.61)
$SIZE_t$	0.0387^{***}	0.0399^{***}	0.0426^{***}	0.0427^{***}
	(3.69)	(3.80)	(4.43)	(4.45)
$COMPETITION_t$	0.0735	0.0998	0.1029	0.1133
	(0.23)	(0.32)	(0.50)	(0.55)
$PROFIT_{t-1}$	-0.1202^{***}	-0.1216^{***}	−0.0088	−0.0102
	(−2.62)	(−2.64)	(−0.20)	(−0.23)
$PROFIT_{t-2}$	−0.0377	−0.0389	-0.1308^{***}	-0.1314^{***}
	(−0.90)	(−0.92)	(−2.64)	(−2.66)
$INVESTMENT_{t-1}$	-0.2358^{*}	-0.2451^{*}	0.0861	0.0859
	(−1.86)	(−1.95)	(0.74)	(0.74)
$INVESTMENT_{t-2}$	0.0468	0.0435	−0.1304	−0.1313
	(0.35)	(0.33)	(−1.19)	(−1.19)
$SELLEXP_{t-1}$	0.0529	0.0528	0.0350	0.0352
	(1.24)	(1.24)	(0.85)	(0.85)
$SELLEXP_{t-2}$	0.0127	0.0126	0.0513	0.0511
	(0.36)	(0.35)	(1.02)	(1.02)
$COGS_{t-1}$	-0.4211^{***}	-0.4218^{***}	-0.3956^{***}	-0.3966^{***}
	(−7.14)	(−7.10)	(−9.97)	(−10.01)
$COGS_{t-2}$	0.2387^{***}	0.2355^{***}	0.2260^{***}	0.2244^{***}
	(4.34)	(4.28)	(5.65)	(5.62)
$PENALTY_{t-1}$	-0.0019^{***}	-0.0019^{***}	−0.0001	−0.0001
	(−2.60)	(−2.69)	(−0.29)	(−0.33)
$PENALTY_{t-2}$	-0.0014^{**}	-0.0014^{**}	−0.0007	−0.0007
	(−1.99)	(−1.98)	(−1.61)	(−1.59)
CONSTANT	−0.0910	−0.1170	-0.4329^{***}	-0.4382^{***}
	(−0.54)	(−0.70)	(−3.66)	(−3.72)
N	6,830	6,830	8,342	8,342
R-squared	9.14%	9.31%	21.25%	21.31%
Firm F.E.	Y	Y	Y	Y
Year × Industry F.E.	Y	Y	Y	Y

Panel B

	High-tech Industry		Manufacturing and Retail Industries	
	(1)	(2)	(3)	(4)
$REGEXPO_{t-2} \times HLEV_{t-2}$	-0.0302^{*}		-0.0123^{**}	
	(−1.78)		(−2.37)	
$REGEXPO_{t-2}$	0.0109		0.0057^{*}	
	(1.11)		(1.82)	
$PHYEXPO_{t-2} \times HLEV_{t-2}$		−0.0053		-0.0230^{*}
		(−1.62)		(−1.86)
$PHYEXPO_{t-2}$		0.0031		0.0009
		(0.62)		(0.28)
$CSR_{t-2} \times HLEV_{t-2}$	0.0022	0.0024	0.0028	0.0030
	(0.36)	(0.40)	(0.77)	(0.81)
CSR_{t-2}	-0.0101^{***}	-0.0100^{***}	-0.0044^{*}	-0.0045^{*}
	(−2.90)	(−2.87)	(−1.65)	(−1.70)

Table 7: Continued.

Panel B				
	High-tech Industry		Manufacturing and Retail Industries	
	(1)	(2)	(3)	(4)
$HLEV_{t-2}$	−0.0138	−0.0144	−0.0205***	−0.0198***
	(−1.43)	(−1.48)	(−3.17)	(−3.05)
$SIZE_t$	0.0411***	0.0408***	0.0538***	0.0542***
	(3.84)	(3.82)	(5.42)	(5.45)
$COMPETITION_t$	0.1048	0.1066	0.1017	0.1027
	(0.33)	(0.34)	(0.49)	(0.49)
$PROFIT_{t-1}$	−0.1245***	−0.1244***	−0.0053	−0.0068
	(−2.68)	(−2.68)	(−0.12)	(−0.16)
$PROFIT_{t-2}$	−0.0473	−0.0469	−0.1500***	−0.1509***
	(−1.08)	(−1.07)	(−3.16)	(−3.16)
$INVESTMENT_{t-1}$	−0.2419*	−0.2407*	0.1003	0.1037
	(−1.90)	(−1.89)	(0.85)	(0.89)
$INVESTMENT_{t-2}$	0.0518	0.0516	−0.1526	−0.1470
	(0.38)	(0.38)	(−1.40)	(−1.34)
$SELLEXP_{t-1}$	0.0539	0.0539	0.0399	0.0375
	(1.29)	(1.29)	(1.02)	(0.97)
$SELLEXP_{t-2}$	0.0066	0.0067	0.0396	0.0402
	(0.19)	(0.19)	(0.91)	(0.91)
$COGS_{t-1}$	−0.4304***	−0.4299***	−0.4046***	−0.4019***
	(−7.10)	(−7.11)	(−10.55)	(−10.49)
$COGS_{t-2}$	0.2371***	0.2369***	0.2354***	0.2358***
	(4.24)	(4.24)	(6.07)	(6.08)
$PENALTY_{t-1}$	−0.0021***	−0.0021***	0.0001	0.0001
	(−2.94)	(−2.91)	(0.16)	(0.16)
$PENALTY_{t-2}$	−0.0013*	−0.0013*	−0.0008*	−0.0008*
	(−1.90)	(−1.90)	(−1.78)	(−1.78)
CONSTANT	−0.0856	−0.0833	−0.2183*	−0.2195*
	(−0.52)	(−0.51)	(−1.76)	(−1.77)
Observations	6,694	6,694	8,968	8,968
R-squared	9.10%	9.07%	20.15%	20.12%
Firm F.E.	Y	Y	Y	Y
Year × Industry F.E.	Y	Y	Y	Y

Note: Panel A reports the results of the effect of climate exposure on high leverage costs in different business sectors. Models 1 and 2 report regression results for a sample of firms in the high-tech sector; Models 3 and 4 report regression results for a sample in the manufacturing and retail sectors. Following Kile and Phillips (2009), we identify high-tech sectors with 3-digit SIC codes 283, 357, 366, 367, 382, 384, 481, 482, 489, 737, and 873. Following Ho *et al.* (2005) and McGurr and DeVaney (1998), we identify manufacturing sectors with 2-digit SIC codes ranging from 20 to 39 (excluding firms classified as high-tech industries), and retail sectors with 4-digit SIC codes ranging from 5200 to 5999. The main variable of interest is the interaction term between industry-adjusted climate change exposure (*CCEXPO*) and a dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample (*HLEV*). Panel B reports the results of the effect of regulatory climate exposure or physical climate exposure on high leverage costs in different business sectors, respectively. Models 1 and 2 report the regression results for a sample of firms in the high-tech sector; Models 3 and 4 report the regression results for a sample in the manufacturing and retail sectors. The dependent variable is industry-adjusted sales growth (SALES_G). The main variables of interest in Models 1 and 3 are the interaction term between industry-adjusted regulatory exposure (*REGEXPO*) and a dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample (*HLEV*). The main variables of interest in Models 1 and 3 are the interaction term between industry-adjusted physical exposure (*PHYEXPO*) and a dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample (*HLEV*). Additional variable definitions are in the Appendix. All control variables are adjusted to their industry-year means and are winsorized at the 1st and 99th percentiles. Further, we require that each industry-year contains at least four firms to be qualified in the analysis so that the industry-year mean is not biased toward outliers. The sample period is 2004–2020. The t-statistics based on heteroskedasticity-robust standard errors and clustered at the firm level are reported in parentheses. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level.

are negative and significant in both Models 1 and 3, suggesting that regulatory exposure negatively affects highly leveraged firms in both subsamples. Models 2 and 4 report the results of physical exposure. The effect of physical exposure on high leverage costs varies across industries: manufacturing and retail firms are more vulnerable to physical exposure, while high-tech firms exhibit greater resilience. The coefficient estimates on $PHYEXPO \times HLEV$ are negative and significant in Model 4, but not significant in Model 2.

5 Channels of Influence: Stakeholder Responses

In this section, we extend our analyses by studying whether climate exposure influences high leverage costs via a wide set of stakeholders. To test this idea, we examine how the main relation changes under conditions modifying stakeholder behaviors.

In Table 8, Panel A, we investigate the relation between climate exposure and high leverage costs related to customer factors. Previous research suggests that customer purchasing behavior is heavily dependent on industries. Corey (1991) posits that firms with industrial purchasing typically have well-established processes and procedures, whereas those producing consumer goods are more susceptible to social and psychological influences. In Models 1 and 2, we classify firms producing consumer goods as operating in high customer sensitivity industries, and firms with industrial purchasing as operating in low customer sensitivity industries. We employ the industry classification system of Lev *et al.* (2010). High customer sensitivity industries have SIC codes [0, 999], [2000, 2399], [2500, 2599], [2700, 2799], [2830, 2869], [3000, 3219], [3420, 3429], 3523, [3600, 3669], [3700, 3719], 3751, [3850, 3879], [3880, 3999], 4813, [4830, 4899], [5000, 5079], [5090, 5099], [5130, 5159], [5220, 5999], [6000, 6999], [7000, 7299], and [7400, 9999]. The rest are considered low customer sensitivity industries.

In Models 3 and 4, we further examine firms' customer characteristics using customer segment data. We split firms into two samples by their major customer type. We argue that a firm operates in high customer sensitivity industries if their primary customer segment comprises retail customers and a firm operates in low customer sensitivity industries if their main customer segment comprises government and corporations.

Customer behaviors also depend on product differentiation. Customers are more averse to high leverage if they purchase differentiated goods, since those products carry after-sale services, so customers cannot easily switch (Bae *et al.*, 2019). We rely on product similarity, as documented by the Hoberg–Phillips Data Library (Hoberg and Phillips, 2010, 2016). In Models 5 and 6, we define a firm as having low (high) product differentiation if its product similarity score is above (below or equal to) the median two years before the base year.

Table 8: Climate change exposure and the costs of high leverage: Customers, competitors, and employees.

Panel A	Customers – Industry Sensitivity		Customers – Major Customer Type		Customers – Product Differentiation	
	Low	High	Retail	Government and Corporations	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)
$CCEXPO_{t-2}$	−0.0132	−0.0141***	−0.0193**	0.0017	0.0013	−0.0145***
$\times HLEV_{t-2}$	(−1.53)	(−2.82)	(−2.31)	(0.18)	(0.10)	(−3.39)
$CCEXPO_{t-2}$	0.0099**	0.0060	0.0110*	0.0051	0.0230***	0.0050
	(2.51)	(1.37)	(1.72)	(1.23)	(3.34)	(1.41)
$CSR_{t-2} \times HLEV_{t-2}$	0.0073*	0.0026	−0.0018	0.0080	0.0023	0.0043
	(1.67)	(0.62)	(−0.24)	(1.23)	(0.44)	(1.15)
CSR_{t-2}	−0.0094***	−0.0062**	−0.0025	−0.0134***	−0.0127***	−0.0041
	(−3.21)	(−2.19)	(−0.55)	(−3.37)	(−3.76)	(−1.61)
$HLEV_{t-2}$	−0.0162**	−0.0259***	−0.0303***	−0.0244**	−0.0258***	−0.0117**
	(−2.33)	(−3.69)	(−2.75)	(−2.55)	(−2.98)	(−2.04)
$SIZE_t$	0.0625***	0.0457***	0.0756***	0.0773***	0.0594***	0.0652***
	(7.22)	(4.72)	(4.84)	(6.56)	(6.44)	(7.63)
$COMPETITION_t$	0.0318	0.2573	−0.1731	0.0378	−0.2025	0.2374
	(0.15)	(1.01)	(−0.51)	(0.12)	(−0.63)	(1.34)
$PROFIT_{t-1}$	−0.1151***	−0.0170	−0.1821***	−0.1161***	−0.1151***	−0.0535
	(−2.83)	(−0.42)	(−2.67)	(−2.79)	(−2.76)	(−1.10)

$PROFIT_{t-2}$	−0.0323	−0.0806*	−0.0796	−0.0839*	−0.0654	−0.0649
	(−0.98)	(−1.89)	(−1.48)	(−1.78)	(−1.64)	(−1.31)
$INVESTMENT_{t-1}$	0.0108	0.1428	−0.1948	0.0642	0.0399	0.0544
	(0.11)	(1.40)	(−1.28)	(0.54)	(0.44)	(0.46)
$INVESTMENT_{t-2}$	−0.0487	0.0268	0.1330	−0.0718	−0.0211	−0.0716
	(−0.46)	(0.30)	(0.98)	(−0.53)	(−0.22)	(−0.64)
$SELLEXP_{t-1}$	0.1163*	0.0405	−0.1491***	0.1648***	0.0494	0.0442
	(1.78)	(0.99)	(−3.23)	(5.73)	(1.02)	(1.25)
$SELLEXP_{t-2}$	0.0793***	−0.0035	0.1534**	0.0706***	0.0145	0.0374
	(2.64)	(−0.10)	(2.11)	(5.21)	(0.36)	(0.93)
$COGS_{t-1}$	−0.3727***	−0.3278***	−0.4849***	−0.3105***	−0.3102***	−0.3647***
	(−9.42)	(−7.59)	(−8.99)	(−6.01)	(−7.16)	(−9.73)
$COGS_{t-2}$	0.1896***	0.1552***	0.3441***	0.1935***	0.1200***	0.2446***
	(5.42)	(3.77)	(6.50)	(4.15)	(2.97)	(6.94)
$PENALTY_{t-1}$	−0.0013**	−0.0003	−0.0006	−0.0004	−0.0019***	−0.0002
	(−2.58)	(−0.73)	(−0.73)	(−0.58)	(−3.52)	(−0.42)
$PENALTY_{t-2}$	−0.0014***	−0.0007	−0.0005	−0.0000	−0.0012**	−0.0011***
	(−2.81)	(−1.59)	(−0.63)	(−0.05)	(−2.14)	(−2.69)
CONSTANT	0.1930*	−0.1181	0.0159	0.0211	−0.0692	−0.1161
	(1.65)	(−0.85)	(0.09)	(0.13)	(−0.44)	(−1.15)
N	11,093	8,497	7,259	7,037	9,596	10,318
R-squared	22.03%	17.56%	25.99%	27.05%	26.17%	19.65%
Firm F.E.	Y	Y	Y	Y	Y	Y
Year × Industry F.E.	Y	Y	Y	Y	Y	Y

Table 8: Continued.

Panel B	Competitors – Product Market Competition		Employees – Labor Intensity	
	Low	High	Low	High
	(1)	(2)	(3)	(4)
$CCEXPO_{t-2} \times HLEV_{t-2}$	−0.0079	−0.0148***	−0.0069	−0.0141**
	(−0.79)	(−3.77)	(−1.07)	(−2.01)
$CCEXPO_{t-2}$	0.0114**	0.0053*	0.0048	0.0054
	(2.04)	(1.74)	(1.29)	(1.21)
$CSR_{t-2} \times HLEV_{t-2}$	0.0074	0.0062	0.0108**	0.0102**
	(1.49)	(1.57)	(2.18)	(2.44)
CSR_{t-2}	−0.0139***	−0.0037	−0.0145***	−0.0089***
	(−4.20)	(−1.28)	(−4.44)	(−2.87)
$HLEV_{t-2}$	−0.0203***	−0.0131*	−0.0320***	−0.0040
	(−2.67)	(−1.95)	(−4.41)	(−0.51)
$SIZE_t$	0.0726***	0.0609***	0.0747***	0.0527***
	(6.94)	(6.99)	(7.24)	(5.58)
$COMPETITION_t$	0.1894	0.2004	0.1009	0.3320**
	(0.81)	(1.10)	(0.46)	(2.29)
$PROFIT_{t-1}$	−0.1428***	−0.0751**	−0.0991**	−0.0875**
	(−2.63)	(−2.09)	(−2.25)	(−2.30)
$PROFIT_{t-2}$	−0.0429	−0.0425	−0.1281***	0.0428
	(−1.12)	(−0.93)	(−2.85)	(1.27)
$INVESTMENT_{t-1}$	0.1234	0.0661	0.0385	0.0548
	(1.12)	(0.76)	(0.36)	(0.64)
$INVESTMENT_{t-2}$	−0.0285	0.0003	−0.0374	0.0670
	(−0.23)	(0.00)	(−0.33)	(0.78)
$SELLEXP_{t-1}$	0.1436***	0.0557	0.0607	0.1051*
	(5.92)	(0.79)	(1.39)	(1.72)

$SELLEXP_{t-2}$	0.0527**	0.0210	0.0103	0.0657
	(2.21)	(0.26)	(0.31)	(1.62)
$COGS_{t-1}$	−0.3105***	−0.3708***	−0.2874***	−0.3974***
	(−7.74)	(−8.99)	(−7.33)	(−8.40)
$COGS_{t-2}$	0.1992***	0.1825***	0.0809**	0.2710***
	(5.31)	(4.29)	(2.07)	(6.23)
$PENALTY_{t-1}$	−0.0020***	−0.0003	−0.0011*	−0.0012***
	(−3.28)	(−0.71)	(−1.96)	(−2.59)
$PENALTY_{t-2}$	−0.0008	−0.0010**	−0.0017***	−0.0006
	(−1.46)	(−2.34)	(−3.30)	(−1.43)
CONSTANT	0.0441	0.0968	−0.0425	−0.1476
	(0.34)	(1.13)	(−0.36)	(−1.12)
N	8,694	10,139	5,061	5,191
R-squared	29.11%	9.18%	22.15%	16.96%
Firm F.E.	Y	Y	Y	Y
Year × Industry F.E.	Y	Y	Y	Y

Note: Panel A reports the results of the effect of climate exposure on high leverage costs related to customer characteristics. The dependent variable is industry-adjusted sales growth (*SALES_G*). The main variable of interest is the interaction term between industry-adjusted climate change exposure (*CCEXPO*) and a dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample (*HLEV*). In Models 1 and 2, high (low) customer sensitivity refers to industries in which the predominant customer is a consumer (industrial buyer). Following Lev *et al.* (2010), high customer sensitivity industries have SIC4 ranges [0, 999], [2000, 2399], [2500, 2599], [2700, 2799], [2830, 2869], [3000, 3219], [3420, 3429], 3523, [3600, 3669], [3700, 3719], 3751, [3850, 3879], [3880, 3999], 4813, [4830, 4899], [5000, 5079], [5090, 5099], [5130, 5159], [5220, 5999], [6000, 6999], [7000, 7299], and [7400, 9999]; the remaining industries are defined as low customer sensitivity industries. In Models 3 and 4, we categorized firms into two distinct groups: one comprised firms of which primary customer segment consisted of retail customers, while the other comprised firms of which main customer segment consisted of government and corporations. In Models 5 and 6, we define a firm as having low (high) product differentiation if the product similarity score is above (below or equal to) the median two years before the base year. We rely on product similarity created by the Hoberg–Phillips Data Library. Panel B reports the results of the effect of climate exposure on high leverage costs related to industry concentration and labor intensity. The dependent variable is industry-adjusted sales growth (*SALES_G*). The main variable of interest is the interaction term between industry-adjusted climate change exposure (*CCEXPO*) and a dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample (*HLEV*). In Models 1 and 2, we classify an industry as highly (less) concentrated if its HHI is above (below) the overall sample median two years before the base year. In Models 3 and 4, we classify an industry as high labor intensity if the wage-to-capital ratio is greater than the median for all industries two years before the base year. Additional variable definitions are in the Appendix. All control variables are adjusted to their industry-year means and are winsorized at the 1st and 99th percentiles. Further, we require that each industry-year contains at least four firms to be qualified in the analysis so that the industry-year mean is not biased toward outliers. The sample period is 2004–2020. The t-statistics based on heteroskedasticity-robust standard errors and clustered at the firm level are reported in parentheses. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level.

In Models 1 and 2, the coefficient estimates on *CCEXPO* × *HLEV* are significant at the 1% level (insignificant) for high (low) customer sensitivity industries and for firms with high (low) industry sensitivity. In Models 3 and 4, the coefficient estimates on *CCEXPO* × *HLEV* are negative and significant at the 5% level (insignificant) for firms of which the main customer segment comprises retail (government and corporation) customers. In Models 5 and 6, the coefficient estimates on *CCEXPO* × *HLEV* are significant at the 1% level (insignificant) for firms with high (low) product differentiation. Overall, the results show that climate exposure intensifies high leverage costs in conditions where customers display more sensitive reactions.

In Table 8, Panel B, we further examine the role of competitors and employees. We expect highly leveraged firms facing strong competition in the product market to experience substantial market share losses, amplifying the effect of climate exposure on high leverage costs. In Models 1 and 2, we divide our sample into low and high product market competition categories. Low (high) product market competition refers to the Herfindahl index of firm sales that is above (below) the overall sample median two years prior to the base year. A lower Herfindahl index implies a more competitive market with more firms exerting greater competitive pressure. Our findings indicate that climate exposure is more likely to affect the sales growth of highly leveraged firms in more competitive environments. The coefficient estimates on *CCEXPO* × *HLEV* are significant at the 1% level (insignificant) in the subsample with more (less) market competitions.

As mentioned earlier, implicit contracts between employees and firms include job training, work environment quality, and career development. High leverage could cause a firm to breach these implicit contracts, resulting in significant costs for employees, particularly those in high-intensity labor. In Models 3 and 4, we classify an industry as a high (low) labor intensity industry if the wage-to-capital ratio is greater (smaller) than the median for all industries two years before the base year. We find that the coefficient estimates on *CCEXPO* × *HLEV* are significant at the 5% level (insignificant) in the high (low) labor intensity subsample. The finding is consistent with our notion that climate exposure is more likely to affect employees who are highly sensitive to firm leverage.

Last, we attempt to understand how investors' capital decisions toward high leverage are influenced by climate exposure. Specifically, we examine equity issuance, defined as the difference between equity issuances minus equity repurchases scaled by total assets, and debt issuance, defined as the difference between long-term debt issuance and debt reduction scaled by total assets.[17]

In Table 9, we replace the dependent variable sales growth with the capital issuance measures. Notably, the standalone terms of *HLEV* load significantly

[17]See the Appendix for variable definitions and construction.

positively on equity issuance and significantly negatively on debt issuance. This suggests that firms carrying high leverage may find it harder to issue more debt, while at the same time they may need to issue more equity to balance their capital structure. More importantly, the coefficient estimates on $CCEXPO \times HLEV$ are significantly negative (insignificant) for debt issuance (equity issuance). This implies strong adverse debtholder reactions towards highly leveraged firms with high climate exposure. In this case, debtholders may not be willing to provide more capital. These results are consistent with the debt overhang theory (Myers, 1977).

Collectively, the findings presented in Tables 8 and 9 indicate adverse responses from stakeholders toward highly leveraged firms when they are concurrently exposed to climate change risk. These results provide insights into the mechanisms through which climate exposure impacts the costs of high leverage.

6 Robustness Tests

To ensure the robustness of our main findings, we conduct a series of tests to investigate the sensitivity of our results. This section discusses the outcomes of these robustness tests and discusses their implications for our main conclusions. All results are presented in the Online Appendix A1 to A9.

To begin with, various studies have highlighted limitations and challenges associated with the MSCI ESG STATS dataset (Mackey *et al.*, 2007; Goss and Roberts, 2011). Additionally, researchers have demonstrated significant discrepancies in firms' CSR ratings (Berg *et al.*, 2022; Avramov *et al.*, 2022) and have suggested using multiple datasets as a robustness check. To address this concern, we utilize the new MSCI ESG Ratings dataset to measure a firm's CSR performance. MSCI ESG Ratings is an integrated rating system that aims "to measure a company's resilience to long-term, financially relevant ESG risks." It covers around 2,800 companies and tracks 35 ESG Key Issues that are related to a firm's core business and industry-specific features. MSCI states that although the ESG score and pillar scores before 2011 are backfilled into the time-series based on new methodologies, the data used to create those calculations were point-in-time, and no new research was incorporated.[18] We replace a firm's overall CSR score with its new ESG rating and replicate the main analyses. Table A1 in Online Appendix reports the new results. They are consistent with our previous findings. In Models 1 and 2, we replicate the baseline regression outlined in Equation (2). The coefficient estimates for $CCEXPO \times HLEV$ are negative and statistically significant at the 1% level.

[18]For more information about MSCI ESG Rating Methodology, see https://www.msci.com/our-solutions/esg-investing/esg-ratings.

Table 9: Climate change exposure and the costs of high leverage: Investors.

	Investors – Equity Issuance		Investors – Debt Issuance	
	(1)	(2)	(3)	(4)
$CCEXPO_{t-2} \times HLEV_{t-2}$	−0.0020	−0.0019	−0.0054**	−0.0053*
	(−1.40)	(−1.38)	(−1.99)	(−1.96)
$CCEXPO_{t-2}$	−0.0001	−0.0001	0.0011	0.0011
	(−0.08)	(−0.09)	(0.74)	(0.73)
$CSR_{t-2} \times HLEV_{t-2}$		0.0010		0.0023
		(0.68)		(1.18)
CSR_{t-2}		0.0003		−0.0001
		(0.27)		(−0.05)
$HLEV_{t-2}$	0.0140***	0.0138***	−0.0459***	−0.0461***
	(5.86)	(5.82)	(−13.24)	(−13.27)
$SIZE_t$	0.0233***	0.0234***	0.0840***	0.0841***
	(4.66)	(4.66)	(17.02)	(17.04)
$COMPETITION_t$	−0.1664	−0.1670	0.0256	0.0258
	(−1.21)	(−1.22)	(0.29)	(0.29)
$PROFIT_{t-1}$	−0.1366***	−0.1366***	0.0317	0.0318
	(−2.79)	(−2.79)	(1.16)	(1.16)
$PROFIT_{t-2}$	−0.0788***	−0.0789***	−0.0069	−0.0070
	(−2.77)	(−2.77)	(−0.26)	(−0.26)
$INVESTMENT_{t-1}$	0.1285***	0.1285***	0.3534***	0.3531***
	(3.14)	(3.14)	(8.20)	(8.20)
$INVESTMENT_{t-2}$	0.0371	0.0374	−0.0475	−0.0470
	(1.02)	(1.03)	(−1.19)	(−1.18)
$SELLEXP_{t-1}$	−0.0037	−0.0038	0.0213*	0.0213*
	(−0.37)	(−0.37)	(1.95)	(1.95)
$SELLEXP_{t-2}$	−0.0278***	−0.0278***	0.0182**	0.0182**
	(−3.32)	(−3.32)	(2.41)	(2.41)
$COGS_{t-1}$	0.0010	0.0011	0.1534***	0.1536***
	(0.08)	(0.09)	(9.10)	(9.10)
$COGS_{t-2}$	0.0341*	0.0341*	0.0149	0.0148
	(1.90)	(1.90)	(0.94)	(0.94)
$PENALTY_{t-1}$	−0.0002	−0.0002	−0.0005**	−0.0005**
	(−1.10)	(−1.09)	(−2.19)	(−2.18)
$PENALTY_{t-2}$	−0.0004**	−0.0004**	−0.0005**	−0.0005**
	(−2.45)	(−2.45)	(−2.04)	(−2.05)
CONSTANT	0.1237*	0.1245*	−0.0028	−0.0019
	(1.70)	(1.71)	(−0.04)	(−0.02)
N	18,304	18,304	18,858	18,858
R-squared	10.80%	10.80%	11.92%	11.93%
Firm F.E.	Y	Y	Y	Y
Year × Industry F.E.	Y	Y	Y	Y

Note: This table reports the results of the effect of climate exposure on the costs of high leverage related to financing capacities. The dependent variable in Models 1 and 2 is firms' equity issuance (*EQUITY_ISSUE*); the dependent variable in Models 3 and 4 is firms' debt issuance (*DEBT_ISSUE*). The main variable of interest is the interaction term between industry-adjusted climate change exposure (*CCEXPO*) and a dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample (*HLEV*). Additional variable definitions are in the Appendix. All control variables are adjusted to their industry-year means and are winsorized at the 1st and 99th percentiles. Further, we require that each industry-year contains at least four firms to be qualified in the analysis so that the industry-year mean is not biased toward outliers. The sample period is 2004 –2020. The t-statistics based on heteroskedasticity-robust standard errors and clustered at the firm level are reported in parentheses. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level.

In Models 3 and 4, we split the sample based on party affiliation. We find that the coefficient estimates for $CCEXPO \times HLEV$ are only negative and significant in the subsample of firms headquartered in blue states. In Models 5 and 6, we further divide the sample by the passage of the Paris Agreement. We observe that the coefficient estimates for $CCEXPO \times HLEV$ are only negative and significant in the sub-period after the 2015 Paris Agreement.

Secondly, in our main tests, we use a firm's aggregate CSR score. However, this aggregate score may not fully capture the nuances of the firm's environment-related performance. To address this concern, we replace the overall CSR score with the environmental area score. This adjustment allows us to specifically focus on the relation between climate concerns and environmental performance, as highlighted by multiple studies (Engle *et al.*, 2020; Pástor *et al.*, 2022). The results, presented in Table A2 in Online Appendix, remain consistent with the findings from the main regression analyses. We also replace a firm's overall ESG rating with its environmental pillar rating. The results, presented in Table A3 in Online Appendix, demonstrate consistent findings as well.

Furthermore, we conduct separate analyses controlling for CSR strengths and concerns. In Table A4 in Online Appendix, we replicate the baseline regression as outlined in Equation (2) and replace the overall CSR score with separate control variables for CSR strengths and concerns. In Table A5 in Online Appendix, we split the sample based on party affiliation, and in Table A6 in Online Appendix, we divide the sample by passage of the Paris Agreement. The results of these additional tests remain consistent with the main findings. Finally, we use environmental area strengths and concerns as control variables in Tables A7, A8, and A9. The results remain robust as well.

7 Conclusion

Climate change exposes firms to a new set of uncertainties in business operation, policy change, and shifts in social sentiment. Highly leveraged firms are especially vulnerable to climate change shocks, and may be subject to stricter scrutiny from stakeholders. In this paper, we take a newly developed measure of firm-level climate change exposure, and examine whether climate change concerns intensify stakeholders' adverse reactions and thereby increase the costs of high leverage.

Based on a sample of 2,547 U.S. firms from 2004 to 2020, we document that the costs of high leverage rise with firms' climate change exposure. The effect is both economically and statistically significant. Our empirical findings are robust to the inclusion of a variety of control variables, including firms' CSR performance. It shows that climate change exposure stands independently from CSR, and is not fully captured by traditional social or environmental measures. In additional analyses, we find that the relation between climate change exposure and the costs of high leverage vary by stakeholders' political affiliation, climate awareness, consumption sensitivity, product market competition, and labor intensity. Moreover, different types of climate change exposure (i.e., physical risk exposure and transition risk exposure) have distinct effects on firms in different sectors.

Our study contributes to the fast-growing literature on climate finance research. To the best of our knowledge, our paper is the first to incorporate climate change exposure into an examination of the high leverage costs. The empirical results provide valuable insights into how climate change can affect firm value through the channels of customers, competitors, employees, and investors. Our paper extends the understanding of how climate change affects firms' financial and capital structure decisions, and will help further future streams of research on the implications of climate risk. For example, does climate change exposure always bring negative effects? In our context, we document negative effects on corporate performance. However, from a macro-level perspective, climate exposure may play a positive role. Specifically, if climate change drives out vulnerable firms in the long run, then it should lead to more efficient allocation of scarce economic resources, consistent with the theory of creative destruction (Schumpeter, 1942). Further research addressing this question is warranted.

Appendix. Variable definitions

Variable	Definition	Source
Panel A. Climate change exposure variables		
REGEXPO	Firm's transition risk exposure to climate change, of which the initial bigrams include keywords associated with climate-related regulatory interventions.	Sautner *et al.* (2023)
PHYEXPO	Firm's physical risk exposure to climate change, of which the initial bigrams include keywords associated with climate-related physical hazards.	As above
CCEXPO	Firm's overall exposure to climate change risk, captured by averaging *REGEXPO* and *PHYEXPO*.	As above
Panel B. High-leverage variable		
HLEV	A dummy variable that equals 1 if, in that year, the firm's long-term debt-to-assets ratio ranks in the top three deciles of the overall sample.	Compustat
Panel C. Outcome variables		
SALES_G	Sales growth, equal to percentage growth in sales from the end of the previous year to the end of the current year.	Compustat
EQUITY_ISSUE	Net equity issuances, equal to equity issuances minus equity repurchases divided by total assets (Compustat items: (SSTK-PRSTKC)/AT).	As above
DEBT_ISSUE	Net debt issuances, equal to long-term debt issuances minus long-term debt reductions divided by total assets (Compustat items: (DLTIS-DLTR)/AT).	As above
Panel D. Other variables		
CSR	For each firm-year, we calculate a firm's overall CSR score by aggregating all seven areas except for corporate governance and obtain *CSR* using the number of strengths minus the number of concerns.	MSCI ESG STATS
SIZE	Natural logarithm of total assets.	Compustat
PROFIT	Profitability, captured by operating earnings plus depreciation over total assets.	As above
INVESTMENT	Investment, captured by capital expenditures over total assets.	As above
SELLEXP	Selling expenses, the ratio of advertising and selling expenses to total sales.	As above
COGS	Cost of goods sold, the ratio of cost of goods sold to total sales.	As above

Variable	Definition	Source
COMPETITION	The market share of the four largest firms in a certain industry	As above
PENALTY	The logarithm of 1 plus *Penalty* by each firm from the given year and the following year. Penalty refers to the dollar amount of penalties.	Violation Tracker
BLUE STATE	Dummy variable that equals 1 if a firm's headquarters is in a blue state, and 0 otherwise. We classify a state as blue if it voted Democratic in the last presidential election, and red if it voted Republican.	270towin.com
PARIS AGREEMENT	Dummy variable that equals 1 for years after the Paris Agreement was signed (2015), and 0 otherwise.	Compustat
HIGH-TECH, *MANUFACTURING*, and *RETAILING*	We identify firms with 3-digit SIC codes 283, 357, 366, 367, 382, 384, 481, 482, 489, 737, and 873 as high-tech firms; firms with 2-digit SIC codes ranging from 20 to 39 (excluding firms classified as high-tech firms) as manufacturing firms; and firms with 4-digit SIC codes ranging from 5200 to 5999 as retail firms.	McGurr and DeVaney (1998); Ho *et al.* (2005); Kile and Phillips (2009)
Customer Sensitivity	High customer sensitivity industries have the following four-digit SIC codes: [0, 999], [2000, 2399], [2500, 2599], [2700, 2799], [2830, 2869], [3000, 3219], [3420, 3429], 3523, [3600, 3669], [3700, 3719], 3751, [3850, 3879], [3880, 3999], 4813, [4830, 4899], [5000, 5079], [5090, 5099], [5130, 5159], [5220, 5999], [6000, 6999], [7000, 7299], and [7400, 9999]. The remainder are low customer sensitivity industries.	Lev *et al.* (2010)
Product Differentiation	We rely on product similarity created by the Hoberg–Phillips Data Library. We define a firm as having low (high) product differentiation if the product similarity score is above (below or equal to) the median two years before the base year.	Hoberg–Phillips Data Library
Product Market Competition	Low (High) product market competition refers to the Herfindahl index of firm sales above (below) the overall sample median two years before the base year.	Compustat
Labor Intensity	We classify an industry as high (low) labor intensity if the wage-to-capital ratio is higher (lower) than the median for all industries two years before the base year.	As above

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