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RESEARCH ARTICLE

Firm climate risk, risk management, and bank loan financing

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Abstract

Research Summary: We estimate firm-level physical risk from climate change based on managerial evaluation and firms' exposure to climate hazard events and find that climate risk results in unfavorable corporate financing terms related to bank loans (higher interest paid, higher likelihood of being required to collateralize the loan, and greater number of covenant constraints). Firms that take measures aimed at managing climate risk, including corporate climate strategy, board-level governance, specific or integrated process to cope with climate change, climate opportunities, and climate policy involvement, are able to mitigate the negative impact of climate risk on loan contracting. We further find that higher climate risk level is associated with inferior financial performance and higher default probability, which potentially lead to more stringent loan terms.

Managerial Summary: We examine how a firm's exposure to climate risk affects its financing terms from bank loans. Climate risk exposure is assessed by firm managers and also reflects the degree to which the firm is subject to climate-induced natural disasters. The results show that if exposed to higher climate risk, which hurts financial performance and heightens default likelihood, firms face higher interest rates and more stringent collateral and covenant constraints when borrowing from banks. Nevertheless, firm managers could significantly mitigate this adverse climate impact on loan financing by integrating climate change into business strategy, having the board take direct responsibility for climate change issues, establishing a climate change-focused risk management process, seeking business opportunities from climate change, and engaging in activities that influence climate policies.

KEYWORDS

bank loan terms, climate risk management, credit risk, financial performance, firm climate risk

1 | INTRODUCTION

Climate change is mostly described in a general framework: it is a magnificent challenge to planet Earth and human beings; it manifests through global warming, water shortage, ocean acidification, and coastal flooding; it inflicts catastrophic damage to the economy and welfare, etc. We are frequently warned that, inter alia, unmitigated climate change may increase global mean temperature by 2–5°C by sometime between 2030 and 2060 (IPCC, 2007); an increase of 3°C could result in a 1.3% decline in global income (Nordhaus, 1994); severe climate conditions already caused economic losses of over US$3.08 trillion worldwide between 1996 and 2015 (Kreft, Eckstein, & Melchior, 2017). Shocking and disturbing, such messages are, however, not particularly informative or useful for managers of individual firms. How does climate change impact a firm's business in a precise way? Are firms with differing exposures to climate damage impacted differently? Can managerial climate-related practices make any meaningful difference in mitigating the impact of climate change on the firm? We believe that these questions are of more direct relevance and interest to corporate managers facing the imminent threats from climate change.

Addressing these questions requires *firm-level* analysis. More precisely, we need to know firm-specific exposure to climate risk as well as firm-specific climate risk management practices. The climate business scholarship generally lacks analyses of this kind, as focus is primarily given to the effects of climate conditions on the economic outcomes of geographic areas as a whole (e.g., Dell, Jones, & Olken, 2014; Gallup, Sachs, & Mellinger, 1999; Nordhaus, 2006) or the impact of a geographic area's overall climate risk on corporate performance in that area (Huang, Kerstein, & Wang, 2018). In these studies, the explanatory variable (climate change) is at the *aggregate* level, preventing any clear-cut cross-sectional inferences about the effects of *firm-specific* climate risk and its management on corporate particulars. On the other hand, managers have in-depth understanding of their companies' specific exposures to climate risk. For example, in response to the 2009 Carbon Disclosure Project (CDP) survey,[1] Walgreen Company writes:

[1]The CDP is a nonprofit organization that works with shareholders and firms to disclose climate change-related issues of major corporations; see https://www.cdp.net/en-US/Pages/About-Us.aspx.

> In recent years, changes in weather patterns have resulted in intense hurricanes (Katrina, Rita, Wilma, Ike), wildfires caused by drought (Southern California and Nevada), flooding in the Midwest (Iowa, Minnesota), tornadoes (Mid-west, Mid-southern states). Each of these events caused both a disruption in regular operations as customers and employees were displaced, and increased cost to our organization for repair of damaged facilities, donations to assist local recovery, delivering power, fuel and other necessities (generators, fuel, temporary employee housing, etc.) in order to reopen facilities and serve the public.

A firm's specific exposure to climate risk can also be revealed by the particular spatial distribution of its business, such as the locations of its subsidiaries that could be negatively impacted by climate-related natural disasters. For example, in its 2012 10-K report, O'Reilly Automotive discusses its risk exposure to inclement weather events tied to the sites of its stores:

> Unusually inclement weather, such as significant rain, snow, sleet, freezing rain, flooding, seismic activities and hurricanes, has historically discouraged our customers from visiting our stores during the affected period and reduced our sales, particularly to DIY customers. In addition, our stores located in coastal regions may be subject to increased insurance claims resulting from regional weather conditions and our results of operations and financial condition could be adversely affected.

Therefore, firms have different levels of exposure to climate risk depending on their locations and activities, business inventory, supply chain, continuity plans, etc. (European Bank for Reconstruction and Development [EBRD], 2018). These firm-specific climate risk exposures are bound to have unique influences on corporate operations.

In this work, we tackle this issue by seeking evidence on how firm-specific climate risk, estimated from managerial evaluation of physical climate change exposure and firms' vulnerability to real climate disasters, influences a particularly important factor for business operations—corporate financing through bank loans. Our focus on bank loans is motivated by the following considerations. (1) Bank credit constitutes a significant source of corporate financing. According to Bradley and Roberts (2015), private debt such as bank loans constitutes two to three times the amount of public debt. In addition, debt issues are more than twice the size of equity issues (World Bank, 2015). Consequently, examining the climate impact on firms' bank loan contracting is economically important. (2) Loan contracts have comprehensive features involving both price and non-price terms that are potentially affected by climate risk but have not been explored in extant literature. The price term, mainly consisting of interest and fees, is a critical component of firms' cost of capital. The limited research regarding the effect of climate conditions (e.g., Huang, Kerstein, & Wang, 2018) mainly focuses on firm performance indicators, such as earnings and cash flows, but climate impact on the cost of capital has never been examined. According to the economic theory on firm valuation, earnings and cash flows capture the "numerator" effect while cost of capital relates to the "denominator" (i.e., discount rate) effect (e.g., Kruschwitz & Loeffler, 2005). Evaluating how climate influences the cost of corporate financing is interesting in its own right and also makes an important complement to existing literature. The non-price terms of bank loan contracts, mainly related to collateral and covenants, represent additional, implicit costs to corporate operations because they may significantly constrain firms' asset utilization and capital management (Strahan, 1999). Non-price terms also help address the agency problem embedded in the incomplete contracting nature of credit arrangements (Coase, 1937). These features have significant implications for corporate managers, assisting them in a more comprehensive understanding of the impacts of climate risk on their companies.

Another important component of our analysis is that we explore whether firms' management efforts can moderate the influence of climate risk on bank loan financing. With regard to firm-level management of climate risk, different firms, again, adopt differing responses. For example, in the 2014 CDP survey, Rockwell Collins Inc. states how it integrates climate risk into business strategy:

> Climate change is evaluated and incorporated into our business strategy in several ways. Climate change affects our decisions as to where to locate our business operations which includes, in general, the avoidance of new locations that could be impacted by events caused by weather extremes such as local flooding, extreme snowfall, or hurricane. We have relocated operations that could be affected by local flooding to areas that would not be directly affected.

In the same CDP survey, Kellogg Inc. describes its approach to managing climate risk:

> More significant changes in weather could potentially impact crop growth, including yields and quality of materials grown. We regularly engage in scenario planning on our key agricultural commodities to understand and develop plans around these potential changes to our agricultural material supply. Our strategy for procurement is to work to identify partners in our sourcing efforts that are aware of and working to address some of these risks.

Existing literature on firms' climate risk mitigation measures mostly focuses on how firms use organizational resilience to absorb and recover from the impacts of climate change (Berkes, Colding, & Folke, 2003; Berkhout, Hertin, & Gann, 2006; Linnenluecke & Griffiths, 2010; Tschakert & Dietrich, 2010). However, authors of prior studies in this field separate climate adaptation from climate impact; a novel feature of our study is that we integrate resilience-building and risk management into climate influence on firm operations. Moreover, we specifically examine whether, and if so how, such managerial practices help firms obtain better corporate financing terms.

In our empirical analysis, we incorporate two measures of climate risk, based respectively on managerial appraisal of firm conditions that are subject to climate impact using information obtained from the CDP survey (referred to as *perceived* climate risk), and on firm exposure to actual climate change-related natural disasters using information stored in the Spatial Hazard Events and Losses Database for the United States (SHELDUS) (referred to as *real* climate risk). The CDP survey also probes into strategies firms employ to cope with risks induced by climate change, allowing us to identify an array of climate change-related risk management variables indicating whether a firm has (1) climate risk consideration in business strategy, (2) board of director's direct oversight of climate risk, (3) specific or integrated management process for climate risk, (4) potential opportunities arising from climate change, and (5) activities to influence climate policies.

We estimate firm-specific climate risk for 2,763 U.S. companies and identify a total of 11,805 loans they secured during the period of 2007–2014. To test for the incremental impact of climate risk in addition to other factors considered by banks when providing corporate loans, we include our firm-level climate risk measures alongside other variables traditionally used in models for explaining bank contracting terms. Specifically, in our multivariate regression analyses, we control for loan characteristics (loan size, maturity, and performance pricing), firm characteristics (size, tangibility, leverage, return on assets [ROA], and cash flow volatility), and macroeconomic factors (credit spread and term spread). We also control for year and industry fixed effects. We document that borrowing firms with higher climate risk exposure face higher loan spread, higher likelihood of collateral requirement, and a larger number of covenants in their contracts with banks, implying a positive relationship between climate risk and loan term stringency. These results are qualitatively consistent and quantitatively comparable in both measurement schemes for climate risk regardless of being perceived or real. To the extent that real climate risk, being driven by climate shocks, is associated with an exogenous nature, the similar impacts on loan financing from perceived climate risk imply that managers have good understanding of their climate risk status. In addition, we show that climate risk management can effectively alleviate the unfavorable bank loan terms imposed on firms with climate risk exposure, suggesting that firms are able to mitigate some of the financial risks associated with climate change by taking certain proactive managerial actions. In further analyses, we find that a firm's climate risk level is negatively associated with its financial performance and positively associated with its likelihood of default, both of which suggest a credit risk channel for the influence of climate risk on loan contracting.

2 | THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

2.1 | Conceptual framework

Climate risk manifests in both direct destruction of firms' properties (e.g., buildings and equipment) used in business operations and indirect damage to supply chains, products, and markets (EBRD, 2018). According to IPCC (2013), extreme weather and climate events have become more frequent and intense, with material first-order impacts on business activities. Climate change could also entail second-order impacts beyond the boundary of a firm, including limited availability of natural resources, changes in energy provision and prices, disruption to transport, migration, labor supplies, etc. (EBRD, 2018).

The physical impacts of climate change hurt firms' performance and makes their future prospects more uncertain (Lenox & Duff, 2021). Reisch (2005) documents that many firms experience lower earnings due to the lost production facilities and surging energy costs. King and Lenox (2002) show that pollution reduction leads to financial gain. Fabrizio and Kim (2016) indicate that a firm's environmental performance significantly influences its operations and potential for future profitability. Tadasse, Algieri, Kalkuhl, and Braun (2016) and World Energy Council (2015) find that regional extreme weather renders costs of raw materials less predictable, as reflected in increased food and energy price volatilities. Firms also express climate impacts consistent with these findings. For instance, Genie Energy Ltd. reports in its 2014 10-K filing that "The loss of use or destruction of third-party facilities that are used to generate or transmit electricity due to extreme weather conditions, breakdowns, … or other occurrences could greatly reduce our potential earnings and cash flows." Nobel Corp. acknowledges in its 2014 annual report that adverse weather conditions can cause earnings and cash flows from its

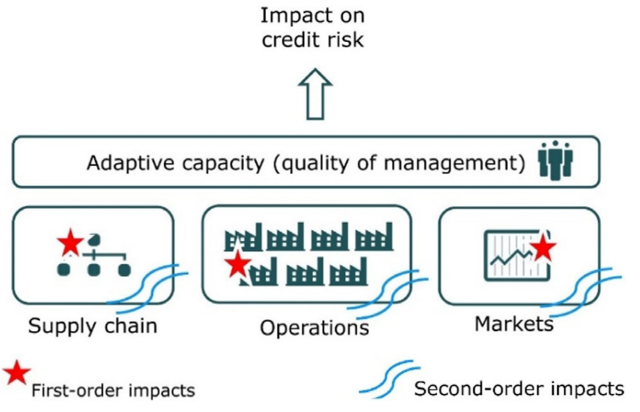

FIGURE 1 Physical climate risk, risk management, and impact on credit risk (adapted from EBRD, 2018)

oil and gas exploration and development to be less stable. Decreased earnings and increased income uncertainty lead to heightened credit risk, which is a key concern for creditors. Therefore, higher climate risk could potentially have an adverse effect on firms' borrowing terms.

Facing the detrimental impact of climate change on their operations and related business engagements, many firms take actions to mitigate or prepare for climate risk. Management science has offered robust evidence indicating that high-quality management and governance are associated with superior environmental performance (Bloom, Genakos, Martin, & Sadun, 2010). Linnenluecke and Griffiths (2010) suggest that firms resort to organizational resilience to systematically anticipate, absorb, accommodate, and recover from the adverse influences of physical climate risks. Firms may also take adaptive actions to moderate the negative impacts and enhance the positive impacts of climate change (Wilbanks et al., 2007). These managerial practices have the potential to alleviate the influence of climate risk, which helps mitigate the cost and constraints in firms' loan financing.

In sum, as illustrated in Figure 1, the impacts of a changing climate on a firm's supply chain, operations, and markets translate into credit risk exposure of its lending banks, thus affecting the terms of its loan contracts. On the other hand, the firm's adaptive capacity, which is determined by the quality of its management, could alleviate the negative impact of climate on bank loan financing terms.

2.2 | Climate change and banking practices

The banking industry is a prominent sector that actively responds to climate issues. As a result, there is presently a growing community of financial institutions taking action and demonstrating leadership in dealing with climate change. Banks are the major participants in many high-profile initiatives addressing climate problems in business. As early as in 1991, several banks, including Deutsche Bank, HSBC, Natwest, Royal Bank of Canada, and Westpac, together with the United Nations Environmental Programme (UNEP), launched the UNEP Financial Initiative (UNEP FI), committing to incorporating environmental risks into all facets of their lending process.[2] In 2003, a climate risk management framework—the Equator

[2]https://www.unepfi.org/about/unep-fi-statement/history-of-the-statement/.

Principles—was formulated, followed by the Carbon Principles and the Climate Principles, both established in 2008. These principles address various aspects of banks' financing behaviors related to climate change and environmental sustainability.[3] In 2018, 16 leading banks from four continents, convened by the UNEP FI, published a jointly developed methodology to increase financial institutions' understanding of how climate change and climate action could impact their business.[4] In 2019, a coalition of 130 banks, representing one-third of the worldwide banking sector, committed to aligning their actions to tackle climate challenges and protect those most vulnerable to climate change impacts.[5] One of the cornerstones of these climate-related banking initiatives is the recognition of the urgency of climate crisis and the potential for physical risk to give rise to credit risk to loan issuers.

Consistent with the banking industry's active involvement in climate management frameworks, individual banks have expressed their specific concern over credit risk induced by climate change. For example, a global survey among financial institutions by the Environment and Finance Research Enterprise (1995) indicates that 94% of the respondents integrate environmental risk into their credit risk management process. Thompson and Cowton's (2004) survey involving a large sample of U.K. banks shows that borrowing firms facing environmental risk must go through stringent lender monitoring before their loan applications are approved. Ceres (2008) similarly finds that a majority of the 40 world's largest banks have incorporated climate change issues in their business and have implemented climate change risk assessment policies, including the consideration of whether borrowing firms have developed climate change mitigation or adaptation strategies. In addition, most of the 45 financial institutions surveyed by Colas, Khaykin, and Pyanet (2019) have adjusted variables in their credit risk models to capture climate-related risks or to qualitatively override their internal credit rating systems. More specifically, HSBC has embedded climate change in its trade, infrastructure, and project and export financing (Furrer, Hoffmann, & Swoboda, 2009), whereas ICBC shows that incorporating climate risk into credit rating affects the cost of capital for its clients (UNEP FI, 2016), and HBOS imposes a higher risk premium for borrowers with particularly high exposure to climate change (Furrer et al., 2009). More recently, the European Central Bank (ECB) issued a guidance on climate-related risk for banks' operations in 2020 (ECB, 2020).

Banks have also developed specific models to assess the impacts of physical risks of climate change on their borrowing firms. A widely adopted approach is to model the potential impact on a firm depending on how much of its asset base is located in climate sensitive areas. For example, the TD Bank Group uses geospatial mapping to assess physical risks on the credit rating of borrowers within the bank's lending portfolio. Similarly, Santander produces environmental risk maps of companies with a focus on extreme weather events. DNB applies its Megatrends Initiative to model climate risk scenarios such as sea level increases and extreme weather situations, and BBVA employs an eco-rating tool to assign each customer a credit risk rating according to factors such as location, consumption of resources, etc. Moreover, UBS, together with eight other banks, adopts a drought risk model for loan portfolios, which includes several scenarios of varying geographic extent, and maps drought hazard to change in revenues.

[3]http://equator-principles.com./about/, https://issuu.com/tobend/docs/the_principle_matter, https://en.wikipedia.org/wiki/The_Carbon_Principles.

[4]http://www.unepfi.org/news/industries/banking/tcfd-recommendations/.

[5]https://www.edie.net/related.asp?id=39105.

Relatedly, ANZ and Westpac recognize the impact of draught as a serious concern in their agribusiness.[6]

As can be seen from the above, banks are among the first institutions to have climate change incorporated into their lending business and have special expertise in assessing credit risk exposure associated with the climate risk of their clients. These financial institutions have taken individual and collective actions to mitigate and compensate for their losses from climate change, which is likely to affect the cost and terms of borrowing.

2.3 | Firm climate risk and bank loan terms

The characteristic features of loan contracts in relation to the nature of climate change determine how banks address climate-related credit risk in loan contracting. First, both bank loan payoff structures and climate systems exhibit nonlinear dynamics characterized by abrupt changes. As shown by Merton (1974), limited liability corporations hold an implicit put option written by banks, which imposes sudden, severe losses to banks in case of delinquency. Severe climate events with a rapid onset or gradual changes with a tipping point may incur significant losses for borrowing firms, making the put option in the money and leaving banks' payoff at risk. Under such circumstances, climate risk becomes a major concern for banks.

Second, climate risk induces agency costs due to borrowers and lenders adopting conflicting attitudes toward climate risk (Jensen & Meckling, 1976), as banks have to bear the potential loss from borrowing firms' projects with significant climate risk exposure but cannot share the potential benefits. Agency problems could also arise from the impairment of existing debt claims, which decreases the likelihood of full repayment. This outcome can occur when, for example, climate change depreciates the value of borrowers' assets against which loans are collateralized. If climate shocks on firm performance and asset value drive a firm to the edge of delinquency, managers are motivated to take riskier operational actions because larger volatility makes the implicit put option more valuable, while the downside payoff is limited (nothing to lose). These agency issues expose banks to even larger risks.

Third, the great uncertainty in climate impacts presents significant information risk to banks (Blackrock, 2015). Informational uncertainty regarding climate change also renders loan contracting inherently incomplete, as contracting parties cannot anticipate all future states of the world, leading to post-contractual opportunism that adversely affects lenders' welfare (Coase, 1937; Grossman & Hart, 1986; Klein, Crawford, & Alchian, 1978). The difficulty in writing and enforcing loan contracts in the context of climate uncertainty creates a demand for control rights (e.g., non-price terms of the loan contract) that serve as a complement to market mechanisms (e.g., the price term) to coordinate the lending transactions. Overall, these multi-faceted problems need to be addressed in a comprehensive and dynamic manner, for which banks have unique advantages.

Bank loan contracts have flexible characteristics, mainly reflected in the inclusion of both price and non-price terms. The price term, often known as loan spread, is a pricing tool for incorporating the risk of borrowers' default, or a risk premium for possible credit loss (Strahan, 1999). Stated another way, loan spread is a compensation in the event of the put

[6]For further details and additional examples, refer to Boston Common (2015), Furrer et al. (2009), and Marlin (2018).

option on firm assets being in the money, in which case loans cannot be fully repaid. Economists (e.g., Strahan, 1999) have asserted that loans that are more likely to end in default carry higher interest rate spreads, and a similar rationale applies to loans issued to firms with higher climate risk exposure, which tend to have less favorable price term in the form of higher loan spread. In line with these arguments, we hypothesize:

Hypothesis 1a (H1a). *Larger climate risk exposure of a firm is associated with greater loan spread when it borrows from banks.*

Non-price terms can be utilized to address problems arising from agency conflicts and informational costs. A common practice is to securitize loans with collateral. The secured feature of a loan contract is pertinent because collateralization could make a loan's effective priority contingent on monitoring by the lender, thus incentivizing banks to apply better supervision to mitigate climate-related agency costs (Rajan & Winston, 1995). The climate damage-induced devaluation of properties also entails requirements for a larger package of security pledged to a bank in return for a loan (UNEP FI, 2018). Moreover, collateralization could inhibit opportunistic divestiture of pledged assets upon climate crisis, which helps maintain firms' production capacity and their repayment ability (Fraysse, 2019). These arguments lead to the following hypothesis:

Hypothesis 1b (H1b). *Larger climate risk exposure of a firm is associated with higher likelihood of its bank loans being secured by collateral.*

Setting covenants to ensure contingency for future loan term revision is another non-price contracting strategy. Loan covenants improve the ex post supervision of change in creditworthiness according to the change in borrowers' climate risk exposure (Rajan & Winston, 1995). They also help address the incompleteness of loan contracts in view of uncertain climate prospects by assigning climate-contingent control rights to creditors (Christensen, Valeri, & Wittenberg-Moerman, 2016). Environmental covenants in loan agreements have long been an important mechanism for banks to control their credit risk exposure from climate change (Asian Development Bank, 1993; Bekhechi, 1999; Case, 1999). Covenants specific to climate change are also necessitated by the fact that climate events tend to be catastrophic, with consequences extending beyond the range banks are able to control by traditional financial ratio dynamics.[7] Thus, we hypothesize:

Hypothesis 1c (H1c). *Larger climate risk exposure of a firm is associated with more covenant constraints in its bank loans.*

2.4 | The moderating role of corporate climate risk management

Just as they differ in their climate risk exposure, firms also differ in their policies and practices aimed at climate risk management. These management actions are the outcome of firms' prioritization, capability, resources, and collaboration related to climate issues (Berkhout, 2012), thus reflecting the quality of information processing, corporate innovation, asset allocation,

[7]In particular, environmental covenants are included in the Key Evaluation Indicators for Green Credit Implementation of China (China Banking Regulatory Commission, 2014).

investment efficiency, and active engagement in adaptation to climate change.[8] In general, the strength of the climate impact on credit risk and corporate financing is likely to be influenced by firms' organizational resilience strategies. Strategy researchers have established a fundamental framework for management practices underlying the success of business relating to targets, incentives, and monitoring (e.g., Bloom, Genakos, et al., 2010; Bloom, Genakos, Sadun, & Van Reenen, 2012; Bloom, Lemos, Sadun, Scur, & Van Reenen, 2014, 2016; Bloom, Lemos, Sadun, & Van Reenen, 2015; Bloom, Sadun, & Van Reenen, 2010, 2012; Tsai et al., 2015). Consistent with this framework, institutions focusing on climate change highlight several key aspects of climate risk management. For example, the ISO 14001 Environmental Management System Standard stipulates creating corporate policy, corporate planning (including setting objectives), implementing a program to achieve the objectives, performance assessment, and monitoring and reviewing as essential elements (Delmas & Toffel, 2008). Ceres—a national coalition of investors, environmental groups, and other organizations—advocates for the adoption of governance structures to comprehensively address climate issues, including board oversight, management accountability, executive compensation, corporate management systems, and public policy.[9] According to EBRD (2018), for physical climate impacts, aspects of particular interest to financial institutions include corporate climate change strategy, risk management processes, planned facility moves or retrofits, and engagement with local authorities to build climate resilience.

Given the proven importance and wide acceptance of the aforementioned climate risk management framework, the CDP has solicited in its surveys specific information regarding (1) firms' climate strategy, (2) climate issues supervision, (3) climate issues management, (4) climate change-induced opportunities, and (5) public policy involvement. We expect that these managerial actions help ease banks' credit risk concern over the impact of climate on borrowing firms, and thus hold the potential to mitigate the stringency of loan contracting terms.

First, climate change is a strategically relevant issue for companies, as it has long-lasting, multi-faceted influences on products and services, value chain, adaptation activities, investments, and operations (Linnenluecke, Griffiths, & Winn, 2012). A firm-wide strategy incorporating climate impact is thus necessary to enable firms to deal with the widest range of plausible variations in the long term and deploy organizational resources accordingly (Galbreath, 2010; Hendry & Kiel, 2004; Lempert, Nakicenovic, Sarewitz, & Schlesinger, 2004). Aragon-Correa and Sharma (2003) consider the natural environment as an integral part of a company's competitive environment. Similarly, Porter and Reinhardt (2007) argue that "the effects of climate on companies' operations are now so tangible and certain that the issue is best addressed with the tools of the strategist" (p. 22). Firms that fail to integrate climate risk into their business strategy tend to have lower operational performance and firm value (Epstein, 2008; Hart, 1995; King & Lenox, 2001)

[8]As reviewed by IPCC (2014), firm-level climate management is determined by various factors, including, inter alia, transaction costs, externalities, information asymmetry, moral hazards, behavioral obstacles, uncertainties, and technical limits, and thus differs among firms. Specifically, transaction costs occur when acquiring information as well as making replacement decisions related to long-lived capital, that is, adjustment costs. Externalities, information asymmetry, and moral hazards represent market failure and missing market; these factors could also relate to ethics and distributional issues. Behavioral obstacles include time-inconsistent decisions and decisions made without using all available information; they could also include inertia, procrastination, and high discount rate (Fankhauser, 2017). Uncertainties in future developments of demographics, technologies, economics, and climate conditions represent additional barriers to adaptation. Relatedly, technical limits and limits in capabilities and resources present additional difficulties (Berkhout, 2012).

[9]www.ceres.org/roadmap.

and are therefore likely to be viewed less favorably by lenders, leading to the imposition of more stringent loan terms by banks. Accordingly, we hypothesize:

> **Hypothesis 2a (H2a).** *Integrating climate change into business strategy is associated with less stringent bank loan terms for firms with climate risk exposure.*

Second, corporate governance, especially the board's oversight of climate-related issues, is essential for guiding the organizational strategy in a more climate-resilient way (McKinsey, 2007). Board-level planning and supervision better motivate a firm to implement climate policies and practices, such as effective monitoring, incentive alignment, performance compensation, data processing, intellectual capital management, and engagement and leadership, all of which help the firm resist climate shocks (Bloom, Genakos, et al., 2010; West & Brereton, 2013). A climate-responsible board also relates to higher informational transparency (Galbreath, 2010; Peters & Romi, 2012), which not only resolves uncertainty in climate impact but also reduces the information risk premium charged by lenders. In line with this notion, Galbreath (2010) finds that corporate boards affect the success with which governance practices address climate change. This observation suggests that a board cognizant of the potential risks of climate change would orient the firm to strengthen its creditworthiness, allowing it to obtain better loan financing terms. Thus, we hypothesize:

> **Hypothesis 2b (H2b).** *Having a board that takes direct responsibility for climate change issues is associated with less stringent bank loan terms for firms with climate risk exposure.*

Third, given the novelty of the risks imposed by climate change, firms cannot resort to traditional practices to cope with climate variability, which necessitates the adoption of specific climate risk management systems.[10] Such systems facilitate identifying, assessing, and managing (e.g., mitigating, transferring, controlling) physical climate risks, and are crucial for business success and competitiveness (Busch & Hoffmann, 2007). Having dedicated management teams with the requisite expertise and specific mission to recognize and address climate change problems assists firms in building resilience, allowing them to take control over the climate impacts on their operations. Efficient management also helps reduce firms' vulnerability to adverse business developments caused by climate change that would impair profitability and diminish the value of asset base. Supporting these arguments, authors of extant studies have linked various beneficial economic effects to environmental risk management (e.g., Matten, 1995; Sharfman & Fernando, 2008). We thus expect that climate risk management should facilitate sustainment of a firm's creditworthiness and attract better loan financing terms from banks, giving rise to the following hypothesis:

> **Hypothesis 2c (H2c).** *Having a risk management process specifically for climate change is associated with less stringent bank loan terms for firms with climate risk exposure.*

[10]Okereke, Wittneben, and Bowen (2012) argue that "Relying on old and pre-existing set of skills and capabilities to handle the new risks and challenges posed by climate change is bound to lead to suboptimal and ineffective response strategy" (p. 25).

Fourth, in addition to its capacity to withstand negative climate impacts, a firm's overall resilience to climate change also depends on the potential to capitalize on business opportunities that climate change may present. These opportunities may arise from changes in physical conditions, product and technology advances, and/or changes in customer preferences. For example, a changing climate brings an evolving set of investment needs in climate-resilient assets (UNEP FI, 2018). Innovations and know-how in growing markets related to climate change can offer a competitive advantage to firms with opportunity-oriented adaptation approaches (Gasbarro & Pinkse, 2016). Changes in prevailing climate conditions also create new demands for, among others, urban drainage solutions, water-efficient or drought-resistant appliances, and risk mitigation and consultation services (Fankhauser, 2017). Firms that better grasp or pursue these opportunities are equipped with a natural hedge mechanism against downside climate damage (Haanaes et al., 2011; Hoffman, 2007; Whiteman et al., 2011), which reduces the credit risk for lending banks, resulting in less costly and less constrained loan financing. Therefore, we hypothesize:

Hypothesis 2d (H2d). *Having business opportunities from climate change is associated with less stringent bank loan terms for firms with climate risk exposure.*

Finally, no firm copes with climate change in isolation as businesses are heavily reliant on the environmental and institutional infrastructures provided by the government and the local community (EBRD, 2018; Holburn & Zelner, 2010; Teece, 2007). Climate policies affect business practices of (especially carbon emitting) partners, the availability of technology, and product prices, all of which could translate into climate risks for the firm. Therefore, firms are likely to benefit from relationships developed through their involvement in climate-related policymaking. Such benefits could involve governmental relief or disaster aid in case of climate damage, business opportunities from rebuilding or reconstructing public facilities and related projects, access to more nuanced and diverse information regarding climate regulation, and affiliated network-building. Therefore, engagement and cooperation with local, regional, and national governments are crucial for firms' ability to leverage public knowledge and capacities to improve the climate resilience of their facilities. Available evidence also indicates that corporate decision-making in synergy with public policies is critical for disaster risk reduction (Brito, de Souza Miguel, & Pereira, 2017; Useem, Kunreuther, & Michel-Kerjan, 2015), and collaborative effort and social reciprocity are also likely to result in environmentally sound practices (Marshall, Cordano, & Silverman, 2005). Accordingly, we hypothesize:

Hypothesis 2e (H2e). *Engaging in activities that influence public policy on climate change is associated with less stringent bank loan terms for firms with climate risk exposure.*

3 | DATA AND MEASURES

3.1 | Bank loan contracting term variables

In our analyses, we treat specific bank loan terms as the dependent variable. For this purpose, we retrieve detailed bank loan contract information related to studied firms from DealScan, a widely used dataset in loan contracting studies (e.g., Graham, Li, & Qiu, 2008; Hasan, Hoi, Wu, & Zhang, 2017; Huang, Lobo, Wang, & Zhou, 2018; Kim, Song, & Zhang, 2011). For each loan (referred to as a facility in DealScan), we identify the price term (i.e., loan spread) as the rate of interest and fees paid in basis points (bps) in excess of LIBOR or its equivalent, adopting its natural logarithmic form denoted by *Ln(Spread)*. We use collateral requirement (*Secured*, which equals one if the facility has secured assets, and zero otherwise) and number of covenants (*Covenants*) as non-price terms. Economically, higher loan spread, requiring collateral assets, and more covenants indicate more stringent loan contracting terms, which increase borrowing firms' funding cost and related constraints from lending banks.

3.2 | Firm-level climate risk variables

For firm-level climate risk, we adopt two primary measures. The first measure is based on managers' assessment of their firms' physical climate risk exposure, as revealed in the CDP survey. Specifically, the CDP surveys major corporations (e.g., S&P500 companies) annually on their climate risk exposure by asking "How is your company exposed to physical risks from climate change?" The available answers are: (1) we consider our company to be exposed to physical risks; (2) we do not know the answer to this question; and (3) we do not consider our company to be exposed to physical risks. For example, in the 2010 CDP survey, 211 of the 390 participating firms chose answer (1), 38 answered (2), and 141 answered (3), reflecting the firm managers' perception of climate impact on their firms' operations. Accordingly, we refer to this measure as perceived climate risk of a firm and capture it by an indicator variable *Perceived Climate Risk* that takes the value of one if, according to the CDP survey, the firm is exposed to physical climate risk, and zero otherwise.[11]

The second firm-specific climate risk measure is based on a firm's exposure to extreme climate events, that is, natural disasters, which we denote as real climate risk. The rationale of this measurement is that firms that are frequently subjected to natural disaster shocks tend to be more prone to the adverse impacts of climate change. Following the strategies adopted in prior literature (e.g., Cortes & Strahan, 2017; Dessaint & Matray, 2017), we estimate a firm's real climate risk exposure according to the number of climate-related disasters in the geographic regions of its subsidiaries. For this purpose, we first obtain data for different climate-related natural hazard events from SHELDUS[12] and aggregate the number of natural disasters that occurred in each year in each state. We then identify for each sample firm the states in which its subsidiaries are located, using the approach described by Dyreng, Lindsey, and Thornock (2013). With the disaster state–firm subsidiary matched data, we compute a subsidiary-weighted average number of natural disasters, denoted by *Real Climate Risk*, to indicate the level of the firm's exposure to real physical impacts from climate change. For example, FairChild Corp. has one subsidiary in Kentucky and two subsidiaries in Ohio. As Kentucky experienced 13 natural disasters in 2007 and Ohio experienced 25, the subsidiary-weighted average is $(1/3 \times 13 + 2/3 \times 25) = 21$. After scaling this

[11]Our results are qualitatively unchanged if we remove the answer (2) "we do not know the answer to this question" before constructing the *Perceived Climate Risk* indicator variable.

[12]SHELDUS contains events that generated a loss exceeding US$1 billion, caused a significant number of fatalities, or were declared by the Governor as "state of emergency" with a formal request for Federal Emergency Management Agency funds to respond to the disaster. For each natural hazard, the database records the beginning date, location (state and county), property losses, injuries, and fatalities. In our analyses, we consider only climate-related natural disasters, namely coastal storms, droughts, flooding, heatwaves, hurricanes/tropical storms, landslides, lightning, severe storms/thunder storms, tornadoes, wildfires, wind, and winter weather.

number by 100, we obtain 0.21 as the value of *Real Climate Risk* for the company in 2007. As such, a higher *Real Climate Risk* indicates greater exposure to physical climate risk.

3.3 | Climate risk management variables

We collect information about firm climate risk management from the CDP survey, which summarizes various metrics regarding managerial practices to cope with climate risk. These metrics are represented by the following five indicator variables: (1) *Business Strategy*, which equals one if the firm integrates climate change into its overall business strategy, and zero otherwise; (2) *Board-Level Governance*, which equals one if highest-level of direct responsibility for climate change issues in the firm is with the board of directors, and zero otherwise; (3) *Risk-Managing Process*, which equals one if the firm has set up a specific climate change risk management process or climate risk is integrated into a multi-disciplinary company-wide risk management system, and zero otherwise; (4) *Climate Opportunity*, which equals one if the firm possesses potential opportunities related to climate change, and zero otherwise; (5) *Policymaking Involvement*, which equals one if the firm engages in activities that could directly influence public policies on climate change, and zero otherwise.

3.4 | Control variables

Drawing on the strategies adopted in prior studies (Boubakri & Ghouma, 2010; Costello & Wittenberg-Moerman, 2011; Graham et al., 2008; Kim et al., 2011; Qi, Roth, & Wald, 2010; Qian & Strahan, 2007), we control for other risk factors that affect loan contracting, at three levels. First, we control for loan-level characteristics, including the natural logarithm of loan amount (*Ln(Loan Size)*), the natural logarithm of the number of months to maturity (*Ln(Maturity)*), and whether the loan has performance pricing provision (*Performance Pricing*), while sourcing the relevant information from DealScan. Second, we control for the following firm-level characteristics: *Ln(Total Assets)*—the natural logarithm of the book value of assets at the beginning of the fiscal year, representing firm size; *Tangibility*—property, plant and equipment (PP&E) divided by total assets; *Leverage*—ratio of total liabilities to total assets; *ROA*— income before extraordinary items divided by total assets; and *σ(CFO)*—standard deviation of yearly cash flow from operations (CFO) divided by total assets over the past five fiscal years. We retrieve firm accounting information from Compustat. Third, we use two variables to control for macroeconomic factors: the difference in yield between BAA- and AAA-rated corporate bonds (*Credit Spread*), and the difference in yield between 10-year and 2-year U.S. Treasury bonds (*Term Spread*). These spreads are measured 1 month before the loan becomes active, and pertinent yield data are sourced from the Federal Reserve Board of Governors. The Appendix S1 provides detailed definitions for all variables used in the empirical analyses.

3.5 | Descriptive statistics

The sample period in focus of our analyses spans from 2007 to 2014. For this period, SHELDUS records 13,890 climate-related natural disaster events, based on which we estimate our real climate risk measure for 2,763 firms and examine contracting terms for 11,805 loans issued to

TABLE 1 Descriptive statistics

Variable	Mean	Std.	P25	Median	P75
Firm climate risk variables					
Perceived Climate Risk	0.660	0.474	0.000	1.000	1.000
Real Climate Risk	0.443	0.877	0.016	0.136	0.437
Firm climate risk management variables					
Business Strategy	0.705	0.456	0.000	1.000	1.000
Board-Level Governance	0.466	0.499	0.000	0.000	1.000
Risk-Managing Process	0.952	0.213	1.000	1.000	1.000
Climate Opportunity	0.671	0.470	0.000	1.000	1.000
Policymaking Involvement	0.406	0.491	0.000	0.000	1.000
Bank loan contracting variables					
Spread	273.000	172.400	150.000	225.000	350.000
Ln(Spread)	5.434	0.605	5.011	5.416	5.858
Secured	0.575	0.494	0.000	1.000	1.000
Covenants	1.961	2.514	0.000	1.000	3.000
Loan-level control variables					
Maturity	54.400	17.870	48.000	60.000	60.000
Ln(Maturity)	3.913	0.464	3.871	4.094	4.094
Loan Size	499.100	820.100	100.000	250.000	588.500
Ln(Loan Size)	5.395	1.363	4.605	5.521	6.380
Performance Pricing	0.344	0.475	0.000	0.000	1.000
Firm-level control variables					
Ln(Total assets)	7.634	1.622	6.497	7.574	8.707
Tangibility	0.571	0.420	0.207	0.485	0.887
Leverage	0.507	0.244	0.348	0.469	0.634
ROA	0.025	0.099	0.004	0.035	0.067
σ(CFO)	0.043	0.040	0.018	0.031	0.053
Macroeconomic control variables					
Credit Spread	1.096	0.440	0.860	0.990	1.270
Term Spread	1.951	0.500	1.530	1.870	2.380

Note: Variable definitions are given in the Appendix S1.

these firms. In addition, using the CDP surveys conducted during our sample period, we retrieve information about manager-perceived climate risk for 294 firms and identify 1,018 bank loan facilities. As can be seen from Table 1, the mean of *Perceived Climate Risk* is 0.66 (i.e., 66% of surveyed managers consider their firms to be exposed to physical climate risk) and the mean of *Real Climate Risk* is 0.443. For the climate management variables, the statistics suggest that about 70.5% of firms incorporate climate change into their business strategy, 46.6% have the board to supervise climate issues, 95.2% adopt climate risk management processes, 67.1% seize climate opportunities, and 40.6% are involved in climate policymaking. For bank loan characteristics, the mean (median) of loan spread, maturity, and loan amount are 273 (225) bps, 54.4 (60) months, and US$499.1 (US$250) million, respectively. Bank loans included in the sample have 1.961 covenants on average, 57.5% of them are collateralized, and 34.4% have performance pricing provisions. On average, our sample firms have a leverage ratio of 0.507 and an ROA of 2.5%. Overall, these descriptive statistics are in line with those reported in previous studies (e.g., Graham et al., 2008; Huang, Lobo, et al., 2018; Kim et al., 2011).

4 | EMPIRICAL APPROACH

4.1 | Model specification for testing H1a–H1c

We estimate the effects of climate risk on bank loan terms using the following regression model:

$$\begin{aligned}
\textit{Bank Loan Terms} = {} & \beta_0 + \beta_1(\textit{Firm Climate Risk}) + \beta_2 Ln(\textit{Loan Size}) + \beta_3 Ln(\textit{Maturity}) \\
& + \beta_4(\textit{Performance Pricing}) + \beta_5 Ln(\textit{Total Assets}) + \beta_6 \textit{Tangibility} + \beta_7 \textit{Leverage} \\
& + \beta_8 ROA + \beta_9 \sigma(CFO) + \beta_{10}(\textit{Credit Spread}) + \beta_{11}(\textit{Term Spread}) \\
& + \textit{Industry Fixed Effects} + \textit{Year Fixed Effects} + \varepsilon.
\end{aligned} \tag{1}$$

In Equation (1), *Bank Loan Terms* refers to one of the following three bank loan terms: the cost of borrowing (*Ln(Spread)*), collateral requirement (*Secured*), or number of covenants (*Covenants*). The variable of interest is *Firm Climate Risk*, which represents the level of a firm's climate risk as reported in the CDP survey (*Perceived Climate Risk*) or as revealed by its spatial exposure to actual climate disasters (*Real Climate Risk*). A significantly positive coefficient on *Perceived Climate Risk* or *Real Climate Risk*, that is, β_1, would suggest that greater climate risk induces stricter loan terms. The control variables are defined as described in the preceding section. We also control for industry (Fama–French 48 industry) and year fixed effects in our analysis, in order to mitigate the influences from industrial features and time trend.[13] We employ the ordinary least squares (OLS), Logit, and Poisson estimation methods when the continuous variable *Ln(Spread)*, the dichotomous variable *Secured*, and the ordinal variable *Covenants* are used as the dependent variable, respectively.

4.2 | Model specification for testing H2a–H2e

To examine how corporate climate risk management influences bank loan terms offered to climate risk-impacted firms, we exclusively focus on firms that explicitly indicate physical climate risk exposures in the CDP survey, that is, those with *Perceived Climate Risk* equaling one, as well as firms that are exposed to natural disaster shocks as indicated in SHELDUS, that is, those with non-zero *Real Climate Risk*. The rationale behind this strategy is that managing climate risk is only meaningful for firms facing climate risk. For these firms, we directly investigate the effects of climate risk management on their bank loan terms, which helps in clear identification

[13]In unreported robustness checks, we alternatively control for industry-by-year fixed effects or firm fixed effects, and find that the main results are generally unchanged.

of the role of climate adaptation and risk management efforts in corporate financing. Specifically, we estimate the following regression model:

$$\begin{aligned} \mathit{Bank\ Loan\ Terms}_{(\mathit{Firm\ Climate\ Risk} \neq 0)} = {} & \gamma_0 + \gamma_1(\mathit{Climate\ Risk\ Management}) + \gamma_2 Ln(\mathit{Loan\ size}) \\ & + \gamma_3 Ln(\mathit{Maturity}) + \gamma_4(\mathit{Performance\ Pricing}) + \gamma_5 Ln(\mathit{Total\ Assets}) + \gamma_6 \mathit{Tangibility} \\ & + \gamma_7 \mathit{Leverage} + \gamma_8 \mathit{ROA} + \gamma_9 \sigma(\mathit{CFO}) + \gamma_{10}(\mathit{Credit\ Spread}) + \gamma_{11}(\mathit{Term\ Spread}) \\ & + \mathit{Industry\ Fixed\ Effects} + \mathit{Year\ Fixed\ Effects} + \varepsilon. \end{aligned} \tag{2}$$

$\mathit{Bank\ Loan\ Terms}_{(\mathit{Firm\ Climate\ Risk} \neq 0)}$ refers to bank loan terms (*Ln(Spread)*, *Secured*, and *Covenants*) for firms with climate risk exposure (i.e., *Percieved Climate Risk* = 1 or *Real Climate Risk* ≠ 0). *Climate Risk Management* refers to the five climate-related management measures (*Business Strategy*, *Board-Level Governance*, *Risk-Managing Process*, *Climate Opportunity*, and *Policymaking Involvement*). The key variable in this model is the coefficient on the climate risk management measure, that is, γ_1.

5 | RESULTS

5.1 | Test results related to H1a–H1c: The relationship between firm climate risk and bank loan terms

Table 2 presents the results relating to the effects of firm-specific climate risk on the terms of bank loan contracting as shown in Equation (1). Results yielded by models in which *Perceived Climate Risk* and *Real Climate Risk* are treated as the key independent variable, respectively, are reported in Panels A and B. The findings reported in Columns (1), (2), and (3) of each panel are obtained when loan spread (*Ln(Spread)*), collateral requirement (*Secured*), and number of covenants (*Covenants*) are adopted as the dependent variable, respectively.

As shown in Column (1) of Panel A, *Perceived Climate Risk* is significantly positively related to *Ln (Spread)*, as indicated by the coefficient β_1 that equals .155 with a p-value of .000. This finding suggests that firms affected by physical climate risk (as indicated by their CDP survey responses) are associated with higher interest rate (and fees) charged by lending banks. Economically, firms that are subject to climate risk are charged 15.5% greater in loan spread than firms without such risk, which corresponds to about 42.32 bps on average.[14] We also find that the signs of coefficients on control variables are generally consistent with the results obtained in prior studies (e.g., Costello & Wittenberg-Moerman, 2011; Graham et al., 2008; Kim et al., 2011). Specifically, at the loan level, larger loan amount, shorter maturity, and the existence of performance pricing provision tend to reduce the spread. At the firm level, firms with lower leverage level and better financial position (i.e., higher ROA) can borrow from banks at a lower cost. Firms with more tangible assets can attain lower loan spread, consistent with the notion that banks view borrowers with greater PP&E resources less risky. The macroeconomic factor *Term Spread* is positively associated with loan spread, suggesting that corporates' borrowing cost increases with the term premium in the credit market.

[14]Since in this case the dependent variable is in logarithmic form, according to Graham et al. (2008), the coefficient estimate represents the percentage change effect of the independent variable on the dependent variable. Given the mean spread level of 273 bps (reported in Table 1), the average difference in loan spread between firms with and without climate risk exposure is therefore 15.5% × 273 = 42.32 bps.

TABLE 2 Relation between firm climate risk and bank loan terms—baseline results

Panel A: Perceived climate risk and terms of bank loan financing			
	(1) ***Ln(Spread)***	**(2)** ***Secured***	**(3)** ***Covenants***
Perceived Climate Risk	0.155	0.544	0.309
	(.000)	(.021)	(.001)
Ln(Loan Size)	−0.162	−0.257	0.149
	(.000)	(.000)	(.001)
Ln(Maturity)	0.235	0.677	−0.193
	(.000)	(.014)	(.031)
Performance Pricing	−0.0670	−1.179	0.867
	(.038)	(.000)	(.000)
Ln(Total Assets)	0.0490	0.0100	−0.310
	(.016)	(.924)	(.000)
Tangibility	−0.164	−1.258	−0.027
	(.020)	(.004)	(.861)
Leverage	0.449	2.613	0.300
	(.003)	(.001)	(.353)
ROA	−1.768	−6.621	−2.753
	(.000)	(.002)	(.002)
σ(CFO)	−1.045	6.488	0.256
	(.251)	(.106)	(.875)
Credit Spread	0.114	−0.523	−0.219
	(.184)	(.270)	(.269)
Term Spread	0.133	0.517	0.039
	(.032)	(.147)	(.768)
Intercept	4.080	−11.57	2.353
	(.000)	(.000)	(.004)
Fixed Effects	Yes	Yes	Yes
No. of Observations	1,018	1,018	1,018
Adjusted R^2/Pseudo R^2	.413	.323	.185
Panel B: Real climate risk and terms of bank loan financing			
	(1) ***Ln(Spread)***	**(2)** ***Secured***	**(3)** ***Covenants***
Real Climate Risk	0.031	0.084	0.034
	(.000)	(.002)	(.004)
Ln(Loan Size)	−0.090	0.015	0.049
	(.000)	(.467)	(.000)
Ln(Maturity)	0.240	0.917	0.075
	(.000)	(.000)	(.009)
Performance Pricing	−0.193	0.273	0.855
	(.000)	(.000)	(.000)
Ln(Total Assets)	−0.040	−0.373	−0.151
	(.000)	(.000)	(.000)
Tangibility	−0.130	−0.456	−0.159
	(.000)	(.000)	(.000)

TABLE 2 (Continued)

Panel B: Real climate risk and terms of bank loan financing

	(1) *Ln(Spread)*	(2) *Secured*	(3) *Covenants*
Leverage	0.431	1.833	0.351
	(.000)	(.000)	(.000)
ROA	−1.321	−5.727	−0.714
	(.000)	(.000)	(.000)
σ(CFO)	0.280	1.593	−0.033
	(.032)	(.021)	(.908)
Credit Spread	0.134	0.206	0.182
	(.000)	(.009)	(.000)
Term Spread	0.084	0.099	0.099
	(.000)	(.128)	(.002)
Intercept	4.773	−0.611	0.888
	(.000)	(.193)	(.000)
Industry Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
No. of Observations	11,805	11,805	11,805
Adjusted R^2/Pseudo R^2	.401	.188	.117

Panel C: Comparison of the effects of perceived and real climate risks on loan terms

	(1) *Ln(Spread)*	(2) *Secured*	(3) *Covenants*
STD Perceived Climate Risk	0.071	0.238	0.140
	(.000)	(.035)	(.000)
STD Real Climate Risk	0.032	0.249	0.076
	(.070)	(.021)	(.025)
Controls	Yes	Yes	Yes
Industry & Year Fixed Effects	Yes	Yes	Yes
No. of Observations	1,018	1,018	1,018
Adjusted R^2/Pseudo R^2	.436	.329	.186
p-value for the difference between the coefficient on STD Perceived Climate Risk and the coefficient on STD Real Climate Risk	.12	.95	.24

Note: Columns (1), (2), and (3) report results from OLS, Logit, and Poisson regressions, respectively. *p*-values reported in the parentheses are based on heteroskedasticity robust standard errors. The bottom row of Panel C reports *p*-values for the difference between the coefficients on standardized perceived and real climate risk measures.

We provide results of the Logit regression relating firm climate risk to the collateral requirement measured by *Secured* in Column (2) of Panel A. The results show that *Secured* is significantly positively related to *Perceived Climate Risk* with a coefficient β_1 of .544 (p-value = .021), which implies that the marginal effect of climate risk is 0.074, that is, the likelihood of collateral requirement is 7.4% higher for firms with climate risk exposure than for firms without such exposure. Because a secured loan reduces lending risk, this evidence suggests that banks are more likely to ask for assets as collateral when borrowers are exposed to greater climate risk.

Column (3) of Panel A reports the Poisson regression results for the relationship between firm climate risk and covenant intensity measured by *Covenants*. *Perceived Climate Risk* is significantly positively associated with *Covenants* ($\beta_1 = .309$; p-value $= .001$), suggesting that banks are likely to demand more covenants in loan contracts for firms with higher climate risk. Specifically, the number of covenants for borrowing firms exposed to climate risk (*Perceived Climate Risk* = 1) is 36.21% greater than the number of covenants for firms without climate risk (*Perceived Climate Risk* = 0).[15] Because the average number of covenants is 1.961 (in Table 1), this effect is equivalent to 0.71 covenants per loan contract.

The corresponding results reported in Columns (1)–(3) of Panel B for *Real Climate Risk* as the measure for firm-specific climate risk lead to similar conclusions, that is, higher *Real Climate Risk* is associated with larger bank loan spread, higher likelihood of collateral requirement, and a greater number of covenants. The regression coefficient on *Real Climate Risk* is .031 (p-value $= .000$), .084 (p-value $= .002$), and .034 (p-value $= .004$) for *Ln(Spread)*, *Secured*, and *Covenants* as the dependent variable, respectively. Taken together, the results reported in Panels A and B of Table 2 indicate that firms with greater climate risk exposure, measured either by managerial assessment or objective exposure to climate disaster events, face more stringent loan terms when borrowing from banks. This evidence supports the hypotheses H1a–H1c.

In Panel C of Table 2, we examine whether the two climate risk measures, *Perceived Climate Risk* and *Real Climate Risk*, have similar impacts on loan terms. The results reported in Panels A and B do not allow for a direct inference in this regard because the two measures have different units: *Perceived Climate Risk* is an indicator variable taking the value of zero or one, whereas *Real Climate Risk* is a non-negative continuous variable. To express these variables in comparable units, we apply a standardization approach to each measure by subtracting its mean and scaling by its standard deviation and denote the two standardized variables by *STD Perceived Climate Risk* and *STD Real Climate Risk*. We then conduct a horse-racing test for their magnitudes of impact on each loan contracting term by including the two standardized climate risk measures in the baseline regression model given by Equation (1). We find insignificant differences between the coefficients on *STD Perceived Climate Risk* and *STD Real Climate Risk*, as shown in the bottom row of the panel. These findings suggest that there is no discernible divergence in the loan contracting effects from perceived and real exposures to climate risk. In other words, the role of climate risk in corporate financing from banks does not appear to be sensitive to the particular climate risk measurement schemes.[16]

5.2 | Test results related to H2a–H2e: The influence of corporate climate risk management on bank loan terms for firms with climate risk exposure

In Table 3, we estimate the effects of climate risk management on bank loan terms among firms with climate risk exposure using the model provided in Equation (2). The results reported in Panel A pertain to a company's strategic approach to managing climate risk, measured by the

[15] $\ln(\#\text{covenants}_{\textit{Perceived Climate Risk} = 1}) - \ln(\#\text{covenants}_{\textit{Perceived Climate Risk} = 0}) = 0.309$. Therefore, $\#\text{covenants}_{\textit{Perceived Climate Risk} = 1}/\#\text{covenants}_{\textit{Perceived Climate Risk} = 0} = e^{0.309} = 1.3621$.

[16] In the Appendix S1, we confirm, via a two-stage treatment effect approach, that the climate risk–loan term relationship is preserved even after we adjust for potential self-reporting bias, if any, in the perceived risk metric. We also address potential endogeneity issues using a propensity-score-matching technique and a difference-in-differences method. Our findings are robust and consistent in these alternative econometric scenarios.

indicator variable *Business Strategy* (which takes the value of one if the company has integrated climate change into its grand strategic plan, and zero otherwise). From the results reported in Columns (1)–(3), it is evident that when firms have non-zero *Perceived Climate Risk*, *Business Strategy* loads significantly and negatively across all three regressions with *Ln(Spread)*, *Secured*, and *Covenants* as the dependent variable. This evidence suggests that, if firms are under the threat of climate change, their strategy to manage climate change risk is reflected in more beneficial bank loan terms. For example, in the *Ln(Spread)* regression, the coefficient on *Business Strategy* is −.273 (p-value = .000), indicating that, when firms strategically address climate change problems, their average loan spread is 27.3% lower than if climate risk is not considered in corporate strategy. Similar effects are observed in the *Secured* and *Covenants* regressions as well. Columns (4)–(6) show consistent results when firms' *Real Climate Risk* measure is non-zero, as the coefficients on *Business Strategy* are significantly negative in all three loan term regressions. These results imply that incorporating climate risk management into business strategy helps firms mitigate the climate risk concern of lending banks, which reduces the stringency of loan terms. This empirical evidence supports H2a regarding firms' strategic approach to addressing climate change.

In Panel B of Table 3, we test H2b by considering the role of *Board-Level Governance*, which indicates whether the board of directors has direct responsibility for climate change issues. The results show that the coefficients on *Board-Level Governance* are negative in all model specifications, and are significant in the *Ln(Spread)* and *Secured* cases when firms have non-zero *Perceived Climate Risk* and in the *Ln(Spread)* case when firms have non-zero *Real Climate Risk*. In general, the evidence suggests that firms with board (which is a high-level body in corporate governance) in charge of addressing climate change problems can obtain less stringent loan terms compared with other firms that do not have this level of climate risk oversight; stated another way, their loan terms are less sensitive to firm climate risk relative to peer firms.

In Panel C, we report the test results related to H2c focusing on *Risk-Managing Process* (which takes the value of one if the company has risk management process specifically targeting climate risk or climate risk is considered in a general risk management process, and zero otherwise). *Risk-Managing Process* is a micro-level measure with a specific focus on climate risk. At this level, we find significantly negative coefficient on *Risk-Managing Process* across all three regressions regardless of the consideration of non-zero *Perceived Climate Risk* or *Real Climate Risk*, indicating that the presence of specific or integrated climate risk management process alleviates the negative impact of climate risk on bank loan terms.

Panel D shows the effect of potential opportunities that a company can derive from climate change. The coefficient on *Climate Opportunity* is negative and statistically significant in all columns related to the non-zero *Perceived Climate Risk* and *Real Climate risk* scenarios, suggesting that climate-related opportunities can mitigate (or countervail) the effect of climate-related risks on bank loan terms. This evidence is consistent with H2d purporting that opportunities from climate change could serve as a natural hedge against downside climate impacts, especially when the opportunities are proactively sought by the firm.

In Panel E, we evaluate the moderating role of *Policymaking Involvement* in bank loan contracting. This consideration relates corporate practices to external regulatory factors that exert extensive influence on a firm's business landscape. The obtained results are similar to those reported in the previous panels. Specifically, *Policymaking Involvement* has negative coefficients in all model specifications, as shown in Columns (1)–(6), and the effects on loan spread and collateral requirement are statistically significant. These results are consistent with H2e, which posits that, if a firm actively participates in the policymaking process regarding climate change,

TABLE 3 The moderating role of climate risk management on bank loan terms for firms with climate risk exposure

Panel A: Business Strategy

	Firms with perceived climate risk exposure			Firms with real climate risk exposure		
	(1) *Ln(Spread)*	(2) *Secured*	(3) *Covenants*	(4) *Ln(Spread)*	(5) *Secured*	(6) *Covenants*
Business Strategy	−0.273	−0.749	−0.442	−0.312	−1.030	−0.329
	(.000)	(.081)	(.026)	(.000)	(.034)	(.048)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry & Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of Observations	672	672	672	559	559	559
Adjusted R^2/Pseudo R^2	.525	.340	.200	.527	.396	.210

Panel B: Board-Level Governance

	Firms with perceived climate risk exposure			Firms with real climate risk exposure		
	(1) *Ln(Spread)*	(2) *Secured*	(3) *Covenants*	(4) *Ln(Spread)*	(5) *Secured*	(6) *Covenants*
Board-Level Governance	−0.174	−0.739	−0.034	−0.146	−0.487	−0.077
	(.000)	(.022)	(.759)	(.001)	(.212)	(.518)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry & Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of Observations	672	672	672	559	559	559
Adjusted R^2/Pseudo R^2	.526	.344	.197	.518	.392	.208

Panel C: Risk-Managing Process

	Firms with perceived climate risk exposure			Firms with real climate risk exposure		
	(1) *Ln(Spread)*	(2) *Secured*	(3) *Covenants*	(4) *Ln(Spread)*	(5) *Secured*	(6) *Covenants*
Risk-Managing Process	−0.269	−1.384	−0.693	−0.206	−1.341	−0.614
	(.009)	(.006)	(.000)	(.069)	(.015)	(.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry & Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of Observations	672	672	672	559	559	559
Adjusted R^2/Pseudo R^2	.519	.346	.203	.512	.398	.214

Panel D: Climate Opportunity

	Firms with perceived climate risk exposure			Firms with real climate risk exposure		
	(1) *Ln(Spread)*	(2) *Secured*	(3) *Covenants*	(4) *Ln(Spread)*	(5) *Secured*	(6) *Covenants*
Climate Opportunity	−0.070	−0.922	−0.292	−0.074	−0.704	−0.258
	(.074)	(.002)	(.005)	(.098)	(.063)	(.012)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry & Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

TABLE 3 (Continued)

Panel D: Climate Opportunity						
	Firms with perceived climate risk exposure			Firms with real climate risk exposure		
	(1) *Ln(Spread)*	(2) *Secured*	(3) *Covenants*	(4) *Ln(Spread)*	(5) *Secured*	(6) *Covenants*
No. of Observations	672	672	672	559	559	559
Adjusted R^2/Pseudo R^2	.513	.351	.201	.510	.396	.212

Panel E: Policymaking Involvement						
	Firms with perceived climate risk exposure			Firms with real climate risk exposure		
	(1) *Ln(Spread)*	(2) *Secured*	(3) *Covenants*	(4) *Ln(Spread)*	(5) *Secured*	(6) *Covenants*
Policymaking Involvement	−0.212	−0.975	0.106	−0.201	−0.879	0.177
	(.000)	(.003)	(.381)	(.000)	(.020)	(.157)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry & Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of Observations	672	672	672	559	559	559
Adjusted R^2/Pseudo R^2	.532	.350	.197	.525	.399	.210

Note: Columns (1) & (4), (2) & (5), and (3) & (6) report results from OLS, Logit, and Poisson regressions, respectively. *p*-values reported in the parentheses are based on heteroskedasticity robust standard errors.

its bank loan and loan collateral costs tend to be less adversely affected by its climate risk exposure. To summarize, the findings presented in Table 3 imply that banks recognize climate change-impacted firms' efforts to manage climate risk by offering more favorable loan terms.

6 | CHANNEL TESTS: OPERATIONAL PERFORMANCE AND DEFAULT LIKELIHOOD

We explore potential channels for the adverse consequences of climate risk on a firm's loan contracting with banks, focusing on the factors that are arguably most relevant to creditors: the borrowing firms' operational performance and the risk of loan default. We conjecture that climate risk will undermine operational performance while increasing the likelihood of default, which will, in turn, lead to unfavorable bank loan terms. We consider the one-year ahead ROA (ROA_{t+1}) and CFO (CFO_{t+1}) to proxy for operational performance, and use the probability of default (*Prob. Default*$_{t+1}$), estimated following Bharath and Shumway (2008), to measure loan default risk. We revise Equation (1) by treating the above factors as the dependent variable and excluding loan-level characteristics from the control variables. The results relating climate risk to these measures of operational performance and default risk are shown in Table 4. As can be seen from Columns (1) and (2) where ROA_{t+1} and CFO_{t+1} are the dependent variable, the coefficients on *Perceived Climate Risk* are significantly negative, whereas the coefficient on *Perceived Climate Risk* in Column (3), where *Prob. Default*$_{t+1}$ is the dependent variable, is significantly positive. The results for *Real Climate Risk* reported in Columns (4)–(6) are in general consistent, although only significant in the ROA and CFO cases. These results indicate that climate risk is associated with lower firm performance and higher likelihood of default. They support our proposition that bank loan terms may become more stringent because of worsened operational

TABLE 4 Relation between firm climate risk and bank loan terms—channel tests

	(1) ROA_{t+1}	(2) CFO_{t+1}	(3) $Prob. Default_{t+1}$	(4) ROA_{t+1}	(5) CFO_{t+1}	(6) $Prob. Default_{t+1}$
Perceived Climate Risk	−0.008	−0.015	0.027			
	(.060)	(.000)	(.014)			
Real Climate Risk				−0.002	−0.017	−0.003
				(.071)	(.031)	(.235)
Ln(Total Assets)	0.000	0.000	−0.018	0.003	0.019	−0.010
	(.841)	(.999)	(.003)	(.000)	(.011)	(.000)
Tangibility	−0.049	0.046	−0.045	0.006	0.192	0.064
	(.000)	(.000)	(.029)	(.071)	(.002)	(.000)
Leverage	0.011	−0.033	0.140	0.002	−0.337	0.216
	(.453)	(.006)	(.003)	(.670)	(.080)	(.000)
ROA	0.723	0.536	−0.921	0.441	2.016	−0.848
	(.000)	(.000)	(.000)	(.000)	(.004)	(.000)
σ(CFO)	0.304	0.026	0.918	−0.028	−3.724	0.363
	(.005)	(.736)	(.020)	(.403)	(.038)	(.000)
Intercept	0.016	0.071	0.159	−0.074	0.084	0.069
	(.511)	(.000)	(.027)	(.000)	(.379)	(.016)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of Observations	977	977	977	10,345	10,345	10,345
Adjusted R^2	.472	.501	.368	.234	.045	.498

Note: This table reports OLS regression results. *p*-values reported in the parentheses are based on heteroskedasticity robust standard errors.

performance and heightened default probability resulting from climate risk. These findings also provide additional evidence supporting the adverse financial consequences of climate risk.

7 | DISCUSSION

Our analyses reveal that firm-specific exposure to climate risk adversely affects the terms of a company's bank loan financing, and this adverse effect is mitigated if the company takes viable management efforts to cope with climate change. As such, our study contributes to the extant body of knowledge in related research fields, while also having practical implications.

7.1 | Academic contributions and practical implications

7.1.1 | Contributions to climate risk research

The economic impacts of physical climate risk have been generally, but not specifically, understood. There is a paucity of research on particular climate-related factors in corporate operations. While prior studies have assessed climate change effects in cross-country or cross-region settings (e.g., Gallup et al., 1999; Huang, Kerstein, & Wang, 2018; Nordhaus, 2006), our investigation is among the first attempts to examine climate risk in a firm-specific domestic setting. We employ firm-level climate risk measures and produce strong evidence linking physical climate risk to the cost and terms of bank loan financing, which is an essential aspect of corporate operations. Our firm-specific measures also mitigate the country- or region-specific idiosyncrasies inherent in cross-country or cross-region research.

Our investigation of the climate change effect on bank loan contracting expands the emerging climate risk literature examining corporate financial choices. For example, Huang, Kerstein, and Wang (2018) demonstrate that firms in countries particularly prone to climate change are more likely to choose long-term debt and keep more cash. However, their paper does not specify bank loan financing, and is silent on the concrete corporate financing mechanisms (e.g., specific loan contracting terms) that we explore in this study. Our study extends the work of Huang, Kerstein, and Wang (2018) by documenting that climate risk makes it costlier to borrow from banks, which provides a plausible explanation for firms' tendency to hold more cash if exposed to high climate risk.

In a broader sense, our study supplements a recent strand of research focusing on the impact of climate performance on firm valuation. In this context, climate performance relates to carbon dioxide emissions, hazardous chemical disposal, and the generation of other pollutants that may incur regulatory, reputation, and litigation risks to firms. For example, Beatty and Shimshack (2010) show that firms suffer from negative market returns due to inadequate greenhouse gas emission management. Matsumura, Prakash, and Vera-Munoz (2014) similarly find that more extensive carbon emissions are detrimental to firm value. A salient distinction between our investigation and these extant studies is that the latter focus on firms with inferior climate performance that contribute to the climate change problem (i.e., those deemed "criminals" that harm the climate), while our analyses pertain to firms that may not be responsible for the deteriorating climate conditions (i.e., those deemed "victims" that suffer from climate impacts). Moreover, in extant climate performance-related studies, focus is primarily given to regulatory and reputation concerns, while we explore physical climate risk in particular.

7.1.2 | Contributions to bank loan contracting research

Given the detrimental effects of rapidly worsening climate problems on the economic landscape, it is becoming increasingly necessary for lenders to incorporate climate-related measures into their assessment of borrowing firms' overall financial risk. However, analyses relating to climate risk are rarely reported in the banking literature. Our extensive literature review reveals only one such investigation, as part of which lenders' decisions are linked to borrowers' climate performance (Chava, 2014). However, Chava (2014) focuses on climate factors such as hazardous chemical disposal, pollutant emissions, and environmental concerns that contribute to climate change (i.e., the "criminal" perspective), and only considers interest rates charged by lenders without examining other non-price factors commonly stipulated in lending contracts.

Our investigation is among the first studies examining whether banks go beyond traditional measures of future risk such as cash flow volatility to consider climate impact as a separate factor in loan contracting. Our finding that firms with greater physical risk exposure to climate change are provided significantly less favorable borrowing terms by banks suggests that anticipated climate conditions in the future are considered in banks' lending decisions. Given the relevance of the cost of debt on firm valuation, our study establishes a highly significant linkage between risk and firm value through climate change. As a result, our work contributes to the growing body of literature on the economic consequences of climate change by identifying a relevant systematic factor not typically controlled for in cross-sectional studies involving firms' financing costs.

7.1.3 | Implications for policymakers and managers

The findings reported in this work indicate that climate change imposes a significant burden on corporate financing through bank loans, and several climate risk management approaches can help mitigate the adverse climate impact on loan financing. These findings are valuable to both policymakers and corporate managers. Currently, climate change regulation is mainly driven by the need to curtail carbon emissions and generation of other pollutants, as well as encourage socially compliant managerial practices. These regulatory efforts aim to address the climate-irresponsible behaviors of the emitters or polluters, that is, the "criminal" firms. However, to our knowledge, there is no policy specifically motivated by the physical climate impact on "victim" firms, despite the substantial damage to businesses caused by climate change. Our study is suggestive to such policy-related endeavors in two aspects. First, banks' response to firm climate risk confirms a market-oriented mechanism that incentivizes firms to adopt active approaches to mitigate adverse climate influence. In other words, as market-based solution tends to be effective, *direct* governmental interventions do not seem to be warranted. Second, regulators nevertheless can still play an active role in policymaking that could *indirectly* influence the market reaction to climate risk. For example, the distribution of disaster aids may require government interventions because there is a high likelihood of market failure in this regard; in a similar vein, regulatory initiatives could help broaden commercial insurance coverage for damage incurred by climate change. Policies that facilitate firm-level adaptation and management efforts in dealing with climate risk should also assist firms in securing better financial status (e.g., obtaining cheaper bank funds).

For corporate managers, the effectiveness of several firm-level climate risk management measures (i.e., business strategy, board-level governance, risk-managing process, climate-related opportunities, and policy involvement) that we have documented in this study has significant theoretical and practical implications. First, our findings extend the results reported in extant literature on organizational resilience to climate risk. Second, the moderating role of climate risk management suggests that banks take note of those preventive measures when evaluating borrowers' overall risk, which provides useful information to firm managers when they consider their firms' climate-related strategies. Third, considering the overwhelming and seemly unstoppable ramifications of climate change, managers may be concerned that any efforts to fight climate change at the firm level could be trivial and immaterial. Our evidence that managerial behaviors do make a difference, at least in terms of reducing firms' financial costs, could be encouraging and help lessen the skepticism about winning the "climate war."

7.2 | Limitations and future work

In this study, we elucidate the impact of firm-specific climate risk on firm operations in the context of bank loan contracting. As our sole focus is on the cost and terms of bank loan financing, we anticipate that future studies will examine other related issues, such as equity issuance, public debt issuance, and usage of internal funds (i.e., dividend payout), that could also be influenced by firm climate risk. Such efforts will be important for generating a more robust and theoretically nuanced understanding of the relationship between climate risk and firm operations.

In order to differentiate firm-specific exposures to climate risk, we utilize the dichotomous CDP classifications and location-based exposure to actual climate disasters. Although such identification strategies are adequate for segregating high-exposure from low-exposure firms, finer and more economically informative measures are practically more desirable. However, detailed quantification of each firm's climate risk level is a daunting task and requires much more than indexing country-level or region-level climate conditions. Nonetheless, for future research on firm-level climate risk, this endeavor deserves sufficient attention.

A further limitation of our study stems from the fact that the climate risk management measures we consider are not specific to corporate financing from banks. Thus, a more nuanced examination of the particular mechanisms for bank loan contracting seems worthwhile. For example, a firm may additionally provide tailor-made "soft" information (Liberti & Petersen, 2019) to lending banks, with more detailed explanations of their strategies in dealing with climate change issues and how such strategies could enhance the firm's creditworthiness, which helps further alleviate the lenders' concern about the firm's climate risk. In this circumstance, a specific dossier on the company's climate risk profile could be particularly helpful in gaining better loan terms.

8 | CONCLUSION

It is increasingly evident that climate risk already has and will continue to exert progressively detrimental effects on the general economy in the years ahead. However, it is less clear how firms' specific exposure to climate risk will affect their business operations and access to external funds. In this work, we contribute to this hitherto under-researched area by examining the link between firm-specific climate risk and corporate financing from bank loans. Our findings show that firms with higher physical risk exposure to climate change have significantly more unfavorable bank loan terms, but those that take proactive measures to manage climate risk can alleviate the negative effect of climate risk on loan contracting. As such, we not only demonstrate that the grand threat of climate change is not a remote concept to individual firms, but that management practices can effectively mitigate potential business losses imposed by climate change. Overall, our analyses help elucidate the economic consequences of climate change in a more concrete and informative way, especially to corporate managers.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from commercial vendors such as Compustat, CDP, DealScan, IBES, and SHELDUS, and public sources such as the Federal Reserve Board of Governors and Edgar 10-K forms. Restrictions apply to the availability of these data, which were used under license for this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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