Received: 22 June 2022 | Revised: 7 September 2024 | Accepted: 12 September 2024

DOI: 10.1002/smj.3674

RESEARCH ARTICLE

SMS | Strategic Management Journal

WILEY

Physical climate change exposure and firms' adaptation strategy

Xia Li

London Business School, London, UK

Correspondence
Xia Li, London Business School, Sussex Place, Regent's Park, London NW1 4SA, UK.
Email: xial@london.edu

Abstract

Research Summary: This article examines whether and how firms adapt to physical exposures to climate change. I build a novel dataset that compiles information on the adaptation strategies of publicly traded companies around the globe and merge it with climate science data. I find that firms are sensitive to the nature and level of forecasted climate change exposures, and that they adapt more often and more completely to those most salient to their business. Increased physical climate exposure heightens the perceived impact of climate change, leading to a higher degree of adaptation. Furthermore, the positive relationship between firms' climate change exposure and their adaptation is stronger for firms with greater environmental, social, and corporate governance capabilities and those with longer time horizons.

Managerial Summary: Companies are increasingly exposed to the physical impacts of climate change, yet little is known about how they adapt to these long-term, systemic, and uncertain changes. This study investigates corporate adaptation strategies in response to climate change. By analyzing climate science data and climate change disclosure information from publicly traded companies worldwide, I find that most firms do not adapt to different physical climate change exposures. They adapt more often and more completely when facing higher forecasted climate exposures. Furthermore, firms' environmental, social, and corporate governance capabilities and their time horizons influence their adaptation to greater climate exposures. These findings suggest that targeted interventions may be necessary to improve corporate adaptation to climate change.

KEYWORDS

adaptation, capability, climate change, ESG, firm strategy, time horizon

1 | INTRODUCTION

From American utilities to Australian builders and from Asian manufacturers to European winemakers, corporations face increasing exposure to the direct, physical effects of climate change. Extreme weather events, such as wildfires and floods, threaten to damage properties and disrupt operations.[1] More gradual changes, such as water and heat stress, threaten to restrict access to needed resources and cause productivity losses.[2] In addition, increasing physical climate exposures also impact firms indirectly, for example, through higher insurance premiums and increased cost of debt (Hope & Friedman, 2018; Kling et al., 2021; Quinson, 2021). Physical climate change exposures are inherently forward-looking and long-term, surpassing typical managerial and business cycle time frames (Bansal et al., 2018; Carney, 2015; Flammer et al., 2021; Wright & Nyberg, 2017). The nature of these exposures is dynamic and highly uncertain, filled with model-selection ambiguities, unknown outcomes within a climate model, and forecast uncertainties about future effects and financial implications (Barnett et al., 2020; Pindyck, 2022, pp. 56–77). Moreover, climate change is systemic and impacts various sectors and countries (Li et al., 2021; Winn et al., 2011). These long-term, uncertain, and systemic features make physical climate change exposures different from short-term shocks or experienced changes (Aghion et al., 2012; Anand & Singh, 1997; Eggers & Park, 2018; Flammer & Ioannou, 2021), suggesting significant implications for firms' strategies (Howard-Grenville & Lahneman, 2021; Linnenluecke et al., 2013).

Facing increasing physical exposures to climate change, it is critical for firms to adapt and address its consequences. First, they need to adapt to external environmental changes for their own survival and growth (Amit & Wernerfelt, 1990; Helfat & Martin, 2015; Tashman & Rivera, 2016). Moreover, their adaptation is critical for the societies and communities they serve (Surminski, 2013; Winn & Pogutz, 2013). Extant management literature on climate change has primarily focused on firms' mitigation strategies—decreasing the firms' impact on

[1]For example, catastrophic wildfires worsened by climate change led to billions of dollars in damage and liability to utilities such as Pacific Gas & Electric (Gold, 2019).

[2]Rising temperatures have increased cooling costs in energy-intensive data centers (Plumer, 2019) and caused substantial labor productivity losses (The Australia Institute, 2020; Zander et al., 2015).

the environment (Bolton & Kacperczyk, 2022; Hart & Dowell, 2011; Jira & Toffel, 2013; Krueger, 2015). Climate change adaptation strategies that firms pursue to address the impact of the changing environment are less well understood (Fankhauser, 2017; Howard-Grenville & Lahneman, 2021; Linnenluecke et al., 2013). Prior works on climate change adaptation include conceptual frameworks (Berkhout, 2012; Clement & Rivera, 2017; Howard-Grenville & Lahneman, 2021), case studies (Canevari-Luzardo et al., 2020; Hamann et al., 2020; Linnenluecke et al., 2012), and a small number of empirical works in selected industries (Haigh & Griffiths, 2012; Weinhofer & Busch, 2013). These studies suggest that climate awareness and perception (Hoffmann et al., 2009; Linnenluecke et al., 2013; Pinkse & Gasbarro, 2019) and experienced adverse climate patterns (Rivera & Clement, 2019; Tashman & Rivera, 2016; Yoon et al., 2024) may influence firms' adaptation. What remains unclear is firms' response to forecasted, rather than experienced, physical climate change exposures.

This study advances the literature by examining whether and how firms adapt to forecasted climate exposures. This focus is crucial, as climate change is fundamentally about future challenges and requires an inherently forward-looking perspective. Specifically, I propose that firms' adaptation strategies depend on the level of climate exposures. Greater climate exposures will increase the perceived impact of climate change—how companies perceive and interpret the magnitude of the impact of climate change on their business operation and performance—thereby driving greater adaptation. Furthermore, considering the uncertainties associated with climate change in the future, firms' environmental, social, and corporate governance (ESG) capabilities—firms' ability to integrate ESG concerns into their business models—should play a significant role. Given the long-term nature of climate change, firms' time horizon—how far into the future firms consider risks when making decisions—should influence their perceived impact of climate change and adaptation strategies in response to higher climate exposures.

This article leverages novel datasets that enable a systematic investigation into these relationships. Quantifying a firm's physical climate change exposure is challenging. It cannot be simply calculated based on historical weather data but demands the use of forward-looking predictions drawn from climate models (Dell et al., 2014; Hsiang, 2016; Li & Gallagher, 2022). Equally complex is measuring adaptation, given the vast array of strategies that firms across countries and industries might deploy in response to diverse climate exposures (Linnenluecke et al., 2013). In addressing these challenges, I collect and use climate science data based on geospatial, historical, and projection models developed by Four Twenty Seven (currently Moody's). To measure firms' adaptation strategies, I hand-code the climate disclosure text that publicly traded companies reported with CDP (formerly, the Carbon Disclosure Project). Then, I merge these two datasets at the firm–climate exposure–year level. The final sample covers 1068 public companies headquartered in 43 countries across industries and their adaptation to 5 climate exposures: heat stress, water stress, sea-level rise, floods, and hurricanes/typhoons. The descriptive results show that the average rate of adaptation across all firms and different types of climate exposures is only 23%.

The empirical results suggest that firms are sensitive to the nature and level of forecasted climate change exposures, adapting more often and more completely to those most salient to their business. Greater climate exposure leads to a higher perceived impact of climate change, thereby increasing firms' adaptation efforts. Furthermore, the positive relationship between firms' forecasted climate exposure and their adaptation is stronger for firms with greater ESG capabilities and longer time horizons. Firms with longer time horizons perceive a greater magnitude of climate change when facing higher climate exposures. However, I do not find that the positive relationship between firms' climate exposure and their perceived impact of climate change is stronger for firms with greater ESG capabilities.

This article makes several contributions to the literature. First, it advances the body of research on organizational adaptation to external changes (e.g., Adner & Helfat, 2003; Gulati et al., 2005; Levinthal, 1997; Sarta et al., 2021). While previous studies have focused on organizational responses to experienced stresses (Tashman & Rivera, 2016) or short-term shocks (Aghion et al., 2012; Anand & Singh, 1997; Eggers & Park, 2018; Flammer & Ioannou, 2021), this study examines firms' proactive adaptation to long-term and systemic changes. This distinction is significant because the dynamics governing adaptation to long-term, systemic changes may differ from those governing responses to short-term ones. The findings underscore the importance of forecasted climate exposures and time horizons in shaping firms' climate change adaptation strategies. Second, it contributes to the sustainability literature (Brekke & Nyborg, 2004; Hawn & Ioannou, 2016; Pinkse & Kolk, 2012; Tilcsik & Marquis, 2013) by shifting the focus from firms' environmental and financial performance (Aragón-Correa & Sharma, 2003; Flammer, 2015; McWilliams & Siegel, 2001) to how ESG capabilities influence corporate adaptive strategies in response to varying levels of climate impact, thereby extending the understanding of ESG capabilities. Finally, this study uses innovative datasets to measure firms' climate change exposures, adaptation strategies, and perceived impacts of climate change. To the best of my knowledge, this is the first quantitative study that directly models perceived impact of climate change and examines its relationship with climate exposure and adaptation.

2 | THEORETICAL FRAMEWORK

2.1 | Definition

In this study, *physical climate change exposure* (henceforth, climate change exposure or climate exposure) refers to the assets and settings of firms that could be adversely affected by the physical effects of climate change. It is also called *physical climate risk* in some academic literature (Bolton & Kacperczyk, 2022; Flammer et al., 2021; Gu & Hale, 2023; Krueger et al., 2020; Kunreuther et al., 2013) and in practice (CDP, 2016; McKinsey Global Institute (MGI), 2020; TCFD (Task Force on Climate-related Financial Disclosures), 2017). Climate change may cause a broad scale and scope of exposures (Gasbarro & Pinkse, 2015), such as water stress, heat stress, excess rainfall, sea-level rise, wildfires, and hurricanes. These exposures can be categorized as acute, such as discontinuous events like floods or hurricanes that will become more frequent and intense because of climate change; or chronic, such as heat stress from rising temperatures and water stress from droughts (TCFD (Task Force on Climate-related Financial Disclosures), 2019).

Climate change adaptation (henceforth, adaptation) is the "process of adjustment to actual or expected climate and its effects" (IPCC AR6, 2022, p. 1758) to reduce negative impacts and/or leverage positive ones. Firms can employ various measures ranging from insurance or business continuity plans to innovation or M&A in response to the same climate exposure. Firms' adaptation to different climate exposures may vary. For instance, a firm might use more resilient materials in response to heat stress and relocate its assets when facing sea-level rise. This article defines adaptation strategy as a combination of different adaptation measures in response to various types of climate exposure. Firms' adaptation can be classified into routine and non-routine responses (Daft & Macintosh, 1981; Pinkse & Gasbarro, 2019). Routine adaptation modifies a firm's resource base and incorporates adaptation into previously established routine tasks (Cyert & March, 1963; Kraatz & Zajac, 2001), not necessarily in relation to climate change

(Reinhardt & Toffel, 2017). By contrast, nonroutine adaptation creates a resource base with new actions taken specifically in response to climate change (Pinkse & Gasbarro, 2019). Figure 1 depicts different adaptation strategies in response to different climate exposures.

2.2 | Climate change adaptation strategy

Qualitative evidence suggests that business adaptation to climate change is limited (Bank & Wiesner, 2011; Linnenluecke et al., 2013; Pinkse & Kolk, 2012). Firms may not have the capacity to accurately estimate the effects of climate change, a measure that cannot be easily calculated based on historical data (Battiston & Monasterolo, 2020; Berkhout, 2012). Given the ambiguity and uncertainties, managers may rely on heuristics that are biased toward maintaining the status quo or underpreparing for future events (Dessaint & Matray, 2017; Gavetti, 2012; Meyer & Kunreuther, 2017). Moreover, the vast spectrum of climate change effects means adaptation to multiple exposures can be expensive (Fankhauser et al., 1999; Kelly & Kolstad, 2005), prompting some firms to offload these costs, possibly to governments (Keeler et al., 2022; Pindyck, 2022). In addition, dimensions such as time and location make firms' adaptation more complex (Bansal, 2003; Pinkse & Gasbarro, 2019; Winn et al., 2011).

Previous literature indicates that both social and physical factors may influence firms' adaptation strategies. Socially derived factors involve awareness and perception of climate change[3] (Berkhout, 2012; Canevari-Luzardo et al., 2020; Pinkse & Gasbarro, 2019). Climate change is an enormous social challenge with complicated causal linkages spanning national boundaries and different time horizons that complicate their ready solutions (Barnett et al., 2018; Reinecke & Ansari, 2016; Rittel & Webber, 1973). Within organizations, conflicting perspectives and interpretations of reality compete to define issues and develop solutions related to climate change (Daft & Macintosh, 1981). Pinkse and Gasbarro (2019) developed a process model that incorporates climate perception and adaptation, drawing from qualitative evidence in the oil and gas sector. Hoffmann et al. (2009) found that climate change awareness is a catalyst for adaptation among Swiss ski-lift operators.

Physical factors encompass experienced climate events or stresses. Linnenluecke et al. (2012) proposed a conceptual framework on organizational resilience to extreme weather events. A small number of empirical studies on the relationship between historical climate impact and adaptation have yielded mixed results. Tashman and Rivera (2016) found that US ski resorts adopt natural-resource-intensive practices in response to historical winter snowpack depth. By contrast, Hoffmann et al. (2009) did not observe significant impacts of climate vulnerability in the past on adaptation among Swiss ski-lift operators. Meanwhile, Rivera and Clement (2019) found an inverted U-shaped correlation between historical temperature and adaptation in US ski resorts. Building on the extant literature, this study explores how firms proactively adapt to forecasted physical climate exposures, rather than how they reactively respond to experienced climate threats. This emphasis is essential because climate change primarily involves future challenges and naturally demands a forward-looking perspective.

[3]Climate change awareness refers to whether companies or people are aware of threats from climate change. Perceived impact of climate change refers to how companies perceive and interpret the magnitude of the impact of climate change on their business operation and performance. The former is about whether climate stimuli are noticed; the latter is about how climate impacts are being interpreted.

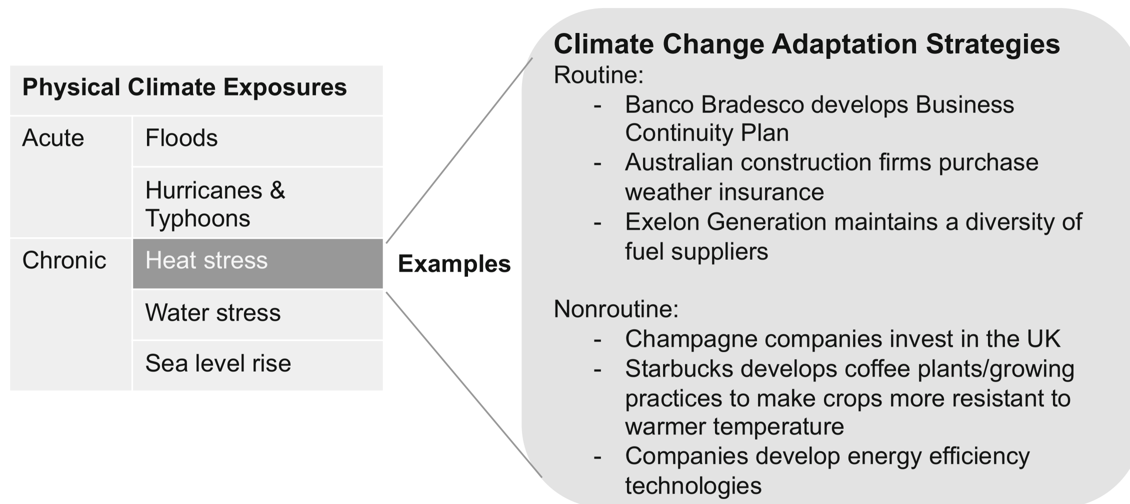

FIGURE 1 Physical climate change exposures and firms' adaptation strategies.

2.3 | Climate exposure and adaptation strategy

An organization's dynamic capabilities focus on its ability to adapt to change (Eisenhardt & Martin, 2000; Helfat & Martin, 2015; Teece et al., 1997). This perspective views firms as capable of developing resources to survive and grow under changing conditions (Helfat et al., 2007; Teece, 2007). Climate change can increase the risk of severe weather events that cause property damage and business interruptions and can lead to gradual environmental changes that reduce a company's resource availability and labor productivity. Accordingly, by purposefully modifying the resource base and adapting to climate change, firms can reduce production costs and increase operational efficiency (Amit & Wernerfelt, 1990), establish alternative natural sources subject to less uncertainty (Tashman & Rivera, 2016), explore innovative opportunities (Eggers, 2012), and improve competitive advantage (Helfat & Martin, 2015; Teece et al., 1997). For example, Juniper Networks migrated part of its headquarter labs from Sunnyvale to Quincy, California, to reduce the impact of sea-level rise on its operations; Sumitomo Chemical has developed chemical agents that enhance the ability of plants to withstand heat stress and drought.[4]

The magnitude of forecasted climate exposure is pivotal for adaptation decisions because the intensity or the speed of future changes can influence organizational adaptation (Teece et al., 1997). The signs of climate change might be ambiguous to some and difficult to differentiate from normal weather variations (Barnett, 2001; Berkhout et al., 2007; Weinhofer & Busch, 2013). Anecdotal evidence suggests that while firms generally respond to extreme weather events when they experience them directly, they may not attribute these events to climate change.[5] Thus, they may not initiate climate-related actions after such events resolve. Unlike past climate threats that may provide ambiguous signals about future impacts, higher forecasted climate exposure indicates a clearer and more significant risk to firms. Firms facing such exposures will likely encounter more frequent and intense physical changes, resulting in financial consequences. Additionally, these changes are expected to occur over a shorter time frame compared with firms having lower exposure. Given the heightened likelihood of climate impact, the expected benefits of adaptation are more likely to outweigh the associated costs, driving firms to overcome organizational inertia and adapt to the probable changes (Dessaint & Matray, 2017; McKnight & Linnenluecke, 2019; Meyer & Kunreuther, 2017).

Companies can derive insights on climate exposures in the future from their own assessment and from external experts. For instance, international institutes, such as the IPCC and some industry associations, can provide general information about forecasted climate exposure at a regional or industry level, and some environmental consultants and (re)insurance companies can provide more specific predictions at a firm or asset level. The climate science information can help shape firms' climate strategies.

Based on the above insights, I expect that increased climate exposures can predict a firm's proactive adaptation:

[4]Information from CDP reports.

[5]For example, as disclosed in one CDP report, one utility company in the United States responded to drought through risk-management procedures but claimed that it "cannot predict whether long-term changes in frequency of severe weather events due to climate change will have more of an impact on the electric distribution infrastructure than normal year-to-year variations in severe weather events."

Hypothesis H1. The greater the forecasted climate exposures, the greater the degree of firms' adaptation to climate change.

2.4 | Perceived impact of climate change

Adaptation is not only a decision based on cost–benefit analyses but also a complex process involving the perception and interpretation of climate impacts (Berkhout, 2012; Simon, 1991). The ways in which companies recognize and interpret the impacts of climate change can shape varying levels of adaptation effort (Pinkse & Gasbarro, 2019). In this section, I unpack the perception mechanism underlying firms' adaptation decisions in response to forecasted climate exposures. The perceived impact of climate change is defined as how companies perceive and interpret the magnitude of the impact of climate change on their business operation. Firms with heightened climate exposure are more likely to perceive greater impacts from climate change, leading them to develop dynamic capabilities for adapting to future changes.

First, when firms face greater forecasted climate exposures, they are more likely to perceive the uncertainty of climate change as less ambiguous and interpret the threat as more impactful. Signs of climate change, often ambiguous (Barnett, 2001; Weinhofer & Busch, 2013), may lead firms to view extreme weather events as isolated rather than systemic. However, those with higher forecasted climate exposure are more likely to encounter an increased frequency and intensity of such events in the future. This heightened exposure encourages them to link extreme weather events and stresses directly to climate change. This recognition transforms their perceived threat of climate change to a greater and more pressing concern.

Second, higher climate exposures signal not just a more intense impact but also a nearer impact. While climate change is fundamentally a long-term issue, its manifestations can vary in immediacy. Given the tendency for corporate myopia (Holmstrom, 1999; March, 1991; Stein, 1988), the immediacy of climate impact can translate into greater tangibility of this issue and increase managers' perception. Shorter-term manifestations of climate change highlight the downside of inaction and emphasize the need for timely adaptation strategies.

Third, firms expecting greater climate exposures in the future tend to engage more deeply with scientific data, leading to greater concerns about climate change. The nature of unprecedented climate impacts necessitates a reliance on scientific sources for insight (Battiston & Monasterolo, 2020; Berkhout, 2012). Greater engagement with scientific information not only results in more accurate interpretations but also translates into greater concerns about future exposure and the perceived need for adaptation (Linnenluecke et al., 2015). Combining the above insights, I hypothesize the following:

Hypothesis H2. Greater forecasted climate exposures increase the perceived impact of climate change, thereby increasing the degree of firms' adaptation to climate change.

2.5 | ESG capabilities

ESG refers to how companies integrate ESG concerns into their business models (Gillan et al., 2021). It includes a firm's activity in response to stakeholder pressure or demands for emissions reduction, workforce diversity, community involvement, and other environmentally and socially responsible practices (Cao et al., 2019; Waddock, 2008; Zollo et al., 2013). In this study, I define ESG capabilities as firms' capabilities to integrate ESG concerns into their business models. They are intangible firm resources and capabilities with multiple uses and benefits (Hawn & Ioannou, 2016).

Firms with superior ESG capabilities are more likely to have organizational resources to not only manage their environmental and social impacts well (Aragón-Correa & Sharma, 2003) but also to influence their adaptation strategies. ESG capabilities enable firms to process climate-related information and interpret climate exposure differently. Furthermore, it can provide firms with knowledge and resources to more effectively respond to the changing environment.[6]

As discussed in Section 2.2, high degrees of uncertainty, ambiguity, and conflicting interpretations of reality are associated with climate change exposure (Daft & Macintosh, 1981), and they compete to define climate issues and develop solutions. The ESG capabilities of firms can help address this equivocality. Firms with better ESG capabilities are more likely to connect extreme weather events with climate change and to accept the responsibility framing for climate change adaptation (Reinecke & Ansari, 2016).

First, firms with better ESG capabilities may have organizational processes in place to address a broad set of climate change issues. They can be more sensitive to stakeholders' concerns about environmental and social issues in general and thus allocate focus to physical climate exposure. A firm's choice of adaptation is not only driven by objective climate exposures but also influenced by subjective factors such as climate change awareness (Arnell & Delaney, 2006; Gasbarro & Pinkse, 2015; Hoffmann et al., 2009; Linnenluecke & Griffiths, 2010). Although most stakeholder concerns focus on climate change mitigation, such as reducing GHG emissions and developing renewable energy, they may spill over to related dimensions including adaptation. Firms' overall awareness of climate change is likely to correlate with the perceived impact of climate change, which motivates them to search for ways to adapt when facing greater climate exposures.

Second, the perceived impact of climate change also depends on the ability to process information about climate exposures (Fankhauser et al., 1999; Linnenluecke et al., 2015) and the knowledge firms have of the ecosystems in which they operate (Aragón-Correa & Sharma, 2003; Hart, 1995; Pinkse & Gasbarro, 2019). Firms with better ESG capabilities can better notice, absorb, and process climate-related information to interpret its impact on their business. For example, CLP Holdings started to conduct a climate change adaptation study for its power assets in different countries in 2011. Their earlier efforts on ESG practices enabled their awareness of different aspects of climate change beyond reducing GHG emissions and their assessment of the potential climate exposures of their power assets.[7] These points lead to the following hypothesis:

> **Hypothesis H3a.** The positive relationship between firms' climate exposures and their perceived impact of climate change is stronger for firms with greater ESG capabilities.

Firms' ESG capabilities can also provide firms with better internal and external competencies to more effectively respond to the changing environment (Teece et al., 1997). Better ESG

[6]Note that firms' ESG capabilities may also heighten the structured organizational attention (Hoffman & Ocasio, 2001) and increase their adaptation to greater climate exposure. Future research can further explore decision-makers' attention in this process.

[7]Climate disclosure from a 2012 CDP report.

capabilities improve a firm's human resource capabilities (Brekke & Nyborg, 2004), strengthen connections with local communities (McKnight & Linnenluecke, 2016; Pinkse & Kolk, 2012; Tilcsik & Marquis, 2013), encourage knowledge-sharing with suppliers (Dyer & Singh, 1998), promote favorable access to local infrastructure (Fombrun, 1996), and increase innovation (Flammer & Kacperczyk, 2016). These capabilities can help firms adapt better when facing greater climate exposures.

ESG covers numerous aspects associated with resource use, emissions reduction, and collaboration with communities, which are particularly relevant and transferable to the climate change adaptive capability of companies. For example, the efforts that Anglo American made to measure and reduce GHG emissions as part of its ESG efforts enabled it to better understand different climate scenarios. The knowledge it developed to reduce its environmental impact helped the company work with regional teams to understand and explore the climate impact on projects in different regions under different climate scenarios. In addition, its experience working with communities and government entities on climate change mitigation research strengthened its capability to work with these stakeholders on a climate change adaptation study that ranked all group operations and projects for climate vulnerability.[8]

Along with environmental and social performance, corporate governance can influence a company's tendency and capability to adapt. Effective corporate governance aims to align managers' interests with shareholders to increase the firm's long-term value and exert better board oversight of their company's risk management (Adams, 2012; Gupta & Leech, 2014), which includes climate risks. Accordingly, firms with better corporate governance are more likely to accurately assess their climate risk exposures and initiate strategies to adapt to climate change.

In sum, ESG capabilities provide an asset orchestration function (Helfat et al., 2007) between the organization and the environment and influence a firm's adaptive capability. This motivates the following hypothesis:

> **Hypothesis H3b.** The positive relationship between firms' climate exposures and their adaptation strategies is stronger for firms with greater ESG capabilities.

2.6 | Firms' time horizon

A firm's time horizon refers to the temporal distance into the past and future that a company typically considers when contemplating events that happened in the past or may happen in the future (Bluedorn, 2002). This concept is particularly relevant to firm strategies in response to climate change, which inherently span a long period of time. In this study, I define firms' time horizon as how far into the future firms consider events and risks when making decisions. Firms with longer time horizons focus more on the remote future, while those with shorter time horizons focus more on the present or near future (DesJardine & Bansal, 2019).

The temporal preferences and time horizons of managers can influence their perceived impact of climate change and decisions in climate change adaptation. Many, if not most, of the time horizons of business management are much shorter than the timescale of climate change impacts. Research suggests that managers tend to be myopic and favor investments that pay off in the short run at the expense of potential long-term benefits (Flammer & Bansal, 2017; Holmstrom, 1999; Slawinski & Bansal, 2015; Stein, 1988). For these reasons,

[8]Climate disclosure from a 2014 CDP Report.

even if the long-term returns from adaptation were higher than the cost, firms might not pursue these strategies.

Firms with longer time horizons, however, are more likely to develop capabilities to perceive and interpret climate exposures differently. They are more inclined to consider future climate events, as these occurrences align more closely with their extended planning time frame. Such companies place greater emphasis on the long-term adverse effects of climate change and are less likely to overly discount future risks. They are more likely to recognize how future climate conditions intersect with their current strategies and perceive the impacts of climate change as more significant and probable. Based on these points, I propose the following hypothesis:

> **Hypothesis H4a.** The positive relationship between firms' climate exposures and their perceived impact of climate change is stronger for firms with longer time horizons.

Firms with longer time horizons not only perceive climate exposures differently, they also have stronger incentives to respond to these exposures and invest more in adaptation. First, firms' temporal dimension affects the saliency of new challenges and managers' attention to address these challenges (Bansal, 2003; Ocasio, 1997). Previous studies indicate that organizations with longer time horizons tend to invest in projects with longer payback periods, such as innovation (Flammer & Bansal, 2017). Similarly, while climate change adaptation incurs significant costs, it offers substantial long-term benefits (IPCC AR6, 2022). Firms with longer time horizons tend to value these long-term benefits more, reinforcing their capabilities to commit to adaptation strategies.

Second, firms with a long-term focus are prone to establish and fortify relationships with their stakeholders (Slawinski & Bansal, 2012). Stakeholders, especially local communities affected by climate change, may exert pressure on firms to act responsively toward physical climate exposures. Companies with longer time horizons are more inclined to collaborate with stakeholders and local communities in climate change adaptation. This stakeholder engagement further bolsters their adaptive capability, ensuring that they remain responsive and resilient in the face of evolving climate challenges. These considerations form the basis of the following hypothesis:

> **Hypothesis H4b.** The positive relationship between firms' climate exposures and their adaptation strategies is stronger for firms with longer time horizons.

3 | DATA

3.1 | Climate change exposure

The assessment of firms' physical exposures to climate change requires climate science to conduct a forward-looking analysis, because climate exposures in the future cannot be derived from historical weather data alone (Dell et al., 2014; Hsiang, 2016; Li & Gallagher, 2022). In this study, I measure the level of forecasted *climate exposure* by using Four Twenty Seven's physical climate risk scores.

Four Twenty Seven evaluates the magnitude of various types of climate exposure of each facility according to its specific location and the nature of its activity. It estimates climate exposure based on geospatial, historical, and projection models at facility locations and uses the period 1975–2005 as a historical benchmark. It further projects future states in 2030–2040 under a business-as-usual scenario and establishes a basis for how climate is expected to shift over time at a given location by comparing future projections against the historical baseline. The criteria for the analysis include detailed climate change projections that measure the relative degree of change in extreme events, such as intensity and frequency of rainfall, high temperatures, cyclone activity, coastal flooding, and water stress. Four Twenty Seven translates these raw indicators of physical climate exposures (e.g., 1°C increase in temperature; 20% more intense rainfall) into a globally comparable standardized score ranging from 0 to 100 across hazards and locations, with higher scores indicating greater climate exposures.[9] Online Appendix A provides methodological details, including the scoring process for each type of climate exposure.

Along with climate modeling at specific locations where facilities are located, Four Twenty Seven assigns a series of sensitivity factors to facilities based on the nature of their activities. These factors vary by type of climate exposure, reflecting the sensitivity of the company's activities to the corresponding risk factor. For example, a thermal power plant is more sensitive to water stress than an office because it requires more water for cooling. As a result, a power plant receives a higher water stress score than an office located in the same area. Appendix A provides details of how these adjustments are made for certain types of climate exposure, such as heat stress and water stress.

To determine company-level climate exposure scores, Four Twenty Seven aggregates the climate exposure of all of a firm's facilities, ranging from manufacturing sites and warehouses to offices and retail facilities. The data include facilities that are at least 50% owned by a company. No weighting is applied based on ownership. Facilities that are being developed and not yet operational are not included. The global database of corporate facilities consists of more than 1 million sites located in 200 countries and 23 Global Industry Classification Standard (GICS) industry groups.[10]

In this study, I focus on the climate exposures of firms' direct operations, and not their market- or supply-chain-related risks. As detailed in Appendix A, both supply-chain and market climate exposures are evaluated at the national or industry level by Four Twenty Seven. These evaluations do not provide the same level of detail as those provided by the climate exposures of a firm's direct operations, which are based on facility information.

The predicted climate exposure scores are generated in 2019 by Four Twenty Seven. The scores are at the firm–climate exposure level. Due to the data availability and consistency discussed in Section 3.2, my sample covers the period from 2011 to 2017. I assume that predicted climate exposure scores are the same for each firm and each type of climate exposure during the sample period. This is a reasonable assumption because a company's forecasted climate exposures would stay the same if its facilities are the same with no major relocation or M&A activities. In the robustness check, I exclude firms with major M&A activities, and the results

[9]The scores measure how an entity is exposed to historical and projected climate exposures, not potential financial or economic impacts, which depend on numerous factors (including climate exposure) and are difficult to evaluate. A higher score indicates that a particular type of climate exposure is more salient to an entity.

[10]All company facilities are weighted equally because data about each site's value or contribution to a company's revenues are not available.

remain robust. The dataset includes 2233 public companies[11] headquartered in 47 jurisdictions and includes the assessment of several types of climate exposure, including heat stress, water stress, sea-level rise, floods, and hurricanes/typhoons.

3.2 | Disclosed climate change adaptation strategies

Measuring firms' adaptation to climate change is complex. First, the set of potential strategies is large and heterogeneous (e.g., firms can use alternative materials in response to heat stress, while relocating their assets when facing the risk of sea-level rise). Second, adaptation strategies cannot easily be compared and translated into a single quantitative measure.

To overcome measurement difficulties, I use the disclosed adaptation of firms to approximate their adaptation strategies and manually code the disclosure data. I obtain these climate disclosure reports from the CDP. Each year, public firms provide comprehensive information on their climate risks and management methods in response to a survey from CDP, mainly driven by pressures from investors (Kolk et al., 2008). These surveys collect information about firms' physical and transition climate risks, climate change opportunities, GHG emissions, and climate change mitigation and adaptation strategies. The sample period is 2011–2017, during which the CDP survey consistently asked for physical climate risk information.[12]

I read through all firms' disclosed adaptation strategies in CDP reports and perform two rounds of intensive manual text coding. The first round consists of inductive coding of the disclosed adaptation activities of 1000 firms in 2017, which generates a list of 23 categories of adaptation strategies. I partly use the categories of existing studies, such as *buffer*, *diversification*, *innovation*, and *ecosystem-based adaptation* (Goldstein et al., 2019; Tashman & Rivera, 2016; Yoon et al., 2024). Some of the categories emerge from my analysis because this study covers more industries, climate exposures, and a longer period. For example, JBS assumes advance purchases of financial derivative contracts to purchase agricultural commodities, and I code it as *Risk Transfer*. Three researchers code the firms' disclosed adaptation measures into different categorizations, and the interrater agreement is above 95%. The categories and definitions are summarized in Table 1. Examples of different categories of adaptation are detailed in Table B.1 in Appendix B.

The second round consists of using this list of categories to code the remaining firms and years. I code a category equal to 1 for a firm that discloses adaptation to one type of climate exposure in a specific category, and equal to 0 if not. I iterate this process for each category, and the final outputs result in 23 scores for each firm and each type of climate exposure in each year. For firms that do not disclose any adaptation to a specific type of climate exposure, I fill in all categories as zero. Some firms do not disclose climate-related information in certain years (i.e., not all firms disclosed climate information consistently from 2011 to 2017). Because I do not know why some firms opt out in certain years, I treat these cases as missing data. The results are still robust when I assume the missing data are zero.

[11]Four Twenty Seven data cover most large public companies. For instance, the 2019 climate exposure data cover 94% of S&P 500 companies; 83% of the companies in the dataset are multinational companies.

[12]The CDP changed the questionnaire in 2011 and 2018. Accordingly, I did not include the years prior to 2011 and after 2017 in the baseline. In 2017, the CDP sent the questionnaire to over 6000 companies, covering all S&P 500 companies, and received responses on physical climate risks and adaptation strategies from 2003 companies.

TABLE 1 Coding for climate change adaptation strategies.

Form	Category	Definition
Routine	Risk assessment	Risk identification, risk monitoring, risk modeling, risk profiling
	Risk management	Different risk management plans such as safety management, crisis management, disaster management, loss prevention plan, business continuity plan (BCP)
	Risk transfer	Insurance and other financial instruments such as derivatives
	Supplier management	Supplier and procurement diversification
	Enterprise risk management (ERM)	Development of firm-wide strategies to identify and prepare for hazards with a company's finances, operations, and objectives
	Buffer	Building more facilities, preparing more stocks
	Other routine adaptation	Other routine adaptation measures
Nonroutine	Hard technology	Adopting physically tangible new designs and technologies
	Soft technology	Adopting physically non-tangible technologies such as a new IT system, digital technology, platform
	Resilient input	Adopting more resilient inputs and materials
	Diversification of market	Targeting at and investing in alternative markets
	Diversification of product	Producing different types of products
	Diversification of location	Building assets or factories at alternative locations
	Corporate strategy	Considering climate issue when making Investment, Mergers & Acquisition (M&A), Joint Venture (JV), and spin-off decisions
	Substitution	Decisions regarding self-production or outsourcing
	Relocation	Relocation of factories or headquarters
	Ecosystem-based adaptation (EbA)	Cooperating with ecosystems
	Research and Development (R&D)	Research, new product or new technology development
	Stakeholder engagement	Engagement with stakeholders such as communities and governments
	Energy reduction	Reducing energy use, using renewable energy
	Water management	Reducing water use, reusing, seeking alternative water sources
	Climate study	Climate specific assessment/study at the corporate level
	Other nonroutine adaptation	Other nonroutine adaptation measures

As with most corporate disclosures, firms' disclosed adaptation in CDP reports may not accurately reflect their actual practices because of selective disclosure, such as greenwashing or brownwashing (Callery & Perkins, 2021; Kim & Lyon, 2011; Lyon & Maxwell, 2011). However, the selective disclosure possibilities of adaptation are likely lower than firms' environmental practices. Unlike firms' impact on the environment, there are few regulations on how firms adapt to the changing environment. Thus, firms' inadequate adaptation measures are not likely to trigger immediate regulatory risk the way the poor management of toxic emissions does. Furthermore, because most ESG rating agencies had not incorporated firms' adaptation to climate exposures into their rating scope by 2017 (the last year of the sample period), firms may not have incentives to use linguistic tactics in disclosing their adaptation strategies to influence environmental ratings (Fabrizio & Kim, 2019). For instance, 32% of firms in the sample disclose their climate exposures but do not report adaptation measures with the CDP.

I use *Adaptation* to measure whether a firm initiates an adaptation strategy. It is a dummy variable equal to 1 if a company has one or more adaptation strategies directed to a specific climate exposure and 0 otherwise. I use *Adaptation Breadth* to measure the diversity and extent of firms' adaptation by pursuing different strategies simultaneously. To construct *Adaptation Breadth*, I follow Hoffmann et al. (2009) and Slawinski and Bansal (2015) and count the number of adaptation categories a firm has in response to each type of climate exposure.

Following the definition in Section 2.1, I classify firms' adaptation strategies into two types, *Routine* and *Nonroutine*, depending on different levels of effort firms make in changing their resource base and developing adaptation strategies in response to climate change. Routine adaptation focuses on the familiar characteristic of problems and potential solutions (Gavetti, 2012). For example, when facing sea-level rise, firms may assess their risk profile, secure backup power generators, purchase insurance, or create a business continuity plan as part of routine risk management. These enable firms to develop operational capabilities to maintain business as usual (Dosi et al., 2000; Nelson & Winter, 1982; Scott, 1981). They require less information processing and fewer resources, and they are usually operated by one unit within the organization.

By contrast, nonroutine adaptation involves building or reconfiguring internal and external competencies (Teece et al., 1997), changing a firm's boundaries (Scott, 1981), or shifting to a new mode of management (Clement & Rivera, 2017; Hannah et al., 2013; Scott & McBoyle, 2007). For example, when facing heat stress, firms may innovate or adopt new technologies that use less energy for cooling, develop crops more resilient in warmer temperatures, or diversify their locations. In many cases, this involves multiple departments within an organization and therefore is more disruptive to the organization.

The two types and underlying categories are detailed in Table 1. Overall, there are six outcome variables: three measurements for *Adaptation—Adaptation*, *Routine Adaptation*, and *Nonroutine Adaptation*—and three measurements for *Adaptation Breadth—Adaptation Breadth*, *Routine Breadth*, and *Nonroutine Breadth*.

3.3 | Perception, ESG, and time horizon

I measure *Perception*, that is, the perceived impact of climate change, by using firms' disclosed magnitude of climate impact in their CDP reports. Each year the CDP asked companies to describe their inherent risks driven by changes in physical climate parameters for each type of climate exposure. These include the magnitude of impact, ranging from "Low" to "High" with five choices.[13] I code different levels of magnitude by using scores from 1 to 5 (1 = "Low"; 2 = "Low-Medium"; 3 = "Medium"; 4 = "Medium-High"; 5 = "High"). A higher score indicates a higher perceived impact of climate change.

To measure firms' *ESG* capabilities, I use the ESG score provided by Refinitiv (previously ASSET4), which is one of the most comprehensive ESG scores used in the literature (Flammer et al., 2021; Hawn & Ioannou, 2016). A higher ESG score indicates better ESG capabilities. I

[13]Responses in Section CC5.1b of CDP reports.

consider three main categories classified by Refinitiv: environment, social, and corporate governance. To further distinguish ESG capabilities and their various effects, I follow Hawn and Ioannou (2016) and categorize ESG into *Internal ESG* and *External ESG*. In addition, I collect alternative ESG ratings from MSCI ESG STATS and Sustainalytics in lieu of Refinitiv data. The results are robust.

I measure *Time Horizon* by using firms' disclosed risk time horizon in their CDP reports. Since 2014 the CDP has asked companies to describe "how far into the future are risks considered?" at the corporate level and provides four choices.[14] I code firms' time horizon by using scores from 1 to 10 (1 = up to 1 year; 3 = 1–3 years; 6 = 3–6 years; 10 = >6 years). A higher score indicates a longer time horizon. In addition, I use different coding for the scores (e.g., 1 = Up to 1 year; 2 = 1–3 years; 3 = 3–6 years; 4 = >6 years). The results are robust.

3.4 | Control variables

I construct firms' financial control variables based on data from Compustat. *Size* is the natural logarithm of the book value of total assets. *Return on Assets* (ROA) is the ratio of operating income before depreciation to the book value of total assets. *Leverage* is the ratio of debt (long-term debt plus short-term debt) to the book value of total assets. *Cash* holding is the ratio of cash and short-term investments to the book value of total assets. *FirmAge* is the year in the analysis minus the year a firm was founded. The inclusion of control variables mitigates the possibility that the findings are driven by some firm-year-level omitted variables. For example, it could be that larger companies or companies with more cash holdings have more resources to adapt. In addition, larger firms may be under more intense public scrutiny, which may lead to more action. Controlling for firm size and cash holdings addresses this potential confounding influence. Similarly, the other controls account for differences in performance (ROA and market-to-book) and financing policies (leverage and cash holdings) that may correlate with decisions to adapt.

I calculate other firm-level control variables based on facility statistics from Four Twenty Seven. *Diversity* is the number of GICS industry groups that a firm's facilities cover. *Multination* is a dummy variable and equals 1 if a firm has operations in countries outside its headquarters. I also include some country-level controls. *Climate Awareness* is the percentage of people who believe climate change is a serious concern in a given country. I collect this information from a cross-sectional survey conducted across 119 countries (Lee et al., 2015) by Gallup World Poll. *Carbon Pricing Coverage* is the percentage of CO_2 emissions that are covered by carbon pricing initiatives—carbon tax or emissions trading systems—in a given country each year. I collect carbon pricing information from Our World in Data.[15]

3.5 | Sample selection

I merge firms' adaptation data with financial data at the firm and year level. I perform firm-level matching using the International Securities Identification Number (ISIN) as the primary

[14]Responses in Section CC2.1a of CDP reports. For years before 2014, I assume firms' time horizons are the same as those in 2014.
[15]https://ourworldindata.org/carbon-pricing.

identifier. I merge the adaptation data with climate exposure data at the firm–climate exposure level, as illustrated in Figure B.2 of Appendix B. For matching at the climate exposure level, I manually adjust the climate exposure names in the CDP data based on textual descriptions of different types of exposures to match the names and definitions of climate exposures in the Four Twenty Seven data. The final sample covers adaptation strategies of 1068 public companies headquartered in 43 countries in response to five types of climate exposure between 2011 and 2017.[16] Table 2 provides definitions and summary statistics for the variables used in the analysis.

In addition to quantitative data, I collect some qualitative evidence to facilitate the interpretation of the empirical results. First, I interview 12 sustainability directors/consultants in the United States and Asia. Second, I review the CDP reports, sustainability reports, and annual financial reports of over 1500 firms between 2010 and 2019, which provide textual information on firm adaptation. Online Appendix C provides more information on the qualitative evidence.

4 | METHODOLOGY

To assess firm adaptation in response to the level of forecasted climate exposures (*H1*), I estimate the following model in the baseline:

$$Adapt_{irt} = \alpha_i + \alpha_r + \alpha_t + \beta ClimateExposure_{ir} + \gamma' X_{it-1} + \varepsilon_{irt} \tag{1}$$

The unit of analysis is firm–climate exposure–year. Firms are indexed by *i*; exposures are indexed by *r*; and years are indexed by *t*. $Adapt_{irt}$ is a generic term standing for one of the six outcome variables described in Section 3.2. $ClimateExposure_{ir}$ measures the level of exposures to climate change of company *i* for climate exposure *r*. Note that climate exposure varies across firms and exposures, but not across years. The regression includes fixed effects for each firm α_i, climate exposure α_r, and year α_t, and a vector of control variables *X*, including *Size*, *ROA*, *Leverage*, *Cash Holdings*, *Climate Awareness*, and *Carbon Pricing Coverage*. I denote the residual as ε_{irt}, and cluster standard errors at the firm level.

I estimate Equation (1) using ordinary least squares (OLS).[17] The coefficient of interest is β, which measures the relationship between climate exposures and the likelihood or scope of a firm's adaptation strategies. The firm fixed effects control for unobserved factors that might lead

[16]To assess whether the companies disclosing climate information through the CDP are representative of the broader universe of public firms, I focus on S&P 500 companies and compare firms with and without CDP climate exposure disclosure. As shown in Table J.1 in Appendix J, the two groups of firms are similar in most aspects, such as climate exposure scores and financial performance. The companies disclosing climate exposure information through the CDP are larger. To assess whether companies in the merged sample are representative of all companies disclosing climate information through the CDP, I consider all companies disclosing data through the CDP and compare firms with and without climate exposure scores. As shown in Table J.2 in Appendix J, the two groups of firms are similar in most aspects, such as financial performance and ESG performance. The only difference is that firms in the sample are larger. While the size difference does not bias the estimates within the estimation sample, they can potentially restrict the external validity of the findings. Whether the results of the study generalize to smaller companies is an important avenue for future research.

[17]I also use logistic regression when outcome variables are binary. As detailed in Section 5.6, the marginal effect of *ClimateExposure* on *Adaptation* in the logistic regression is the same as the coefficient estimated in the OLS model. In other words, the OLS model with clustered standard errors provides coefficients that can be directly interpreted as marginal effects in the logistic model.

TABLE 2 Summary statistics.

Panel a: Description							
Variable	Mean	Std. dev.	Min	Max	Unit of Obs	Data source	Note
AdaptationBreadth	0.49	1.04	0.00	11.00	i,r,t	CDP	AdaptationBreadth is constructed by adding up adaptation categories the firms have taken in response to one particular climate exposure.
RoutineBreadth	0.31	0.71	0.00	4.00	i,r,t	CDP	The sum of routine adaptation categories. Routine adaptation modifies a firm's resource base and incorporates adaptation into previously established routine tasks.
NonroutineBreadth	0.17	0.56	0.00	8.00	i,r,t	CDP	The sum of nonroutine adaptation categories. Nonroutine adaptation creates a resource base with new actions taken specifically in response to climate change.
Adaptation	0.23	0.42	0.00	1.00	i,r,t	CDP	Adaptation is a dummy equals to 1 if a firm adapt to one type of climate exposure in any adaptation category.
Routine	0.19	0.40	0.00	1.00	i,r,t	CDP	A dummy variable that equals to 1 if a firm has routine adaptation in place.
Nonroutine	0.11	0.32	0.00	1.00	i,r,t	CDP	A dummy variable that equals to 1 if a firm has nonroutine adaptation in place.
ClimateExposure	28.13	17.10	0.00	100.00	i,r	Four Twenty Seven	The average climate risk score of different climate exposure types for a given firm's direct operation.
HeatStress	39.62	12.14	2.98	93.10	i,r	Four Twenty Seven	Increase in temperature. One type of the five climate exposures analyzed in the study.
WaterStress	42.89	12.56	0	89.98	i,r	Four Twenty Seven	Change in water supply and demand. One type of the five climate exposures analyzed in the study.
SeaLevelRise	12.66	11.44	0	80.00	i,r	Four Twenty Seven	Heightened storm surge, augmented by sea level rise. One type of the five climate exposures analyzed in the study.
Floods	25.05	12.18	0	89.82	i,r	Four Twenty Seven	Change in rainfall conditions and size and frequency of possible floods. One type of the five climate exposures analyzed in the study.
Hurricanes/Typhoons	29.87	25.24	0.00	100.00	i,r	Four Twenty Seven	Exposure to cyclones. One type of the five climate exposures analyzed in the study.
PerceivedImpactOfClimate	0.86	1.51	0.00	5.00	i,r,t	CDP	Firms' disclosed magnitude of climate impact: 1—"Low"; 2—"Low-medium"; 3—"Medium"; 4—"Medium-high"; 5—"High."
ESG	0.63	0.16	0.01	0.95	i,t	Refinitiv	ESG—firms' overall environmental, social, and corporate governance scores in a given year.
TimeHorizon	6.99	3.27	0.00	10.00	i,t	CDP	Firms' disclosed time horizon: 1—"<1 year"; 3—"1–3 years"; 6—"3–6 years"; 10—">6 years." Since 2014, CDP has asked firms to disclose information on risk related time horizon. For years before 2014, I assume firms' time horizons are the same as those in 2014.

TABLE 2 (Continued)

Panel a: Description

Variable	Mean	Std. dev.	Min	Max	Unit of Obs	Data source	Note
Size	10.11	1.56	0.00	15.08	i,t	Compustat	The natural logarithm of the book value of total assets.
ROA	0.12	0.08	−0.54	0.70	i,t	Compustat	The ratio of operating income before depreciation to the book value of total assets.
Cash	0.12	0.11	0.00	0.89	i,t	Compustat	The ratio of debt (long-term debt plus short-term debt) to the book value of total assets.
Leverage	0.25	0.15	0.00	1.17	i,t	Compustat	The ratio of cash and short-term investments to the book value of total assets.
FirmAge	73.28	53.82	0.00	358.00	i,t	Compustat	The year in the analysis minus the year a firm was founded.
Diversity	6.06	2.19	1.00	11.00	i	Four Twenty Seven	The number of GICS divisions a firm's facilities cover.
CarbonPricingCoverage	27.41	29.13	0.00	93.82	c,t	Our World in Data	The percentage of CO2 emissions that are covered by a carbon tax or emissions trading system in a given country each year.
ClimateAwareness	73.28	10.81	36.09	96.81	c	Gallup World Poll	The percentage of people who believe climate change is a serious concern in a given country based on a climate change perception survey.
Multination	0.94	0.25	0.00	1.00	i	Four Twenty Seven	A dummy variable and equals to 1 if a firm has operations in countries outside of its headquarters.

Panel b: Correlation

	Adaptation breadth	Routine breadth	Nonroutine breadth	Adaptation	Routine	Nonroutine	Climate exposure	Perceived impact of climate	ESG
AdaptationBreadth	1.000								
RoutineBreadth	0.852	1.000							
NonroutineBreadth	0.759	0.306	1.000						
Adaptation	0.851	0.797	0.556	1.000					
Routine	0.801	0.896	0.343	0.890	1.000				
Nonroutine	0.722	0.355	0.871	0.638	0.410	1.000			
ClimateExposure	0.096	0.038	0.128	0.096	0.051	0.126	1.000		
PerceivedImpactOfClimate	0.607	0.581	0.382	0.733	0.654	0.445	0.125	1.000	
ESG	0.123	0.110	0.088	0.114	0.106	0.086	−0.044	0.054	1.000

TABLE 2 (Continued)

Panel b: Correlation	Adaptation breadth	Routine breadth	Nonroutine breadth	Adaptation	Routine	Nonroutine	Climate exposure	Perceived impact of climate	ESG
TimeHorizon	0.146	0.117	0.120	0.135	0.121	0.115	0.003	0.100	0.216
Size	0.081	0.078	0.049	0.060	0.069	0.031	−0.078	0.003	0.372
ROA	0.005	−0.004	0.013	−0.010	−0.010	0.014	−0.019	−0.030	0.073
Cash	−0.048	−0.053	−0.022	−0.048	−0.055	−0.015	0.014	−0.050	−0.036
Leverage	0.062	0.054	0.045	0.057	0.054	0.041	0.013	0.071	0.017
FirmAge	0.001	0.010	−0.009	−0.002	0.003	−0.016	−0.001	−0.025	0.090
Diversity	0.034	0.032	0.021	0.024	0.025	0.011	−0.028	−0.004	0.209
CarbonPricingCoverage	−0.006	0.002	−0.013	0.030	0.017	−0.011	0.025	0.061	0.034
ClimateAwareness	0.028	0.032	0.010	0.058	0.043	0.021	0.124	0.140	−0.019
Multination	−0.016	−0.010	−0.018	−0.012	−0.010	−0.008	−0.011	−0.004	0.094

Panel b: Correlation	Time horizon	Size	ROA	Cash	Leverage	FirmAge	Diversity	Carbon pricing coverage	Climate awareness	Multination
AdaptationBreadth										
RoutineBreadth										
NonroutineBreadth										
Adaptation										
Routine										
Nonroutine										
ClimateExposure										
PerceivedImpactOfClimate										
ESG										
TimeHorizon	1.000									
Size	0.152	1.000								

TABLE 2 (Continued)

Panel b: Correlation	Time horizon	Size	ROA	Cash	Leverage	FirmAge	Diversity	Carbon pricing coverage	Climate awareness	Multination
ROA	0.002	−0.326	1.000							
Cash	−0.089	−0.160	0.185	1.000						
Leverage	0.081	0.062	−0.121	−0.273	1.000					
FirmAge	0.019	0.121	−0.025	−0.099	0.014	1.000				
Diversity	0.161	0.253	0.000	−0.153	0.115	0.212	1.000			
CarbonPricingCoverage	0.112	0.039	−0.162	−0.057	−0.047	0.021	0.207	1.000		
ClimateAwareness	−0.042	−0.023	−0.212	−0.031	0.085	−0.106	−0.084	0.183	1.000	
Multination	0.038	0.085	0.079	0.155	−0.002	0.079	0.263	0.099	0.019	1.000

Note: i indexes firms, r indexes climate exposure, t indexes year, c indexes country. $N = 25{,}535$ firm–climate exposure–year (i, r, t) observations pertaining to 1068 firms (i) headquartered in 43 countries (c) between 2011 and 2017. $N = 5107$ firm–climate exposure (i, r) observations. $N = 1503$ country–climate exposure–year (c, r, t) observations. $N = 301$ country-year (c, t) observations. All variables (except for dummy variables) are standardized to a mean of 0 and a standard deviation of 1 in regression analyses for easy interpretation.

some firms to take more adaptation measures overall. A positive coefficient indicates that firms are more likely to adapt to the specific types of exposure that Four Twenty Seven estimates are most salient given the locations where they operate. The inclusion of climate exposure fixed effects accounts for unobserved heterogeneity in the average costs and benefits of responding to different types of climate exposure. For example, if it is more costly to adapt to certain types of exposure, we might see less responsiveness for that category.

If we assume that climate exposures are exogenous, then Equation (1) estimates a causal impact of physical climate exposure on adaptation strategies. Although this assumption seems reasonable, there are two concerns. First, one might be concerned that unobserved variables could lead to spurious correlations. For instance, the geographic sorting of people with different attitudes toward climate might lead to a correlation between physical climate exposure and firm strategies, even if the mechanism is not a direct response to climate exposure per se but rather a correlation between the climate in a particular location and the attitude of the managers who live there. Concerns of this type should be addressed, however, by including firm fixed effects that capture any overall tendency of a firm toward adaptation. Second, one might be concerned that firms' adaptation strategies influence their climate exposure. If a firm adapts through measures that do not involve location change, its exposures to climate change would not change. A firm's non-location-related adaptation may reduce the financial impact of climate change, because such adaptations may reduce the vulnerability and increase the resilience of its facilities. However, it will not change its exposure to climate change, because it is only associated with site location and the nature of its activities. If a firm adapts to climate change by relocating its facilities or diversifying through M&A strategies, this could be a valid concern. However, between 2010 and 2019, the CDP reports that less than 1% of firms relocated their headquarters or facilities in response to climate exposures each year. Although it is reasonable to assume climate exposure is exogenous, I avoid causal claims because I cannot rule out all potential concerns.

To explore the role of the perceived impact of climate change, I conduct several analyses that provide evidence on the channel described in *H2*—greater climate exposures increase the perceived impact of climate change, thereby driving greater adaptation. First, I replace the outcome variable in Equation (1) with a new variable, *Perception*, and assess the relationship between forecasted climate exposure and the perceived impact of climate change. Second, I employ a bootstrapping mediation regression analysis (Hayes, 2013; Preacher et al., 2007) with 1000 replications to test the indirect path from the explanatory variable (*Climate Exposure*) to the outcome variable (*Adaptation*/*Adaptation Breadth*) through the mediator (*Perception*).

Next, to examine the moderating effects of *ESG* (*H3a*) and *Time Horizon* (*H4a*) on the relationship between *Climate Exposure* and *Perception*, I estimate a model that allows the impact of climate exposure to vary with a firm's characteristics such as its ESG capabilities and time horizon. Specifically, I estimate the following regression:

$$\begin{aligned} Perception_{irt} = {} & \alpha_i + \alpha_r + \alpha_t + \beta_1 ClimateExposure_{ir} + \beta_2 Moderator_{it-1} \\ & + \delta_1 ClimateExposure_{ir} * Moderator_{it-1} + \gamma' X_{it-1} + \varepsilon_{irt} \end{aligned} \tag{2}$$

Finally, to assess the moderating effects of *ESG* (*H3b*) and *Time Horizon* (*H4b*) on the relationship between *Climate Exposure* and *Adaptation*, I replace the outcome variable in Equation (2) with *Adapt* and estimate the following specification:

$$Adapt_{irt} = \alpha_i + \alpha_r + \alpha_t + \beta_3 ClimateExposure_{ir} + \beta_4 Moderator_{it-1} + \delta_2 ClimateExposure_{ir} * Moderator_{it-1} + \gamma' X_{it-1} + \varepsilon_{irt} \quad (3)$$

5 | RESULTS

5.1 | Descriptive findings

Figure 2 shows firms' average probability of adaptation by climate exposure and suggests some interesting findings. First, most firms do not adapt to most climate exposures. The average rate of adaptation across all firms and exposures is 23%. The climate exposure with the highest probability of adaptation is flooding, although fewer than 30% of firms report adaptation to that exposure. Several reasons may contribute to this. Firms may not have the capacity to accurately estimate the effects of climate change. For instance, one US retail company stated that "due to the lack of consensus on the magnitude and likelihood of sea-level rise, the company is challenged to develop a strategy to reduce this particular risk" (CDP, 2016). Also, adaptation to multiple exposures can be expensive. Furthermore, some companies focus on climate change mitigation, not adaptation. One energy company in Canada disclosed that their "climate risks are primarily concerned with policy and regulation changes, not with changes in physical climate parameters" (CDP Report, 2017).

Second, Figure 2 shows that firms adapt more through routine than nonroutine strategies. A plausible explanation for this finding is that routine strategies are relatively quick to initiate. They require fewer resources and companies are more familiar with these tasks compared with nonroutine adaptation. Moreover, they can be easily justified even if there is no climate change. For instance, one financial firm in Japan developed a business continuity plan not only for climate risks but also "for a major earthquake or the potential outbreak of a new strain of influenza".[18] By contrast, shifting nonroutine adaptation is more difficult. A US financial company

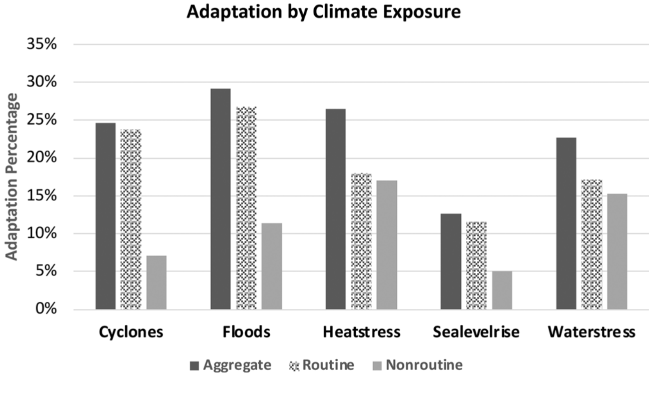

FIGURE 2 Climate change adaptation by type of climate exposure.

[18]Climate disclosure from a 2017 CDP report.

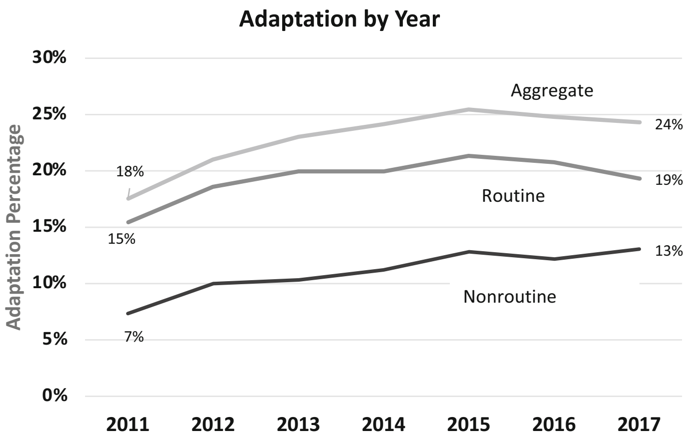

FIGURE 3 Climate change adaptation by year.

targeting low-income communities said that they could not easily withdraw from their existing customers, even though their physical climate change exposure is high.[19]

Third, the differences in the adaptation rate between routine and nonroutine strategies are salient for acute climate exposures like floods and hurricanes/typhoons, but not for chronic climate exposures like water and heat stresses. One possible explanation is that chronic climate exposures bring gradual shifts in climate parameters and provide time for firms to respond. Thus, firms might be more likely to adapt through nonroutine strategies. Appendix D provides more detailed climate exposure and adaptation information by industry and climate exposure.

Figure 3 shows the evolution of adaptation strategies over time. Firm adaptation increases over the sample period, particularly for adaptations that I categorize as nonroutine strategies. While only about 7% of firms disclose nonroutine adaptation in 2011, that number increases to 13% in 2017. Nevertheless, firms are more likely to adapt through routine than nonroutine measures through the entire sample period. This suggests that firms take time to perceive, assess, and respond to climate change. Firms' perceptions of climate change may evolve as new information is gathered over time via climate-related weather events, news reporting of climate events, and the publication of climate science studies. In addition, because routine adaptation strategies typically require fewer resources and are relatively quick to initiate, firms may adopt them at an early stage. Nonroutine adaptations need more time, and firms may adopt them gradually at a later stage. Thus, it is not surprising the adoption of nonroutine adaptation grows more over time compared with routine adaptation.[20]

5.2 | Climate exposure and adaptation strategies

I estimate the baseline specification in Equation (1) to test *H1*. The estimates show whether firms facing greater forecasted climate exposures are more likely to adapt and how. Table 3 presents the results. Model 1 uses pooled cross-sectional regression with country-year-industry and

[19]Interview conducted on May 21, 2020.

[20]Appendix D presents additional descriptive statistics related to adaptation strategies. In particular, Table D.2 reports the adaptation breadth data, which suggests similar results to the *Adaptation* dummy.

TABLE 3 Physical climate change exposures and firms' adaptation strategies.

(a) Adaptation and adaptation breadth

	Model 1—Pooled cross section		**Model 2—Firm fixed effects**	
	Adaptation	**Adaptation breadth**	**Adaptation**	**Adaptation breadth**
ClimateExposure	0.029	0.068	0.026	0.061
	[0.007]	[0.016]	[0.008]	[0.017]
Controls				
Size	0.055	0.142	−0.022	−0.023
	[0.013]	[0.034]	[0.018]	[0.072]
Cash	−0.018	−0.043	−0.003	−0.007
	[0.009]	[0.020]	[0.009]	[0.023]
ROA	0.015	0.056	−0.002	−0.017
	[0.012]	[0.035]	[0.008]	[0.021]
Leverage	0.003	0.003	0.007	0.001
	[0.009]	[0.024]	[0.010]	[0.032]
FirmAge	0.003	0.002		
	[0.009]	[0.022]		
Diversity	0.009	0.020		
	[0.011]	[0.026]		
Multination	0.020	0.089		
	[0.043]	[0.111]		
CarbonPricingCoverage			0.000	0.000
			[0.000]	[0.001]
ClimateAwareness			0.001	0.023
			[0.024]	[0.052]
Country-Industry-Year FE	Yes	Yes		
ClimateExposure FE	Yes	Yes	Yes	Yes
Firm FE			Yes	Yes

TABLE 3 (Continued)

(a) Adaptation and adaptation breadth

	Model 1—Pooled cross section		Model 2—Firm fixed effects	
	Adaptation	Adaptation breadth	Adaptation	Adaptation breadth
Year FE			Yes	Yes
N	24,344	24,430	22,662	22,662
R^2	.176	.186	.031	.029

(b) Routine and nonroutine adaptation and adaptation breadth

	Model 1—Pooled cross section				Model 2—Firm fixed effects			
	Routine adaptation	Nonroutine adaptation	Routine adaptation Breadh	Nonroutine adaptation breadth	Routine adaptation	Nonroutine adaptation	Routine adaptation Breadh	Nonroutine adaptation breadth
ClimateExposure	0.031	0.012	0.066	0.042	0.028	0.012	0.058	0.039
	[0.007]	[0.005]	[0.016]	[0.016]	[0.007]	[0.005]	[0.017]	[0.017]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Industry-Year FE	Yes	Yes	Yes	Yes				
ClimateExposure FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE					Yes	Yes	Yes	Yes
Year FE					Yes	Yes	Yes	Yes
N	24,344	24,344	24,430	24,430	22,662	22,662	22,662	22,662
R^2	.171	.167	.175	.174	.029	.033	.027	.036

Note: Unit of analysis is Firm-ClimateExposure-Year. The sample period is 2011–2017. Outcome variable is *Adaptation*, including *Adaptation* (Dummy) and *Adaptation Breadth*. Adaptation has two forms: *Routine* and *Nonroutine*. The main explanatory variable *ClimateExposure* is the climate exposure score. All variables (except for dummies) are standardized to a mean of 0 and a standard deviation of 1 for easy interpretation. Robust standard errors clustered at the firm level are in parentheses. Models 1 and 2 are analyses across different climate exposures and firms. Model 1 includes Country-Industry-Year fixed effects and climate exposure fixed effects. Model 2 includes firm fixed effects, year fixed effects, and climate exposure fixed effects.

climate exposure fixed effects. Model 2 uses Equation (1) with firm, year, and climate exposure fixed effects. I conduct a Hausman Test and find that the differences in coefficients of *ClimateExposure* between Models 1 and 2 are not systematic (Prob > $chi^2 = 0.7467$). This further suggests that the impact of climate exposures on firms' adaptation is likely to be exogenous.

The results in Table 3 support *H1* and indicate that when forecasted climate exposures are greater, the degree of firms' adaptation increases in both likelihood and diversity, including both routine and nonroutine adaptations. Specifically, the positive coefficients on *ClimateExposure* in Model 2 suggest that a 1-standard-deviation (SD) increase of *ClimateExposure* is associated with a 6.1% *SD* increase in *Adaptation Breadth* ($p < .001$). Similarly, a 1-*SD* increase in *ClimateExposure* is associated with a 5.8% *SD* increase in *Routine Adaptation Breadth* ($p < .001$) and a 3.9% *SD* increase in *Nonroutine Adaptation Breadth* ($p = .020$). The results suggest that a firm is more likely to adapt with a broader scope of adaptation to the specific type of climate exposure that is most salient for that individual firm, including both routine and nonroutine adaptations.

The results have two implications. First, because all adaptation strategies require firm resources and compete with other firms' strategic objectives, firms may be more likely to adapt to some types of climate exposures that are more salient to them rather than adapt to all types of climate exposure. They are also more likely to adopt a broader scope of adaptation strategies in response to those climate exposures that are more salient. The results provide one explanation for firms' reluctance to adapt, or their low adaptation rates, as I find in the descriptive result (Figure 2). Second, the coefficients on *ClimateExposure* are not economically large. It is likely that other factors influence firms' adaptation strategies, such as ESG capabilities and time horizon, as discussed in the following sections.

5.3 | Perceived impact of climate change

To examine the mediating role of perceived impact of climate change, I conduct the following analysis. First, I examine the relationship between firms' forecasted climate exposure and their perceived impact of climate change. Table 4a suggests a positive relationship between the two. A 1-*SD* increase in *ClimateExposure* is associated with a 5.4%-*SD* increase in firms' *Perceived Impact of Climate Change* ($p < .01$). Furthermore, I conduct a bootstrapping mediation regression analysis that fits a single model and estimates the indirect effect of climate exposure on adaptation. As shown in Table 4b, the indirect effect of *ClimateExposure* on *Adaptation* (*Breadth*) through *Perceived Impact of Climate Change* is positive ($p < .01$), indicating that the relationship between firms' climate exposures and adaptation is mediated by the perceived impact of climate change. In addition, a firm's *Perceived Impact of Climate Change* is associated with the firm's *Adaptation* ($p < .01$). The results support *H2* and suggest that heightened climate exposures amplify firms' perceived impact, thereby driving greater adaptation.

5.4 | ESG capabilities

To examine whether the positive relationship between firms' climate exposures and their perceived impact of climate change is stronger for firms with greater ESG capabilities (*H3a*), I estimate Equation (2) and present the results in Table 5. Surprisingly, I do not find that ESG positively moderates the relationship between climate exposures and the perceived impact of

TABLE 4 Perceived impact of climate change.

(a) Physical climate exposure and perceived impact of climate change		
	Model 1	**Model 2**
	Perceived impact of climate change	**Perceived impact of climate change**
ClimateExposure	0.049	0.054
	[0.019]	[0.019]
Controls	Yes	Yes
Country-Industry-Year	Yes	
ClimateExposure FE	Yes	Yes
Firm FE		Yes
Year FE		Yes
N	21,363	19,857
R^2	.250	.097

(b) Results of bootstrapping mediation regression analysis for relationships between climate exposure, perceived impact of climate change, and climate change adaptation strategies								
	Adaptation				**Adaptation breadth**			
	B	**SE**	**95% confidence interval**		***B***	**SE**	**95% confidence interval**	
Indirect effects mediated by perceived impact of climate change								
Climate exposure	0.015	0.003	0.008	0.021	0.029	0.006	0.017	0.041
Direct effects								
Climate exposure	0.012	0.003	0.006	0.018	0.036	0.008	0.021	0.052
Perceived impact	0.303	0.003	0.296	0.308	0.596	0.008	0.580	0.612
Total effects								
Climate exposure	0.027	0.004	0.018	0.035	0.065	0.010	0.045	0.085
Perceived impact	0.303	0.003	0.297	0.308	0.596	0.008	0.580	0.613

Note: Unit of analysis is Firm-ClimateExposure-Year. The sample period is 2011–2017. All variables (except for dummies) are standardized to a mean of 0 and a standard deviation of 1 for easy interpretation. (a) Outcome variables are *Perceived Impact of Climate Change*. *Climate Exposure* is the climate exposure score. Robust standard errors clustered at the firm level are in parentheses. Models 1 and 2 are analyses across different climate exposures and firms. Model 1 includes Country-Industry-Year fixed effects and climate exposure fixed effects. Model 2 includes firm fixed effects, year fixed effects, and climate exposure fixed effects. (b) Outcome variable is *Climate Change Adaptation*, including *Adaptation* (Dummy) and *Adaptation Breadth*. Bootstrapping with 1000 replications is employed to test the significance of the indirect path from the explanatory variable (climate exposure) to the outcome variables (adaptation/adaptation breadth) through the mediator (perceived impact of climate change). *B* stands for bootstrapped coefficients. SE stands for bootstrapped standard errors.

climate change. An explanation of the null result might be that the sample in the analysis consists of firms reporting climate change information through the CDP. These firms are aware of climate change in general, with a relatively high level of perceived impact of climate change when facing a high degree of exposure, and a higher level in their ESG rating does not further moderate this relationship. Future research could explore whether the results would still hold

TABLE 5 ESG capabilities, perceived impact of climate change, and adaptation.

	Model 1—Pooled cross section			Model 2—Firm fixed effects		
	Perceived impact of climate change	Adaptation	Adaptation breadth	Perceived impact of climate change	Adaptation	Adaptation breadth
ClimateExposure	0.053	0.030	0.075	0.059	0.028	0.067
	[0.020]	[0.008]	[0.017]	[0.021]	[0.008]	[0.018]
ESG	0.057	0.040	0.081	0.016	0.020	0.019
	[0.018]	[0.008]	[0.020]	[0.020]	[0.009]	[0.025]
ClimateExposureXESG	0.008	0.008	0.027	0.008	0.008	0.024
	[0.009]	[0.004]	[0.010]	[0.010]	[0.005]	[0.011]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year-Industry FE	Yes	Yes	Yes			
ClimateExposure FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE				Yes	Yes	Yes
Year FE				Yes	Yes	Yes
N	20,266	23,174	23,174	18,824	21,484	21,484
R^2	.260	.184	.194	.100	.032	.030

Note: Unit of analysis is Firm-ClimateExposure-Year. The sample period is 2011–2017. Outcome variables include (1) *Perceived Impact of Climate Change*, measured by reported magnitude of climate change impact; and (2) *Adaptation*, including *Adaptation* (Dummy) and *Adaptation Breadth*. *ClimateExposure* is the climate exposure score. ESG is the Refinitiv ESG score. All variables (except for dummy) are standardized to a mean of 0 and a standard deviation of 1 for easy interpretation. Robust standard errors clustered at the firm level are in parentheses. Models 1 and 2 are analyses across different climate exposures and firms. Model 1 includes Country-Industry-Year fixed effects and climate exposure fixed effects. Model 2 includes firm fixed effects, year fixed effects, and climate exposure fixed effects.

for companies with a lower awareness of climate change. In addition, I test the relationship between climate exposure and ESG ratings, as shown in Appendix F (Table F.4), and find that firm-specific climate exposures are not associated with their ESG ratings. This is possibly because, during the sample period, most ESG rating agencies did not incorporate firms' physical climate exposure in their rating criteria, and physical climate exposure differs significantly from the environmental regulatory risks typically covered within the scope.

To test *H3b* and examine whether the positive relationship between firms' climate exposures and their adaptation strategies is stronger for firms with greater ESG capabilities (*H3a*), I estimate Equation (3). The results are also included in Table 5. The positive coefficient on the interaction term *ClimateExposure* × *ESG* in Model 2 ($p = .025$) indicates that a 1-*SD* increase in ESG ratings increases the relationship between climate exposure and adaptation breadth in the baseline by 35.8% (.024/.067 = .358). The results support *H3b* and imply that firms with better ESG ratings obtain capabilities that enable them to adapt more when facing greater climate exposures.

5.5 | Time horizon

Similarly, I examine whether the positive relationship between firms' climate exposures and their perceived impact of climate change is stronger for firms with longer time horizons (*H4a*). The results are presented in Table 6. The positive coefficient on the interaction term *ClimateExposure* × *TimeHorizon* ($p = .051$) indicates that a 1-*SD* increase in the time horizon, equivalent to approximately 3 years, strengthens the relationship between climate exposure and perceived impact of climate change by 34.5% (.020/.058 = .345). The results support *H4a* and suggest that firms with longer time horizons are more likely to perceive higher climate exposures when facing greater climate exposures.

I also examine the moderating effect of firms' time horizon on the relationship between their climate exposures and their adaptation (*H4b*). As shown in Table 6, the positive coefficient on the interaction term *ClimateExposure* × *TimeHorizon* ($p < .001$) suggests that a 1-*SD* increase in the time horizon, equivalent to approximately 3 years, enhances the relationship between climate exposure and adaptation breadth in the baseline by 73% (.046/.063 = .730). The results support *H4b* and imply that firms with longer time horizons adapt more when facing greater climate exposures.

5.6 | Robustness check

In Appendix E, I provide several robustness checks for the baseline analysis. In Table E.1 of Appendix E, I use a logit specification when the outcome is *Adaptation* (Dummy) and obtain average marginal effects for *ClimateExposure*. In Model 1, the marginal effect of *ClimateExposure* on *Adaptation* in the logistic regression is the same as the coefficient estimated in the OLS model, suggesting that the OLS model with clustered standard errors provides coefficients that can be directly interpreted as marginal effects in the logistic model. In Model 2, the marginal effect of *ClimateExposure* on *Adaptation* in the logistic regression is larger than the coefficient estimated in the OLS model. This occurs because, in the logistics model, when the outcome variable is always 0 or 1 within firms, the observation would be dropped, and the sample size is smaller than that in the OLS model. In other words, the OLS model is likely to be

TABLE 6 Time horizon, perceived impact of climate change, and adaptation.

	Model 1—Pooled cross section			Model 2—Firm fixed effects		
	Perceived impact of climate change	Adaptation	Adaptation breadth	Perceived impact of climate change	Adaptation	Adaptation breadth
ClimateExposure	0.058	0.031	0.073	0.058	0.027	0.063
	[0.020]	[0.008]	[0.017]	[0.021]	[0.008]	[0.018]
TimeHorizon	0.055	0.036	0.092	0.019	−0.002	0.005
	[0.018]	[0.007]	[0.018]	[0.018]	[0.007]	[0.019]
ClimateXTimeHorizon	0.017	0.018	0.050	0.020	0.016	0.046
	[0.011]	[0.004]	[0.010]	[0.010]	[0.004]	[0.010]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year-Industry FE	Yes	Yes	Yes			
ClimateExposure FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE				Yes	Yes	Yes
Year FE				Yes	Yes	Yes
N	19,988	23,049	23,049	18,655	21,460	21,460
R^2	.252	.182	.192	.099	.034	.033

Note: Unit of analysis is Firm-ClimateExposure-Year. The sample period is 2011–2017. Outcome variables include (1) *Perceived Impact of Climate Change*, measured by reported magnitude of climate change impact; and (2) *Adaptation*, including *Adaptation* (Dummy) and *Adaptation Breadth*. *ClimateExposure* is the climate exposure score. *Time Horizon* is firms' disclosed risk time horizon. All variables (except for dummy) are standardized to a mean of 0 and a standard deviation of 1 for easy interpretation. Robust standard errors clustered at the firm level are in parentheses. Models 1 and 2 are analyses across different climate exposures and firms. Model 1 includes Country-Industry-Year fixed effects and climate exposure fixed effects. Model 2 includes firm fixed effects, year fixed effects, and climate exposure fixed effects.

superior in this specific case, because it does not drop firms that have no variance in the outcome from the estimation sample.

I find similar results when using alternative fixed-effects models (Table E.2), when using alternative sets of control variables (Table E.3), when running cross-sectional analyses for Model 1 from year 2011 to 2017 (Table E.4), when taking the log of *ClimateExposure* (Table E.5), when aggregating outcome and explanatory variables to the firm level of analysis (Table E.6),[21] when using ordered logistic regression (Table E.7), and when excluding firms with major M&A activities during 2011 and 2017 (Table E.8).

Appendix F reports several robustness checks for the moderating effect of ESG capabilities. The results are robust when I use ESG scores from different rating agencies, such as Sustainalytics and MSCI (Tables F.1 and F.2), and when I use the time-invariant 2011 Refinitiv ESG score instead of the time-varying ESG data (Table F.3).

5.7 | Auxiliary analysis

5.7.1 | Decomposing ESG

Because ESG covers numerous aspects, I explore which aspect of ESG capabilities drives the effect. First, I replace ESG with *Environmental* (E), *Social* (S), and *Corporate Governance* (G) scores, and conduct similar regression analyses separately, as summarized in Tables F.5 to F.7 in Appendix F. The results suggest that the ESG influence on adaptation to greater climate exposure is mainly driven by firms' environmental and social performance, not corporate governance. I also further disaggregate ESG into the 10 subcategories as categorized by Refinitiv: resource use (E), emissions (E), innovation (E), community (S), workforce (S), human rights (S), product responsibility (S), CSR strategy (G), management (G), and shareholders (G), as summarized in Figures F.1 and F.2 in Appendix F. I find positive moderating effects for resource use, emissions, community, and CSR strategy, but not for the other subcategories. This makes sense because these subcategories are more likely to have synergies with firms' climate change adaptation.

Second, following Hawn and Ioannou (2016), I categorize ESG capabilities into internal and external ESG. Internal ESG are actions firms take to achieve structural change (King et al., 2005), and external ESG are actions firms take to gain organizational endorsement by external constituents (McDonnell & King, 2013). As suggested in Tables F.8 and F.9 in Appendix F, while both internal and external ESG have a positive moderating effect on the relationship between climate exposure and adaptation, firms' internal ESG has a stronger moderating effect (Prob > $F = 0.0576$).

5.7.2 | Different types of climate exposures

I also separately assess firms' adaptation to climate exposures within each type of climate exposure and across firms. The results are summarized in Table G.1 in Appendix G. I find that the

[21]As suggested in Table E.6 in Appendix E, a higher level of firms' aggregated climate exposure increases their overall *Adaptation Breadth* ($p = .084$) and *Routine Breadth* ($p = .094$) but not their *Nonroutine Breadth* ($p = .281$). It is plausible that when combining different climate exposures at the firm level, the measurement becomes noisy.

relationship between the level of climate exposure and adaptation is most salient for water stress. For floods, however, the relationship is not statistically different from zero. One potential explanation is that many companies have been adapting to flood risk, particularly through routine measures (e.g., purchasing flood insurance) as suggested in Figure 1, and they do not do much more when facing greater flood exposure. For instance, an executive of a US financial company stated that the company leadership is well aware of their flood exposure, but they have not paid much attention to it because they have flood insurance in place and the insurance premium has not increased much.[22] Table G.2 in Appendix G suggests that firms are less likely to use nonroutine adaptation strategies when the insurability of one climate exposure is higher. Future research could explore drivers of heterogeneities among different types of climate exposure.

6 | DISCUSSION AND CONCLUSION

Are companies proactively adapting to the forecasted climate exposures they are likely to encounter? If they do adapt, in what ways do they do so, and what factors influence their adaptation strategies? This study employs a unique dataset that combines firms' disclosed adaptation strategies with climate science data predicting their various exposures to climate change. This approach allows for a comprehensive investigation into how firms adapt to these climate exposures.

Evidence of adaptation is missing for most of the firms in my sample. As shown in the descriptive results, the average rate of adaptation across all firms and different types of climate exposures is only 23%. Rather than make significant changes in nonroutine adaptation activities, firms are more likely to adapt by adjusting their existing routines. In the baseline, I find that firms adapt more to specific climate exposures that are more salient to their business. Increased climate exposure heightens the perceived impact of climate change, leading to a higher degree of adaptation. Moreover, firms' ESG capabilities and long-time horizons positively moderate the relationship between forecasted climate exposures and adaptation. Companies with longer time horizons tend to perceive a greater extent of climate impact in the face of higher climate exposures. However, I do not find that companies with greater ESG capabilities have a higher perceived impact of climate change when facing greater climate exposures.

The study makes several contributions. First, it extends the work on how organizations adapt to external changes (Adner & Helfat, 2003; Levinthal, 1997; Sarta et al., 2021). While previous research has primarily focused on organizational responses to changes that have already occurred or to short-term disruptions (Aghion et al., 2012; Eggers & Park, 2018; Flammer & Ioannou, 2021; Tashman & Rivera, 2016), this study examines how firms adapt to long-term and systemic changes such as climate exposure. The findings reveal that greater forecasted climate exposures lead to increased adaptation. This may be because high forecasted climate exposure signals clear and significant risks, thereby amplifying the perceived impact of climate change. Moreover, the study sheds light on the dual effects of time horizons on corporate adaptation and perception in response to climate exposures. The results suggest that climate exposures, as forecasted by climate science data, together with firms' temporal preferences, play critical roles in shaping their adaptation strategies to this long-term challenge.

[22]Interview on May 21, 2020.

Second, this article contributes to the sustainability literature (Brekke & Nyborg, 2004; Hawn & Ioannou, 2016; Pinkse & Kolk, 2012) by examining the underappreciated effect of ESG capabilities on firms' adaptation to climate change. While previous studies have primarily focused on the impact of ESG on financial and environmental performance (Aragón-Correa & Sharma, 2003; Flammer, 2015; McWilliams & Siegel, 2001), this article explores the influence of ESG on firms' responses to external changes. It extends the understanding of ESG and suggests that ESG capabilities have broader and more diverse implications for firms.

Finally, this study uses innovative datasets to measure firms' climate exposures, adaptation strategies, and perceived impact of climate change. It takes a comprehensive approach that covers a variety of industries and countries. Given that the systemic nature of climate change affects different sectors globally (Li et al., 2021; Winn et al., 2011), this study's breadth is particularly notable. Thus, we can get a holistic view about this emerging area of inquiry (Graebner et al., 2022; Helfat, 2007; Linnenluecke et al., 2013).

My findings have both policy and managerial implications. Understanding whether and how firms adapt to climate exposures can help regulators and investors decide whether interventions on adaptation are needed, and, if so, what the scope of those policies should be. Although adaptation is affected by the level of forecasted climate exposures, it is also influenced by many other factors, such as a firm's ESG capabilities and its time horizon. Thus, interventions that improve firms' adaptive capabilities and increase their time horizons can be considered. The comprehensive measurement of different adaptation strategies can also be informative for managers seeking to identify best practices or to compare their own risk-management policies with those of their peers and competitors.

This research has limitations and opens several avenues for future research. First, I measure the outcome variable by disclosed adaptation strategies. Future research could collect data on how firms implement specific adaptation strategies. Second, inherent uncertainties in climate exposure data are predicted by climate models. For now, they are the best data available for measuring firms' climate exposures in the future. Also, the climate scores I used cannot measure the economic and financial impacts of climate change. Future research could assess the financial impact of climate change. Third, this study focuses only on the climate exposures of direct operations of large public firms. It would be interesting for future research to explore the impact of climate change on private firms, smaller organizations, and firms' different value chains, such as suppliers and customers. Finally, this study could not analyze all conditions under which firms are more likely to adapt to climate exposure. Future research could examine different factors that affect firms' adaptation, including political ideology, CEO experience, and institutional context, and explore the role of decision-makers' attention in this process.

ACKNOWLEDGMENTS

The author is deeply grateful to Olga Hawn (the Editor), three anonymous reviewers, Caroline Flammer, Timothy Simcoe, Andrew King, and seminar participants at the Boston University, London Business School, 2021 Strategic Management Science conference, 2021 Strategy and the Business Environment conference, 2021 Alliance for Research on Corporate Sustainability research conference, 2022 Strategy Science conferences at New York University, and 2023 Organizations and Environmental Sustainability at Stanford University for helpful comments.

CONFLICT OF INTEREST STATEMENT

The author has no conflict of interest to report in connection with this research. All errors are the responsibility of the author.

DATA AVAILABILITY STATEMENT

The physical climate risk data that support the findings of this study are available from Four Twenty Seven (currently Moody's ESG Solutions). Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the author with the permission of Four Twenty Seven.

ORCID

Xia Li https://orcid.org/0000-0001-6507-2302

REFERENCES

Adams, R. B. (2012). Governance and the financial crisis. *International Review of Finance*, *12*(1), 7–38.

Adner, R., & Helfat, C. E. (2003). Corporate effects and dynamic managerial capabilities. *Strategic Management Journal*, *24*, 1011–1025.

Aghion, P., Askenazy, P., Berman, N., Cette, G., & Eymard, L. (2012). Credit constraints and the cyclicality of R&D investments: Evidence from France. *Journal of the European Economic Association*, *10*(5), 1001–1024.

Amit, R., & Wernerfelt, B. (1990). Why do firms reduce business risk? *Academy of Management Journal*, *33*(3), 520–533.

Anand, J., & Singh, H. (1997). Asset redeployment, acquisitions and corporate strategy in declining industries. *Strategic Management Journal*, *18*, 99–118.

Aragón-Correa, J. A., & Sharma, S. (2003). A contingent resource-based view of proactive corporate environmental strategy. *Academy of Management Review*, *28*(1), 71–88.

Arnell, N. W., & Delaney, E. K. (2006). Adapting to climate change: Public water supply in England and Wales. *Climatic Change*, *78*, 227–255.

Bank, M., & Wiesner, R. (2011). Determinants of weather derivatives usage in the Austrian winter tourism industry. *Tourism Management*, *32*(1), 62–68.

Bansal, P. (2003). From issues to actions: The importance of individual concerns and organizational values in responding to natural environmental issues. *Organization Science*, *14*(5), 510–527.

Bansal, P., Kim, A., & Wood, M. (2018). Hidden in plain sight: The importance of scale on organizational attention to issues. *Academy of Management Review*, *43*(2), 217–241.

Barnett, J. (2001). Adapting to climate change in Pacific Island countries: The problem of uncertainty. *World Development*, *29*(6), 977–993.

Barnett, M., Brock, W., & Hansen, L. P. (2020). Pricing uncertainty induced by climate change. *Review of Financial Studies*, *33*(3), 1024–1066.

Barnett, M. L., Henriques, I., & Husted, B. W. (2018). Governing the void between stakeholder management and sustainability. In S. Dorobantu, R. V. Aguilera, J. Luo, & F. J. Milliken (Eds.), *Advances in strategic management*. Emerald Publishing Limited.

Battiston, S., & Monasterolo, I. (2020). The climate spread of corporate and sovereign bonds. https://doi.org/10.2139/ssrn.3376218

Berkhout, F. (2012). Adaptation to climate change by organizations. *Climate Change*, *3*(1), 91–106.

Berkhout, F., Hertin, J., & Gann, D. M. (2007). Learning to adapt: Organizational adaptation to climate change impacts. *Climatic Change*, *78*(1), 135–156.

Bluedorn, A. C. (2002). *The human organization of time: Temporal realities and experience*. Stanford University Press.

Bolton, O., & Kacperczyk, M. (2022). Global pricing of carbon-transition risk. *Journal of Finance*, *78*(6), 3677–3754.

Brekke, K. A., & Nyborg, K. (2004). Moral hazard and moral motivation: Corporate social responsibility as labor market screening. Memorandum, Department of Economics, University of Oslo.

Callery, P. J., & Perkins, J. (2021). Detecting false accounts in intermediated voluntary disclosure. *Academy of Management Discoveries*, *7*(1), 40–56.

Canevari-Luzardo, L., Berkhout, F., & Pelling, M. (2020). A relational view of climate adaptation in the private sector: How do value chain interactions shape business perceptions of climate risk and adaptive behaviours? *Business Strategy and the Environment*, *29*(2), 432–444.

Cao, J., Liang, H., & Zhan, X. (2019). Peer effects of corporate social responsibility. *Management Science*, *65*(12), 5487–5503.

Carney, M. (2015). *Breaking the tragedy of the horizon—Climate change and financial stability*. Retrieved from https://www.bankofengland.co.uk/knowledgebank/climate-change-what-are-the-risks-to-financial-stability

CDP. (2016). Guidance for companies reporting on climate change on behalf of investors & supply chain members 2016. White paper, Carbon Disclosure Project.

Clement, V., & Rivera, J. (2017). From adaptation to transformation: An extended research agenda for organizational resilience to adversity in the natural environment. *Organization and Environment*, *30*(4), 346–365.

Cyert, R. M., & March, J. G. (1963). *A behavioral theory of the firm*. Prentice-Hall.

Daft, R. L., & Macintosh, N. B. (1981). A tentative exploration into the amount and equivocality of information processing in organizational work units. *Administrative Science Quarterly*, *26*(2), 207–244.

Dell, M., Jones, B. F., & Olken, B. (2014). What do we learn from the weather? The new climate-economy literature. *Journal of Economic Literature*, *52*(3), 740–798.

DesJardine, M., & Bansal, P. (2019). One step forward, two steps back: How negative external evaluations can shorten organizational time horizons. *Organization Science*, *30*(4), 761–780.

Dessaint, O., & Matray, A. (2017). Do managers overreact to salient risks? Evidence from hurricane strikes. *Journal of Financial Economics*, *126*(1), 97–121.

Dosi, G., Nelson, R. R., & Winter, S. G. (Eds.). (2000). *The nature and dynamics of organizational capabilities*. Oxford University Press.

Dyer, J., & Singh, H. (1998). The relational view: Cooperative strategy and sources of interorganizational competitive advantage. *Academy of Management Review*, *23*(4), 660–679.

Eggers, J. P. (2012). All experience is not created equal: Learning, adapting, and focusing in product portfolio management. *Strategic Management Journal*, *33*, 315–335.

Eggers, J. P., & Park, K. F. (2018). Incumbent adaptation to technological change: The past, present, and future of research on heterogeneous incumbent response. *Academy of Management Annals*, *12*, 357–389.

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: What are they? *Strategic Management Journal*, *21*(10/11), 1105–1121.

Fabrizio, K. R., & Kim, E. H. (2019). Reluctant disclosure and transparency: Evidence from environmental disclosures. *Organization Science*, *30*(6), 1125–1393.

Fankhauser, S. (2017). Adaptation to climate change. *Annual Review of Resource Economics*, *9*(1), 209–230.

Fankhauser, S., Smith, J. B., & Tol, R. S. J. (1999). Weathering climate change: Some simple rules to guide adaptation investments. *Ecological Economics*, *30*(1), 67–78.

Flammer, C. (2015). Does corporate social responsibility lead to superior financial performance? A regression discontinuity approach. *Management Science*, *61*(11), 2549–2568.

Flammer, C., & Bansal, P. (2017). Does long-term orientation create value? Evidence from a regression discontinuity. *Strategic Management Journal*, *38*(9), 1827–1847.

Flammer, C., & Ioannou, I. (2021). Strategic management during the financial crisis: How firms adjust their strategic investments in response to credit market disruptions. *Strategic Management Journal*, *42*(7), 1275–1298.

Flammer, C., & Kacperczyk, A. J. (2016). The impact of stakeholder orientation on innovation: Evidence from a natural experiment. *Management Science*, *62*(7), 1982–2001.

Flammer, C., Toffel, M., & Viswanathan, K. (2021). Shareholder activism and firms' voluntary disclosure of climate change risks. *Strategic Management Journal*, *42*(10), 1850–1879.

Fombrun, C. J. (1996). *Reputation: Realizing value from the corporate image*. Harvard Business Press.

Gasbarro, F., & Pinkse, J. (2015). Corporate adaptation behavior to deal with climate change: The influence of firm-specific interpretations of physical climate impacts. *Corporate Social Responsibility and Environmental Management*, *23*(3), 179–192.

Gavetti, G. (2012). Toward a behavioral theory of strategy. *Organization Science*, *23*(1), 267–285.

Gillan, S. L., Koch, A., & Starks, L. T. (2021). Firms and social responsibility: A review of ESG and CSR research in corporate finance. *Journal of Corporate Finance*, *66*, 101889.

Gold, R. (2019). PG&E: The first climate-change bankruptcy, probably not the last. *Wall Street Journal* Retrieved from https://www.wsj.com/articles/pg-e-wildfires-and-the-first-climate-change-bankruptcy-11547820006

Goldstein, A., Turner, W. R., Gladstone, J., & Hole, D. G. (2019). The private sector's climate change risk and adaptation blind spots. *Nature Climate Change*, *9*, 18–25.

Graebner, M. E., Knott, A. M., Lieberman, M. B., & Mitchell, W. (2022). Empirical inquiry without hypotheses: A question-driven, phenomenon-based approach to strategic management research. *Strategic Management Journal*, *44*(1), 3–10.

Gu, W., & Hale, G. (2023). Climate risks and FDI. *Journal of International Economics*, *146*, 103731.

Gulati, R., Lawrence, P. R., & Puranam, P. (2005). Adaptation in vertical relationships: Beyond incentive conflict. *Strategic Management Journal*, *26*, 415–440.

Gupta, P., & Leech, T. (2014). Risk oversight: Evolving expectations for boards. *The Conference Board, Director Notes*, DN-V6N1. https://ssrn.com/abstract=2532215

Haigh, N., & Griffiths, A. (2012). Surprise as a catalyst for including climatic change in the strategic environment. *Business & Society*, *51*(1), 89–120.

Hamann, R., Makaula, L., Ziervogel, G., Shearing, C., & Zhang, A. (2020). Strategic responses to grand challenges: Why and how corporations build community resilience. *Journal of Business Ethics*, *161*, 835–853.

Hannah, L., Roehrdanz, P. R., Ikegami, M., Shepard, A. V., Shaw, M. R., Tabor, G., Zhi, L., Marquest, P. A., & Hijmans, R. J. (2013). Climate change, wine, and conservation. *Proceedings of the National Academy of Sciences*, *110*(17), 6907–6912.

Hart, S., & Dowell, G. (2011). A natural-resource-based view of the firm: Fifteen years after. *Journal of Management*, *37*(5), 1464–1479.

Hart, S. L. (1995). A natural-resource-based view of the firm. *The Academy of Management Review*, *20*(4), 986–1014.

Hawn, O., & Ioannou, I. (2016). Mind the gap: The interplay between external and internal actions in the case of corporate social responsibility. *Strategic Management Journal*, *37*(13), 2569–2588.

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford Press.

Helfat, C. E. (2007). Stylized facts, empirical research and theory development in management. *Strategic Organization*, *5*(2), 185–192.

Helfat, C. E., Finkelstein, S., Mitchell, W., Peteraf, M., Singh, H., Teece, D., & Winter, S. (2007). *Dynamic capabilities: Understanding strategic change in organizations*. Blackwell.

Helfat, C. E., & Martin, J. A. (2015). Dynamic managerial capabilities: Review and assessment of managerial impact on strategic change. *Journal of Management*, *41*, 1281–1312.

Hoffman, A. J., & Ocasio, W. (2001). Not all events are attended equally: Toward a middle-range theory of industry attention to external events. *Organization Science*, *12*(4), 414–434.

Hoffmann, V. H., Sprengel, D. C., Ziegler, A., Kolb, M., & Abegg, B. (2009). Determinants of corporate adaptation to climate change in winter tourism: An econometric analysis. *Global Environmental Change*, *19*(2), 256–264.

Holmstrom, B. (1999). Managerial incentive problems: A dynamic perspective. *Review of Economic Studies*, *66*(1), 169–182.

Hope, B., & Friedman, N. (2018). Climate change is forcing the insurance industry to recalculate. *Wall Street Journal* Retrieved from https://www.wsj.com/graphics/climate-change-forcing-insurance-industry-recalculate

Howard-Grenville, J., & Lahneman, B. (2021). Bringing the biophysical to the fore: Re-envisioning organizational adaptation in the era of planetary shifts. *Strategic Organization*, *19*(3), 478–493.

Hsiang, S. (2016). Climate econometrics. *Annual Review of Resource Economics*, *8*, 43–75.

IPCC AR6. (2022). Climate change 2022: Impacts, adaptation and vulnerability. Retrieved from https://www.ipcc.ch/report/ar6/wg2/

Jira, C., & Toffel, M. W. (2013). Engaging supply chains in climate change. *Manufacturing & Service Operations Management*, *15*(4), 559–577.

Keeler, A. G., Mullin, M., McNamara, D. E., & Smith, M. D. (2022). Buyouts with rentbacks: A policy proposal for managing coastal retreat. *Journal of Environmental Studies and Sciences*, *12*(1), 646–651.

Kelly, D., & Kolstad, C. (2005). Adjustment costs from environmental change. *Journal of Environmental Economics and Management*, *50*(3), 468–495.

Kim, E. H., & Lyon, T. (2011). Strategic environmental disclosure: Evidence from the DOE's voluntary greenhouse gas registry. *Journal of Environmental Economics and Management*, *61*(3), 311–326.

King, A. A., Lenox, M. J., & Terlaak, A. (2005). The strategic use of decentralized institutions: Exploring certification with the ISO 14001 Management Standard. *Academy of Management Journal*, *48*(6), 1091–1106.

Kling, G., Volz, U., Murinde, V., & Ayas, S. (2021). The impact of climate vulnerability on firms' cost of capital and access to finance. *World Development*, *137*, 105131.

Kolk, A., Levy, D., & Pinkse, J. (2008). Corporate responses in an emerging climate regime: The institutionalization and commensuration of carbon disclosure. *European Accounting Review*, *17*, 719–745.

Kraatz, M. S., & Zajac, E. J. (2001). How organizational resources affect strategic change and performance in turbulent environments: Theory and evidence. *Organization Science*, *12*(5), 632–657.

Krueger, P. (2015). Climate change and firm valuation: Evidence from a quasi-natural experiment. Working Paper, University of Geneva.

Krueger, P., Sautner, Z., & Starks, L. T. (2020). The importance of climate risks for institutional investors. *Review of Financial Studies*, *33*(3), 1067–1111.

Kunreuther, H., Heal, G., Allen, M., Edenhofer, O., Field, C. B., & Yohe, G. (2013). Risk management and climate change. *Nature Climate Change*, *3*, 447–450.

Lee, T., Markowitz, E., Howe, P., Ko, C. Y., & Leiserowitz, A. A. (2015). Predictors of public climate change awareness and risk perception around the world. *Nature Climate Change*, *5*, 1014–1020.

Levinthal, D. A. (1997). Adaptation on rugged landscapes. *Management Science*, *43*, 934–950.

Li, H. M., Wang, X. C., Zhao, F. X., & Qi, Y. (2021). Understanding systemic risk induced by climate change. *Advances in Climate Change Research*, *12*(3), 384–395.

Li, X., & Gallagher, P. K. (2022). Assessing the climate change exposure of foreign direct investment. *Nature Communications*, *13*, 1451.

Linnenluecke, M. K., & Griffiths, A. (2010). Beyond adaptation: Resilience for business in light of climate change and weather extremes. *Business & Society*, *49*(3), 477–511.

Linnenluecke, M. K., Griffiths, A., & Mumby, P. J. (2015). Executives' engagement with climate science and perceived need for business adaptation to climate change. *Climatic Change*, *131*, 321–333.

Linnenluecke, M. K., Griffiths, A., & Winn, M. (2012). Extreme weather events and the critical importance of anticipatory adaptation and organizational resilience in responding to impacts. *Business Strategy and the Environment*, *21*(1), 17–32.

Linnenluecke, M. K., Griffiths, A., & Winn, M. (2013). Firm and industry adaptation to climate change: A review of climate adaptation studies in the business and management field. *WIREs Climate Change*, *4*(5), 397–416.

Lyon, T., & Maxwell, J. (2011). Greenwash: Corporate environmental disclosure under threat of audit. *Journal of Economics & Management Strategy*, *20*(1), 3–41.

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization Science*, *2*(1), 71–87.

McDonnell, M.-H., & King, B. (2013). Keeping up appearances: Reputational threat and impression management after social movement boycotts. *Administrative Science Quarterly*, *58*(3), 387–419.

McKinsey Global Institute (MGI). (2020). Climate risk and response: Physical hazard and socioeconomic impacts. Retrieved from https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/climate%20risk%20and%20response%20physical%20hazards%20and%20socioeconomic%20impacts/mgi-climate-risk-and-response-full-report-vf.pdf

McKnight, B., & Linnenluecke, M. K. (2016). How firm responses to natural disasters strengthen community resilience: A stakeholder-based perspective. *Organization & Environment*, *29*(3), 290–307.

McKnight, B., & Linnenluecke, M. K. (2019). Patterns of firm responses to different types of natural disasters. *Business & Society*, *58*(4), 813–840.

McWilliams, A., & Siegel, D. (2001). Corporate social responsibility: A theory of the firm perspective. *The Academy of Management Review*, *26*(1), 117–127.

Meyer, R., & Kunreuther, H. (2017). *The ostrich paradox: Why we underprepare for disasters*. Wharton School Press.

Nelson, R. P., & Winter, S. G. (1982). *An evolutionary theory of economic change*. Belknap Press of Harvard University Press.

Ocasio, W. (1997). Towards an attention-based view of the firm. *Strategic Management Journal*, *18*, 187–206.

Pindyck, R. (2022). *Climate future: Averting and adapting to climate change*. Oxford University Press.

Pinkse, J., & Gasbarro, F. (2019). Managing physical impacts of climate change: An attentional perspective on corporate adaptation. *Business & Society*, *58*(2), 333–368.
Pinkse, J., & Kolk, A. (2012). Addressing the climate change–sustainable development nexus: The role of multi-stakeholder partnerships. *Business & Society*, *51*(1), 176–210.
Plumer, B. (2019). Companies see climate change hitting their bottom lines in the next 5 years. *New York Times* Retrieved from https://www.nytimes.com/2019/06/04/climate/companies-climate-change-financial-impact.html
Preacher, K. J., Rucker, D. D., & Hayes, A. F. (2007). Addressing moderated mediation hypotheses: Theory, methods, and prescriptions. *Multivariate Behavioral Research*, *42*(1), 185–227.
Quinson, T. (2021). *Environmental debt risk is more than Japan's GDP*. Bloomberg. Retrieved from https://www.bloomberg.com/news/articles/2021–01–06/environmental-debt-risk-is-more-than-japan-s-gdp-green-insight
Reinecke, J., & Ansari, S. (2016). Taming wicked problems: The role of framing in the construction of corporate social responsibility. *Journal of Management Studies*, *53*(3), 299–329.
Reinhardt, F., & Toffel, M. (2017). Managing climate change: Lessons from the U.S. Navy. *Harvard Business Review*, *95*, 102–111.
Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *6*, 155–169.
Rivera, J., & Clement, V. (2019). Business adaptation to climate change: American ski resorts and warmer temperatures. *Business Strategy and the Environment*, *28*(7), 1285–1301.
Sarta, A., Durand, R., & Vergne, J. P. (2021). Organizational adaptation. *Journal of Management*, *47*(1), 43–75.
Scott, D., & McBoyle, G. (2007). Climate change adaptation in the ski industry. *Mitigation and Adaptation Strategies to Global Change*, *12*, 1411–1431.
Scott, R. (1981). *Organizations: Rational, natural, and open systems*. Prentice-Hall.
Simon, H. A. (1991). Bounded rationality and organizational learning. *Organization Science*, *2*(1), 125–134.
Slawinski, N., & Bansal, P. (2012). A matter of time: The temporal perspectives of organizational responses to climate change. *Organization Studies*, *33*(11), 1537–1563.
Slawinski, N., & Bansal, P. (2015). Short on time: Intertemporal tensions in business sustainability. *Organization Science*, *26*(2), 331–631.
Stein, J. C. (1988). Takeover threats and managerial myopia. *Journal of Political Economy*, *96*(1), 61–80.
Surminski, S. (2013). Private-sector adaptation to climate risk. *Nature Climate Change*, *3*, 943–945.
Tashman, P., & Rivera, J. (2016). Ecological uncertainty: Adaptation and mitigation in the U.S. ski resort industry: Managing resource dependence and institutional pressures. *Strategic Management Journal*, *37*, 1507–1525.
TCFD (Task Force on Climate-related Financial Disclosures). (2017). Recommendations of the task force on climate-related financial disclosures.
TCFD (Task Force on Climate-related Financial Disclosures). (2019). 2019 status report. Retrieved from https://assets.bbhub.io/company/sites/60/2020/10/2019-TCFD-Status-Report-FINAL-0531191.pdf
Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, *28*(13), 1319–1350.
Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–533.
The Australia Institute. (2020). Heat stress and work in the era of climate change. Retrieved from https://australiainstitute.org.au/report/heat-stress-and-work-in-the-era-of-climate-change/
Tilcsik, A., & Marquis, C. (2013). Punctuated generosity: How mega-events and natural disasters affect corporate philanthropy in U.S. communities. *Administrative Science Quarterly*, *58*(1), 111–148.
Waddock, S. (2008). Building a new institutional infrastructure for corporate responsibility. *Academy of Management Perspectives*, *22*(3), 87–108.
Weinhofer, G., & Busch, T. (2013). Corporate strategies for managing climate risks. *Business Strategy and the Environment*, *22*(2), 122–144.
Winn, M., Kirchgeorg, M., Griffiths, A., Linnenluecke, M., & Gunther, E. (2011). Impacts from climate change on organizations: A conceptual foundation. *Business Strategy and the Environment*, *20*(3), 157–173.
Winn, M. I., & Pogutz, S. (2013). Business, ecosystems, and biodiversity: New horizons for management research. *Organization & Environment*, *26*(2), 203–229.

Wright, C., & Nyberg, D. (2017). An inconvenient truth: How organizations translate climate change into business as usual. *Academy of Management Journal*, *60*(5), 1633–1661.
Yoon, H., Tashman, P., Benischke, M. H., Doh, J., & Kim, N. (2024). Climate impact, institutional context, and national climate change adaptation IP protection rates. *Journal of Business Venturing*, *39*(1), 106359.
Zander, K., Botzen, W., & Oppermann, E. (2015). Heat stress causes substantial labor productivity loss in Australia. *Nature Climate Change*, *5*, 647–651.
Zollo, M., Cennamo, C., & Neumann, K. (2013). Beyond what and why: Understanding organizational evolution towards sustainable enterprise models. *Organization & Environment*, *26*(3), 241–259.

SUPPORTING INFORMATION

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

How to cite this article: Li, X. (2025). Physical climate change exposure and firms' adaptation strategy. *Strategic Management Journal*, *46*(3), 750–789. https://doi.org/10.1002/smj.3674