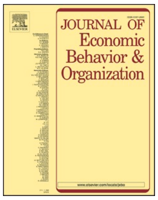
Journal of Economic Behavior and Organization 228 (2024) 106777

Contents lists available at ScienceDirect

Journal of Economic Behavior and Organization

journal homepage: www.elsevier.com/locate/jebo



Research Paper

Sustainability in the wake of crisis: Transforming climate change-induced disasters into drivers of renewable energy innovation in business

Hiva Rastegar [a,*,1], Aymen Sajjad [a,2], Gabriel Eweje [b,3], Kazunori Kobayashi [a,4]

[a] *School of Management, Massey Business School, Massey University, New Zealand*
[b] *School of Business and Law, Edith Cowan University, Australia*

ARTICLE INFO

Keywords:
Renewable energy innovation
Climate change-induced disasters
Behavioral theory of the firm (BTOF)
Threat rigidity model
Firm's history of natural disasters

ABSTRACT

This study examines how climate change-induced disasters affect renewable energy innovation in United States-based firms. To this end, we utilized the behavioral theory of the firm and the threat rigidity model to investigate strategic decision-making in the context of environmental crises. We employed a difference-in-differences approach combined with meta-analysis. Further, we analyzed data from 2013 to 2018 and found a significant increase in renewable energy innovation following climatological disasters, marked by an effect size of 0.74. However, firms exceeding their aspiration levels exhibit a smaller impact, reducing the effect on renewable energy innovation by 0.273 units. Additionally, firms with a frequent history of climatological disasters showed a decrease in renewable energy innovation, with an effect size of -0.349. Our research contributes to green innovation literature, particularly to renewable energy innovation discourse under climate challenges. It extends the behavioral theory of the firm to contexts of climatic uncertainty and applies the threat rigidity model to determine organizational adaptation. The study introduces a novel moderator: the firm's history of natural disasters, linking firm age with disaster frequency and severity. These insights are vital for enhancing strategic decision-making in the business and policy-making contexts, amidst the growing climate change challenges.

1. Introduction

Renewable energy (RE) is imperative to fostering a low-carbon economy and addressing the climate change crisis (Krueger et al., 2020; Xu and Lin, 2018). The significance of RE is increasingly recognized in global policy-making circles such as the Paris Agreement (Steffen, 2020). Similarly, the role of RE was emphasized at the 28th Conference of the Parties (COP 28) to the United Nations Framework Convention on Climate Change (UNFCCC). The world leaders at the conference agreed to a significant expansion in RE,

---

[*] Corresponding author.

E-mail addresses: H.r.m.moadab@massey.ac.nz (H. Rastegar), a.sajjad@massey.ac.nz (A. Sajjad), g.eweje@ecu.edu.au (G. Eweje), K.Kobayashi@massey.ac.nz (K. Kobayashi).

[1] Postal address: QA 3.23, School of Management, Massey Business School, Massey University, New Zealand.

[2] Postal address: QB 2.07, School of Management, Massey Business School, Massey University, New Zealand. Phone: +6492136387

[3] Postal address: School of Business and Law, Edith Cowan University, 270 Joondalup Drive, Joondalup WA 6027, Australia, Phone: +61 8 6304 2674

[4] Postal address: School of Management, Massey Business School, Massey University, New Zealand. Phone: +6469517904

https://doi.org/10.1016/j.jebo.2024.106777
Received 12 March 2024; Received in revised form 3 September 2024; Accepted 9 October 2024

aiming to triple the world's installed capacity of RE generation (COP 28, 2023). Bayer, Dolan, and Urpelainen (2013, p. 289) define RE innovation as "the process of inventing and improving new energy technologies for commercial use." This process presents pioneering firms with the opportunity to secure a competitive advantage (Perruchas et al., 2020; Roper and Tapinos, 2016; Zhou and Wen, 2020).

Despite RE's potential to mitigate climate impacts and address the global fossil fuel-induced environmental crisis, its adoption faces significant barriers, including substantial initial investments and operational complexities (Kim and Park, 2016; Lin and Zhu, 2019; Shin et al., 2018; Steffen, 2020; Xu and Lin, 2018). Furthermore, many countries, including the United States (U.S.), continue to rely heavily on fossil fuels for energy production and consumption (Ghosh and Ghosh, 2020; International Energy Agency [IEA], 2023; Energy Information Administration [EIA], 2023). The economic dominance of low-cost fossil fuels poses further challenges to adopting RE technologies (Lin and Zhu, 2019). This situation highlights a vital gap in existing research, which has predominantly focused on operational strategies for emissions reduction (Zhou and Wen, 2020) and less on proactive environmental practices such as RE innovation.

In parallel, growing evidence suggests that the macroeconomic impacts of climate change are significant, however, a substantial gap remains in understanding how these impacts affect individual firms, particularly regarding RE innovation (Cevik and Miryugin, 2023). Moreover, the literature offers no clear consensus on whether extreme events drive firms toward greater sustainability (Agostino, 2024) despite the rising frequency and intensity of climate change-induced disasters (Frijters et al., 2023; Porto de Albuquerque et al., 2023; Truong et al., 2018). As adverse climate-related events increase, so does the demand from investors for sustainable and responsible investments, such as RE innovation (Fiordelisi et al., 2023). In line with the Paris Agreement, there is mounting pressure on firms to shift their investments away from fossil fuels and toward low-carbon alternatives (Monasterolo, 2020). This suggests that as climate change-induced disasters become more frequent, the pressure on firms to invest in RE technology should intensify. However, contrary to this expectation, recent data shows a decline in RE patent applications in the U.S. over the past decade, suggesting a potential slowdown in RE innovation (United States Patent and Trademark Office [USPTO], 2024). This decline is particularly concerning, given the urgent need for innovative solutions to address the challenges of climate change. Additionally, corporate investments in RE have experienced a significant decline, with their share falling from 65 % to 41 % annually in recent years (IRENA and CPI, 2023).

These trends highlight the need for a deeper understanding of how climate change-induced disasters affect firms' pursuit of RE innovation. The current literature reveals a complex and varied impact of such disasters on firms' pursuit of RE innovation. For instance, Ren et al. (2022) observed that in China, heightened climate risks led to an increase in corporate carbon emissions, indicating that some firms may face difficulties in shifting to low-carbon technologies such as RE technology under certain conditions. Conversely, Ma et al. (2024) found that in Organization for Economic Cooperation and Development (OECD) countries, climate risks often serve as catalysts for green innovation, including RE innovation, especially in regions with robust economic support and political support for sustainable initiatives. Similarly, Li et al. (2023) highlighted that in Bangladesh—a country particularly vulnerable to natural disasters—such events have positively impacted long-term sustainability efforts by increasing reliance on RE technology. However, Huang et al. (2018) pointed out that in countries facing significant climate risks, firms frequently opt for more conservative financial strategies, such as increasing cash reserves and extending debt maturities, rather than directly investing in RE innovation. These mixed findings underline the necessity for further research to clarify how climate change-induced disasters affect firms' pursuit of RE innovation.

Given these complexities, the intersection of RE innovation challenges and the impacts of climate change-induced disasters provides a critical context for our study. While studies have explored how firms adapt to natural disasters through innovation (Li et al., 2023; Ma et al., 2024), rigorous quantitative analyses investigating the intersection of RE innovation and climate change-induced disasters are relatively scarce. Therefore, this study aims to fill this significant gap by providing an in-depth analysis of how RE innovation is adapted in response to climate change-induced disasters. Building on this foundation, our study poses the pivotal question: How do climate change-induced disasters influence firms' pursuit of RE innovation? This inquiry guides our investigation and seeks to enhance our understanding of the interplay between environmental crises and corporate RE innovation strategies.

We draw on the behavioral theory of the firm (BTOF) (Cyert and March 1963) to investigate how climate change-induced disasters affect a firm's strategic decision to pursue RE innovations. The BTOF offers a robust framework for analyzing firm behavior in uncertain contexts (Cyert and March 1963). The theory holds that a firm's aspiration level, which refers to a firm's desired performance target (Cyert and March 1963; Shinkle, 2012), shapes its risk-taking behaviors. Additionally, we incorporate the threat rigidity model (Staw et al., 1981) to dissect firms' reactions to the unique threats posed by climate change-induced disasters. This model elucidates why firms may exhibit rigidity, such as reduced risk-taking strategies, in the face of such threats (Staw et al., 1981). This integration is vital for understanding the spectrum of strategic responses to environmental threats, from inertia to the proactive pursuit of RE innovations.

Our study employs the difference-in-differences (DiD) approach, complemented by meta-analysis, enabling robust testing of our hypotheses. We hypothesize that firms increase their engagement in RE innovation following climate change-induced disasters. To test this, we analyzed the U.S. firms' RE innovation activities before and after climatological disasters from 2013 to 2018. Our findings show that firms in disaster-affected U.S. states significantly increase their RE innovation post-disaster, compared to those in unaffected ones. Furthermore, we recognize that the firms' responses might vary based on specific characteristics. To capture these moderating effects, we utilized difference-in-differences-in-differences (DDD) estimations as suggested by Chen et al. (2022), Osberghaus (2017), and Yu and Zhang (2022), integrating our main DiD variables with factors such as the performance-aspiration gap and the firms' history of natural disasters. Our analysis indicates that the treatment effect is more pronounced in firms performing below their aspiration levels. We also find that firms with a frequent history of natural disasters tend to invest less in RE innovation. These findings provide valuable insights into how environmental crises shape corporate innovation strategies, particularly in the context of RE.

This study makes several contributions to the green innovation literature, especially focusing on RE innovation amidst climate change and its induced disasters. It fills a significant gap by analyzing the influence of such disasters on the pursuit of RE innovation by firms, offering a unique firm-level perspective, a departure from the usual country-level climate risk assessments, as seen in studies such as that by Huang et al. (2018). Unlike the traditional approach employed in the existing literature that typically considers and analyzes a single natural disaster, this study investigates a comprehensive range of climatological disasters in the U.S. from 2013 to 2018. This timeframe aligns with the U.S. Climate Action Plan's initiation in 2013, a plan emphasizing RE innovation as a strategy to combat climate change (Hausker et al., 2015), providing a suitable backdrop for our analysis. This period is also chosen based on the needs of our DiD analysis, which requires four years of data for each disaster. With data available from 2011 to 2019, this period maximizes our analysis scope within the constraints of data accessibility. Employing a DiD analysis across 19 such events, this research stands out for its empirical depth and rigor, setting it apart from the existing literature (Ren et al., 2022). Furthermore, while the BTOF has traditionally been used to study firm behavior under risk conditions, this study extends its application to understanding firm strategies under the uncertain conditions of climate change-induced disasters, marking a substantial theoretical advancement. Additionally, it utilizes the threat rigidity model to investigate how a firm's history with natural disasters influences its RE innovation propensity, offering a new viewpoint on organizational adaptation strategies. A novel aspect of this study is the introduction of a new moderator: the firm's history of natural disasters, measured by combining firm age with the frequency and severity of climatological disasters. This multifaceted approach provides a deeper understanding of a firm's historical context concerning climate change. Lastly, this study offers practical contributions that extend beyond academia, serving as a valuable tool for policy-makers and businesses. It aids in the development of climate action strategies and provides companies with insights into competitor behaviors, thereby enhancing their strategic decision-making in the face of climate challenges.

The remainder of the paper is organized as follows. Section 2 presents the theoretical development and hypotheses. Section 3 outlines our empirical setting, sample, and methodological approach, including the use of DiD and meta-analysis techniques. Section 4 presents the results of our analysis. Finally, Section 5 provides an integrated discussion of our findings, explores their theoretical, managerial, and policy implications, acknowledges the study's limitations, and concludes with suggestions for future research.

2. Theoretical development

2.1. *Climate change-induced disasters and RE innovation*

As scholarly interest in climate risks grows, understanding how these risks are integrated into firms' decision-making processes has become an increasingly critical topic (Krueger et al., 2020). The complexities of the climate system and the difficulty in predicting future scenarios add layers of uncertainty to business strategy and operations in the context of climate change (Howard-Grenville et al., 2014). Previous studies have highlighted that firms in regions with high climate risks often face reduced economic performance and increased earnings volatility, reflecting the adverse effects of extreme weather events (Huang et al., 2018). However, these studies typically rely on broad, national-level data, which may not fully capture the diverse experiences of firms at the individual level. Our study, therefore, shifts the focus to a more granular, firm-level analysis.

Climate change-induced disasters can be viewed as environmental threats that impose immediate challenges on firms, often making them feel constrained in their ability to respond proactively (Staw et al., 1981). This perceived rigidity can lead firms to adopt more cautious behaviors, prioritizing resource conservation over innovation (Hoskisson et al., 2017). For example, firms in high-risk environments may hold more cash reserves and rely on longer-term borrowing to manage liquidity concerns during extreme climate events (Huang et al., 2018). Such conservative financial behaviors might limit the firm's capacity for innovation.

However, some studies present a different perspective, suggesting that extreme climate events can lead firms to take more proactive behaviors to stabilize their operations. For example, firms might increase their production levels after such events to maintain stable performance. Additionally, companies in heavily polluting industries, especially those facing stringent environmental regulations, might respond by reducing their carbon emissions to align with regulatory expectations and mitigate future risks (Ren et al., 2022). Moreover, studies have shown that investment in green funds often increases following natural disasters, reflecting a growing demand for sustainable practices from investors and consumers (Marshall et al., 2021). Furthermore, research from different contexts, such as Bangladesh and OECD countries, highlights how natural disasters can positively influence sustainable development and encourage a shift toward green innovation (Li et al., 2023; Ma et al., 2024). These studies suggest that while climate disasters present significant challenges, they can also act as catalysts for firms to innovate and transition toward more sustainable practices.

Amidst these varied findings, there is a gap in understanding how nature-driven impacts of climate change, particularly climate change-induced disasters, affect RE innovation at the firm level. To address this gap, our study draws on the BTOF. The BTOF challenges the traditional view of firms as purely rational, profit-maximizing entities and instead posits that firms operate as goal-directed systems composed of individuals and groups with collective objectives (Chen and Miller, 2007; Cyert and March 1963). This theory has been widely used to model firm behavior, particularly under conditions of uncertainty, such as when pursuing innovation (Gaba and Bhattacharya, 2012; Greve, 2003). The BTOF provides a comprehensive framework for understanding how firms adjust their behavior in response to external pressures and opportunities, including those arising from climate change-induced disasters. These events often create a discrepancy between a firm's current performance and its aspiration levels, compelling firms to seek innovative solutions to address these shortfalls (Yang and Chen, 2024). While such disasters present significant operational and environmental challenges, they also offer unique opportunities for firms to adapt and innovate, particularly in the realm of RE innovation (Mithani et al., 2021). Firms that find their aspirations threatened by these external shocks are likely to increase investments in sustainability innovations to close the performance gap and enhance their competitive standing (Bettinazzi et al., 2020; Dong et al., 2021).

Incorporating the BTOF, this study hypothesizes that climate change-induced disasters catalyze a shift in firms' pursuit of RE innovation. The theory underscores that firms' responses to these uncertain situations are driven by their ongoing pursuit of satisfactory performance and the need to adapt to new environmental challenges.

Hypothesis 1. *In the aftermath of climate change-induced disasters in the form of climatological disasters, firms experience a positive change in the pursuit of RE innovation compared to the pre-disaster period.*

2.2. Performance-aspiration gap and post-disaster RE innovation

In explorations of organizational responses to climate change-induced disasters, the literature offers contrasting perspectives. For example, Marshall et al. (2021) observed that the U.S. mutual funds with an environmental focus experience increased inflows during disasters, indicating a surge of interest in green initiatives, especially during severe events. Conversely, Huang et al. (2018) noted that climate risk impacts vary across industries, with sectors responding differently to extreme climate events. Ren et al. (2022) suggested that extreme climate events might trigger increased production in certain industries, especially those under strict environmental regulations.

Accordingly, we draw on the BTOF, which emphasizes the critical role of aspiration levels in guiding firms' strategic decision-making. The BTOF posits that firms operate under bounded rationality, meaning they aim for satisfactory rather than optimal performance (Chen and Miller, 2007; Cyert and March 1963). Central to this theory is the concept of the performance-aspiration gap, which arises when there is a discrepancy between a firm's actual performance and its desired goals. This gap is a motivational driver, prompting firms to adopt riskier strategies to improve performance (Gaba and Bhattacharya, 2012; Hoskisson et al., 2017). This theoretical perspective highlights how the performance-aspiration gap influences firms' responses, particularly under conditions of environmental uncertainty.

Building on the BTOF, we developed Hypothesis 2, which posits that firms with performance below their aspiration levels will demonstrate a more pronounced positive change in RE innovation following climate change-induced disasters. This hypothesis underscores the role of the performance-aspiration gap in shaping strategic responses under environmental uncertainty. By analyzing firms' adaptation and innovation strategies in the face of climate risks, this study sheds light on the complex ways firms navigate and respond to evolving climate challenges.

Hypothesis 2. *In the aftermath of climate change-induced disasters in the form of climatological disasters, firms with performance below the aspiration level will demonstrate a stronger positive change in the pursuit of RE innovation.*

2.3. Firm's history of natural disasters

In the context of climate change, uncertainty is a crucial factor, especially in projecting future scenarios. Augustine et al. (2019) differentiated between the near and distant future, associating the latter with ambiguity and Knightian Uncertainty, crucial for understanding long-term climate change challenges. However, Das and Teng (1999) emphasized temporal continuity for understanding future events, and integrating past and present contexts, a concept further explored by Oetzel and Oh (2021) and Raynard et al. (2020).

Aligned with this principle of temporal continuity, our study confirms that a firm's risk attitudes are influenced by its past performance (Imas, 2016). The BTOF also rests on this temporal continuity, emphasizing firms' past experiences over future expectations in shaping strategic decisions (Lant and Shapira, 2008). This perspective is particularly relevant when considering firm age, as younger firms may be more adaptable and willing to invest in modern, environmentally friendly technologies due to their flexibility and lower legacy constraints (George, 2005; Wagner, 2011). Thus, we introduce a novel moderator: the firm's history of natural disasters. This integrates the firm's age with the frequency and magnitude of experienced climatological disasters (Oetzel and Oh, 2021, 2014; Tilcsik and Marquis, 2013). Unlike previous studies that used the number of natural disasters in a country as a proxy for organizational experience (Oetzel and Oh, 2021), our approach differentiates between disasters of varying severity.

Building on Staw, Sandelands, and Dutton's (1981) threat rigidity model, this study explores how firms respond to external threats like climate change-induced disasters. The model posits that when firms perceive significant threats, they tend to adopt more conservative strategies, focusing on risk mitigation and resilience rather than innovation (Staw et al., 1981). This rigidity is driven by two factors: a narrowing of information processing, where firms reduce their attention to external inputs, and a centralization of control, where decision-making becomes more concentrated at higher organizational levels.

In the context of RE innovation, firms with extensive histories of climatological disasters may prioritize survival and stability over pursuing innovations, especially when they perceive the environment as increasingly unstable. This explains why some firms might reduce their investment in RE innovation following such events. According to the BTOF, firms assess their performance relative to their aspirations, influencing their willingness to take risks. Firms falling short of their aspirations might pursue riskier strategies, such as investing in RE innovation. However, when faced with repeated environmental challenges, these firms may lean toward a more conservative, risk-averse approach, reducing their innovation investments to maintain stability.

In summary, integrating the threat rigidity model with the BTOF provides a nuanced understanding of how firms navigate climate change-induced disasters, suggesting that firms with significant disaster experience are more likely to adopt conservative strategies, potentially limiting their engagement in RE innovation.

Hypothesis 3. *The effect of climate change-induced disasters in the form of climatological disasters on the pursuit of RE innovation, compared to the pre-disaster period, is moderated by the firm's history of natural disasters.*

The conceptual framework presented in Fig. 1 illustrates the key relationships explored in this study. It highlights how climatological disasters affect firms' pursuit of RE innovation. Two moderating variables—performance-aspiration gap and a firm's history of natural disasters—are also included to show how these factors influence the strength and direction of the relationship. This framework, grounded in the BTOF and the threat rigidity model, offers a structured view of the study's hypotheses.

3. Data and method

3.1. Empirical setting

This study's empirical analysis is conducted within the U.S. context, chosen for its alignment with our research objectives and its distinct characteristics. The U.S.'s fluctuating climate change stance, including its withdrawal and re-entry into the Paris Agreement, reflects a highly uncertain institutional environment (Leyva-de la Hiz et al., 2019), making it an ideal backdrop for studying the impact of climate change on firms' RE strategies. Additionally, the U.S.'s heightened susceptibility to natural disasters, as per NASA Earthdata, offers a relevant perspective for investigating corporate responses to environmental challenges. Moreover, the RE sector in the U.S. is notably impacted by climatic fluctuations (Sinha et al., 2024), accentuating the significance of this study's focus. As the second-largest global carbon emitter (Friedlingstein et al., 2020), the U.S. role in global climate change impacts and mitigation efforts is also significant. Furthermore, the U.S.'s vibrant innovation landscape, underscored by its innovation performance as reported by the World Intellectual Property Organization (WIPO, 2023), emphasizes its suitability for this study. Overall, the U.S. presents a unique setting to explore the interplay between RE innovation and climate change impacts, owing to its evolving policy, high disaster frequency, and robust innovation ecosystem.

3.2. Sample

Our study examines the impact of climate change-induced disasters between 2013 and 2018 on RE innovation in the U.S. listed firms. We adopt a four-year interval for each disaster, divided into a two-year pre-disaster period and a two-year post-disaster period. For instance, if a disaster occurred in 2015, 2013–2014 is the pre-disaster period and 2015–2016 is the post-disaster period. This framework facilitates a clear comparison of RE innovation trends relative to the occurrence of climate disasters. To encompass this timeframe, we use annual data from 2011 to 2019. Additionally, we exclude financial service firms due to their distinct business models and capital structures, which differ from non-financial firms, ensuring a more precise analysis.

3.3. Measures

3.3.1. Dependent variable

This study focuses on RE innovation, measured by the number of successful RE patent applications. These patents are directly tied to RE technologies, aligning with established research practices in the environmental and innovation literature (Brunnermeier and

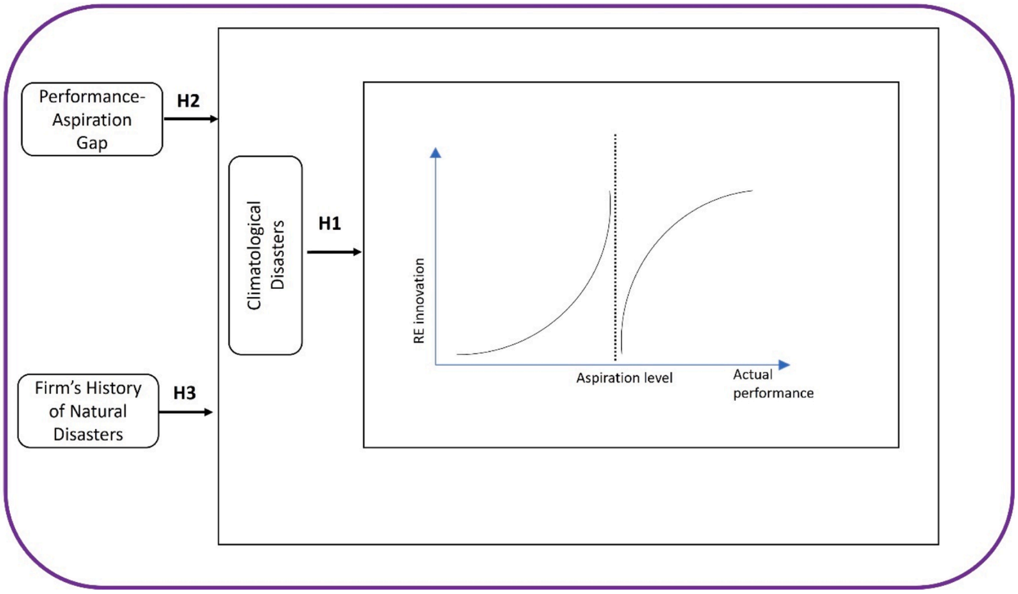


Fig. 1. The conceptual model.
Source: Developed by the authors.

Cohen, 2003; Leyva-de la Hiz et al., 2019; Perruchas et al., 2020). Innovation is commonly gauged using two proxies—R&D expenditure and patent count (Lerner and Seru, 2022)—with our study emphasizing the latter as an indicator of a firm's innovative output. This choice is underpinned by patents' ability to capture tangible innovation outcomes, unlike R&D expenditure (Lerner and Seru, 2022).

While patent counts (including RE patents), are a useful proxy for innovation, they have limitations such as not capturing unpatented innovations, failing to differentiate the value of patents, and not accounting for variations in patenting practices (Johnstone et al., 2010; Lindman and Söderholm, 2016). Nonetheless, they are still considered a valid measure (Leyva-de la Hiz et al., 2019; Perruchas et al., 2020). Historically, measuring green innovation was challenging due to unclear patent classifications (Kunapatarawong and Martínez-Ros, 2016), but the WIPO's International Patent Classification (IPC) system has enhanced this, making it more effective for categorizing RE innovations (Johnstone et al., 2010; Nesta et al., 2014; Noailly and Smeets, 2015).

For this study, we sourced RE patent count data from the United States Patent and Trademark Office (USPTO), as is standard in green innovation research (Amore and Bennedsen, 2016; Bae and Kim, 2022; Smirnova et al., 2021). We opted for RE patent applications rather than RE granted patents due to their immediate representation of innovation efforts and the usual lag in patent approval (Johnstone et al., 2010; Liang and Fiorino, 2013). Acknowledging the extensive R&D time for environmental investments, we also lagged the variable by one year to capture the actual developmental stages of these innovations, aligning with established research practices (Costantini et al., 2017; Dang and Xu, 2018; Greer et al., 2022; Un, 2016). Additionally, to account for the time required for innovations to materialize, we utilized a four-year timeframe around each disaster, with a two-year period preceding the disaster and a two-year period following it. This approach allows us to effectively capture RE innovation activities that may occur up to two years following the disaster.

3.3.2. Independent variables

This research investigates the impact of climate change-induced disasters in the U.S. from 2013 to 2018. Our independent variable is the incidence of these climatological disasters. Data on these events were sourced from the Emergency Events Database (EM-DAT), maintained by the Center for Research on the Epidemiology of Disasters (CRED). CRED categorizes natural disasters into five categories: biological (epidemics and insect infestations), climatological (droughts, extreme temperatures, and wildfires), geophysical (earthquakes, mass movements, and volcanoes), hydrological (floods and mass movements), and meteorological (storms) (Sodhi, 2016). Our focus is specifically on climatological disasters, reflecting our study's emphasis on climate change-induced disasters. This variable has been utilized in existing literature to examine the impacts of such disasters on various outcomes (Donatti et al., 2024; Rosselló et al., 2020). We also adopt CRED's criteria for disaster inclusion, which are: (i) 10 or more fatalities, (ii) affecting 100 or more people, (iii) triggering a State of Emergency declaration, or (iv) necessitating international assistance (Boudreaux et al., 2022). We identified 19 such climatological disasters during the study period and systematically labeled them from D1 to D19, following their chronological occurrence.

3.3.3. Moderators

Performance-aspiration gap

We examine how a firm's performance gap from its aspiration level, whether below or above, influences its RE innovation response to climatological disasters. We use Return on Assets (ROA) to measure actual performance and aspiration levels, following established research practices (Greve, 2003; Xu et al., 2019). ROA, indicating profitability, is derived from a firm's net income divided by its average total assets (Xu et al., 2019) and is sourced from Wharton Research Data Services' (WRDS) Compustat-Capital IQ dataset for North America.

Aspiration levels are assessed using Social Aspiration (SA) and Historical Aspiration (HA). SA represents the industry average performance, while HA is based on a firm's past performance (Smulowitz et al., 2020). We adopt a combined approach where SA is the industry average ROA, and HA is the firm's prior year ROA, with industry peers identified using GIC codes in Compustat. In determining aspiration levels, we explored three models common in BTOF studies: weighted average, separate, and switching models (Bromiley and Harris, 2014; Han, 2022). The switching model, chosen for its relevance and robustness, posits that firms below industry benchmarks aspire to reach these standards, while those exceeding benchmarks aim to surpass their previous performance (Bromiley, 1991; Bromiley and Harris, 2014; Symeou et al., 2019).

In this model, the aspiration level ($\text{Aspiration}_{i,t}$) calculation depends on the firm's prior year performance ($P_{i,t\text{-}1}$) relative to the industry average ($SA_{i,t\text{-}1}$). Specifically:

$Aspiration_{i,t} = SA_{i,t\text{-}1} \rightarrow If\ P_{i,t\text{-}1} < SA_{i,t\text{-}1}$

$Aspiration_{i,t} = 1.05 * P_{i,t\text{-}1} \rightarrow If\ P_{i,t\text{-}1} > SA_{i,t\text{-}1}$

We then compute the performance-aspiration gap using the formula:

$Gap = P_{i,t} – Aspiration_{i,t}$

For clarity in our model, we refer to the 'Performance-Aspiration Gap' simply as 'Gap.' This 'Gap' is used as a moderator and is categorized into two groups: 'Negative' and 'Positive.' 'Negative' indicates a firm's performance below its aspiration level, and is used as the reference baseline, while 'Positive' implies performance above this level.

Firm's history of natural disasters

Our research introduces the 'firm's history of natural disasters' as a novel moderator to explore its impact on RE innovation amidst climate change-induced disasters. This approach goes beyond just counting disasters during a firm's existence (Oetzel and Oh, 2021); it combines the firm's age with the frequency and severity of the climatological disasters it has experienced.

Firm age, indicating operational history and industry experience, is calculated as the difference between the study year and the firm's establishment year, sourced from the Compustat-Capital IQ dataset for North America (Wiklund et al., 2010). For assessing climatological disaster magnitude, we consider economic damages caused by these events, categorized into small-scale (below $1 billion), medium-scale ($1 to $5 billion), and major disasters (at least $5 billion) (Tilcsik and Marquis, 2013), focusing on major disasters to reflect their substantial climatic impacts.

Determining the frequency of these major disasters during the firm's past relies on data from the EM-DAT database (Oetzel and Oh, 2014, 2021). This comprehensive moderator captures the firm's historical engagement with climatological disasters, offering insights into how exposure to such events shapes its RE innovation tendencies in an increasingly climate-conscious business landscape. For clarity in our model, we abbreviate the 'Firm's History of Natural Disasters' to 'History.'

3.3.4. Control variables

In our study, we control for key factors: firm size, lifecycle, and age. This ensures a thorough understanding of the diverse influences on a firm's RE innovation strategy. Data for these variables were gathered from the Compustat-Capital IQ dataset for North America.

Firm size, measured by the natural logarithm of net sales, is a common metric in research (Leyva-de la Hiz et al., 2019; Mithani, 2017). Firm size is included as a control variable to consider the resources and capabilities larger firms might have in adopting sustainable practices and engaging in RE innovation.

A firm's investment activity, encompassing responses to climate change, evolves through different phases of its lifecycle (Faff et al., 2016). By incorporating the firm's lifecycle stage as a control variable, we aim to understand its potential influence on the firm's engagement with RE innovation. We employ Dickinson's (2011) classification model, based on operating, investing, and financing cash flows, to categorize firms into five stages: introduction, growth, mature, decline, and shake-out. The 'Mature' stage is used as a reference in our model to assess the impact of lifecycle stages on RE innovation.

- Introduction: $\text{OCF} < 0$, $\text{INVCF} < 0$, and $\text{FINCF} > 0$
- Growth: $\text{OCF} > 0$, $\text{INVCF} < 0$, and $\text{FINCF} > 0$
- Mature: $\text{OCF} > 0$, $\text{INVCF} < 0$, and $\text{FINCF} < 0$
- Decline: $\text{OCF} < 0$, $\text{INVCF} > 0$, and FINCF $\leq$ or ≥ 0

Any years not fitting these criteria are categorized under the shake-out stage. In this framework, OCF is the operating cash flow, INVCF is the investing cash flow, and FINCF is the financing cash flow (Dickinson, 2011; Habib and Hasan, 2017).

Finally, firm age, indicating the number of years since establishment, offers insights into a firm's experience and maturity in its industry (Tilcsik and Marquis, 2013; Wiklund et al., 2010). The inclusion of firm age as a control variable allows us to consider how accumulated industry experience influences a firm's innovation approach.

3.4. Analytical model

To test our hypotheses, we employ the DiD method, recognized for analyzing the impacts of exogenous shocks such as climate events (Belasen and Polachek, 2009; Yang et al., 2022). This method compares the effects on a treatment group, directly affected by a specific event, with a control group that remains unaffected. DiD stands out for its ability to account for all firm characteristics and include the entire population of firms in both groups, which minimizes the risk of biases often encountered in matched-sample methods that focus on matching firms based on a limited set of attributes (Kacperczyk, 2009; Mithani, 2017).

The DiD model's efficacy lies in using the control group as a baseline to estimate what would have occurred in the treatment group without the intervention (Osberghaus, 2017). This is achieved by analyzing the historical trends of both groups, thus neutralizing pre-existing differences. Our model looks at how firms' pursuit of RE innovation changes before and after climate change-induced disasters. Considering the panel nature of the data and the count value of the outcome, Poisson regression is employed as the estimator. The model employs two dummy variables: 'Period,' which differentiates the time frames as either before or after the disaster, and 'Treat,' distinguishing between the treatment and control groups of firms. This distinction is based on the location of the firms in relation to the disaster; firms operating in a state where the disaster occurred are assigned a value of 1, indicating the treatment group, while those in unaffected states are given a value of 0, classifying them as the control group. For moderating effects, we examine the interaction between the Period and Treat dummies and the focal moderating variable.

Further, we examine the impact of various climatological disasters on the pursuit of RE innovation, by employing a two-stage meta-analysis to synthesize results from different DiD models (Callaway and Sant'Anna, 2021; Deeks et al., 2019). Initially, we derive summary effects for each DiD model, reflecting the specific influence of each disaster. Next, we aggregate these individual effects to form an overall treatment effect, employing a weighted average method. Typically, the weights are determined based on the inverse of the variance of each study's treatment effect. This method is closely associated with the sample size of each study, ensuring that larger, potentially more informative studies have a proportionally greater influence on the overall results (Deeks et al., 2001, 2019). Given the diverse intensity levels of the disasters studied, we chose a random-effect approach for the meta-analysis, acknowledging the unique characteristics of each event. This method allows for variability across studies, providing a comprehensive view of the collective impact of climatological disasters on RE innovation (Deeks et al., 2001, 2019).

4. Results

4.1. Empirical results

Tables 1 and 2 summarize the descriptive statistics for continuous and categorical variables, respectively, across all disasters studied. To test Hypothesis 1, we use the DiD model to compare changes in RE innovation between treatment and control groups against historical control group trends. The primary DiD estimation model is structured as follows:

$$RE\ Innovation = \beta_0 + \beta_1 \times Period + \beta_2 \times Treat + \beta_3 \times Period \times Treat + \beta_4 \times Size + \beta_5 \times Lifecycle + \beta_6 \times Age + \varepsilon$$

This model uses ‘RE Innovation’ as the outcome variable, with coefficient β_3 capturing the interaction effect on the treatment group post-disaster. Control variables include ‘Size,’ ‘Lifecycle,’ and ‘Age.’

Given the broad scope of this analysis, which includes all climatological disasters in the U.S. between 2013 and 2018, we perform a DiD analysis for each disaster individually, comparing two years before and after the disaster. The results of these individual analyses are then aggregated using meta-analysis (Table 3), revealing a significant positive effect of 0.74 at $p < .01$. This indicates that firms increase their level of RE innovation following climatological disasters, confirming our hypothesis that climate change-induced disasters drive enhanced RE innovation in firms. Fig. 2 demonstrates our results by displaying a forest plot for the meta-analysis. This plot focuses on the interaction effect, central to Hypothesis 1. The overall effect, indicated by a diamond at the bottom, shows a significant positive effect of 0.74. The analysis of individual disasters, as illustrated in the plot, consistently shows a positive trend. Heterogeneity analysis shows little variability among studies ($I^2 = 0$ %; Q-test p-value = 0.980), reinforcing the reliability of the findings.

Hypothesis 2 of our study delves into the moderating role of the ‘Gap’ in the relationship established in the first model. To test this hypothesis, we structured the following model:

$$RE\ Innovation = \beta_0 + \beta_1 \times Period + \beta_2 \times Treat + \beta_3 \times Period \times Treat + \beta_4 \times Period \times Treat \times Gap + \beta_5 \times Size + \beta_6 \times Lifecycle + \beta_7 \times Age + \varepsilon$$

Here, the coefficient β_4 assesses the three-way interaction, examining the impact of a firm’s performance relative to its aspiration level on the link between climate change-induced disasters and RE innovation. A meta-analysis of 19 disasters indicates a significant moderating effect of the performance-aspiration gap. Table 3 shows that firms above their aspiration level experience less impact from climate disasters on RE innovation than those below their aspiration level, with an aggregated effect size of -0.273 at $p < .05$. This negative coefficient indicates that a positive performance-aspiration gap reduces the effect size by an average of 0.273 units. Fig. 2 illustrates this trend through a forest plot, displaying each study’s effect size and confidence interval. The low heterogeneity in the studies, indicated by a 16.5 % I^2 and a Q-test p-value of 0.252, suggests minimal variability in effects, reinforcing the credibility of the aggregated results.

This synthesis demonstrates that while the overall direction of climatological disasters’ impact on RE innovation remains consistent, its magnitude is significantly moderated by the firm’s performance relative to its aspiration level. Firms performing above this level experience less impact on their RE innovation post-disaster than those below, confirming Hypothesis 2.

In Hypothesis 3, the moderating role of ‘History’ on the firm’s response to climatological disasters in terms of RE innovation is examined. We propose that a firm’s past experiences with such disasters significantly influence its innovative responses to subsequent events. To investigate this, we conducted the DiD analysis for the same 19 disasters, with the following model:

$$RE\ Innovation = \beta_0 + \beta_1 \times Period + \beta_2 \times Treat + \beta_3 \times Period \times Treat + \beta_4 \times Period \times Treat \times History + \beta_5 \times Size + \beta_6 \times Lifecycle + \beta_7 \times Age + \varepsilon$$

In this model, the coefficient β_4 assesses how ‘History’ influences the firm’s response to climate change-induced disasters in terms of RE innovation. The meta-analysis, presented in Table 3, shows a significant aggregated effect size of -0.349 ($p < .001$), underscoring the impact of ‘History’ on the firm’s RE innovation. The results suggest that firms with extensive disaster histories typically scale back their RE innovation post-disaster. This implies that past experiences with disasters might incline firms towards a more conservative approach, focusing on risk mitigation and resilience rather than pursuing new RE innovation paths following a climate disaster.

The high I^2 statistic of 72.2 % and the Q-test p-value of <0.000, as shown in Fig. 2, indicate considerable variability in the moderating effect of a firm’s history of natural disasters. This variability implies that the specific characteristics of past disasters a firm has encountered, alongside its learning and adaptation strategies, are critical in determining how it responds to future natural disasters.

4.2. Validation and robustness analysis

The DiD methodology in this study is predicated on the parallel trend assumption, which posits that, without intervention, treatment and control groups would follow similar outcome trends (Chen et al., 2022; Murillo-Sandoval et al., 2021). To verify this, we employed parallel trend plots (Agüero, 2021), with Fig. 3 affirming this assumption for our empirical approach. Given the study’s breadth across 19 DiD analyses, we created individual parallel trend plots for each climatological disaster. These plots depict the treatment group’s trends using dashed lines and the control group’s using solid lines, with the Y-axis measuring RE innovation via patent counts and the X-axis charting the years, distinguishing between pre- and post-treatment periods. These visualizations validate

Table 1

Descriptive statistics of continuous variables.

Variables}	Statistics	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19
RE Innovation	Mean	0.033	0.058	0.048	0.033	0.033	0.038	0.055	0.041	0.041	0.041	0.037	0.037	0.037	0.032	0.027	0.027	0.036	0.036	0.036
	Std. Dev.	0.218	0.279	0.255	0.218	0.218	0.358	0.51	0.239	0.239	0.239	0.255	0.255	0.255	0.242	0.226	0.226	0.407	0.407	0.407
Treat	Mean	0.263	0.12	0.066	0.263	0.263	0.331	0.225	0.224	0.224	0.224	0.21	0.21	0.21	0.025	0.205	0.205	0.206	0.206	0.206
	Std. Dev.	0.44	0.325	0.248	0.44	0.44	0.471	0.418	0.417	0.417	0.417	0.407	0.407	0.407	0.156	0.403	0.403	0.405	0.405	0.405
Period	Mean	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Std. Dev.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Treat × Period	Mean	0.132	0.06	0.033	0.132	0.132	0.165	0.113	0.112	0.112	0.112	0.105	0.105	0.105	0.012	0.102	0.102	0.103	0.103	0.103
	Std. Dev.	0.338	0.238	0.178	0.338	0.338	0.372	0.317	0.315	0.315	0.315	0.306	0.306	0.306	0.111	0.303	0.303	0.304	0.304	0.304
Size	Mean	19.318	19.275	19.312	19.318	19.318	19.699	19.714	19.704	19.704	19.704	19.677	19.677	19.677	19.697	19.732	19.732	19.787	19.787	19.787
	Std. Dev.	2.499	2.526	2.499	2.499	2.499	2.348	2.394	2.364	2.364	2.364	2.433	2.433	2.433	2.4	2.439	2.439	2.489	2.489	2.489
Age	Mean	13.768	13.817	13.6	13.768	13.768	14.956	15.458	15.592	15.592	15.592	15.268	15.268	15.268	15.335	15.672	15.672	16.275	16.275	16.275
	Std. Dev.	7.369	7.587	7.623	7.369	7.369	7.559	7.994	7.645	7.645	7.645	8.679	8.679	8.679	8.628	8.949	8.949	9.174	9.174	9.174
History	Mean	0.723	0.741	0.726	0.723	0.723	0.877	0.882	0.969	0.969	0.969	0.932	0.932	0.932	0.943	1.077	1.077	1.148	1.148	1.148
	Std. Dev.	0.798	0.803	0.793	0.798	0.798	0.902	0.945	0.96	0.96	0.96	1.063	1.063	1.063	1.069	1.265	1.265	1.404	1.404	1.404
Observations		3056	2800	2376	3056	3056	5668	4512	3452	3452	3452	4520	4520	4520	5460	5688	5688	5472	5472	5472

Source: Authors' analysis using STATA.

Table 2
Descriptive statistics of categorical variables.

Variables}	Categories}	Statistics	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19
Lifecycle	Mature	Freq.	1147	1037	905	905	905	2553	2036	1520	1520	1520	1961	1961	1961	2395	2555	2555	2461	2461	2461
		Percent	37.53	37.04	38.09	38.09	38.09	45.04	45.12	44.03	44.03	44.03	43.38	43.38	43.38	43.86	44.92	44.92	44.97	44.97	44.97
	Decline	Freq.	247	241	180	180	180	365	313	243	243	243	332	332	332	380	427	427	430	430	430
		Percent	8.08	8.61	7.58	7.58	7.58	6.44	6.94	7.04	7.04	7.04	7.35	7.35	7.35	6.96	7.51	7.51	7.86	7.86	7.86
	Growth	Freq.	843	764	650	650	650	1546	1188	902	902	902	1157	1157	1157	1428	1396	1396	1271	1271	1271
		Percent	27.59	27.29	27.36	27.36	27.36	27.28	26.33	26.13	26.13	26.13	25.6	25.6	25.6	26.15	24.54	24.54	23.23	23.23	23.23
	Introduction	Freq.	549	521	434	434	434	755	602	469	469	469	666	666	666	771	774	774	771	771	771
		Percent	17.96	18.61	18.27	18.27	18.27	13.32	13.34	13.59	13.59	13.59	14.73	14.73	14.73	14.12	18.61	18.61	14.09	14.09	14.09
	Shake-out	Freq.	270	237	207	207	207	449	373	318	318	318	404	404	404	486	536	536	539	539	539
		Percent	8.84	8.46	8.71	8.71	8.71	7.92	8.27	9.21	9.21	9.21	8.94	8.94	8.94	8.9	9.42	9.42	9.85	9.85	9.85
	Total	Freq.	3056	2800	2376	2376	2376	5668	4512	3452	3452	3452	4520	4520	4520	5460	5688	5688	5472	5472	5472
		Percent	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Gap	Negative	Freq.	2458	2275	1882	1882	1882	4097	3274	2521	2521	2521	3240	3240	3240	3867	3926	3926	3815	3815	3815
		Percent	80.43	81.25	79.21	79.21	79.21	72.28	72.56	73.03	73.03	73.03	71.68	71.68	71.68	70.82	69.02	69.02	69.72	69.72	69.72
	Positive	Freq.	598	525	494	494	494	1571	1238	931	931	931	1280	1280	1280	1593	1762	1762	1657	1657	1657
		Percent	19.57	18.75	20.79	20.79	20.79	27.72	27.44	26.97	26.97	26.97	28.32	28.32	28.32	29.18	30.98	30.98	30.28	30.28	30.28
	Total	Freq.	3056	2800	2376	2376	2376	5668	4512	3452	3452	3452	4520	4520	4520	5460	5688	5688	5472	5472	5472
		Percent	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Authors’ analysis using STATA.

Table 3
Meta-analysis results.

Meta-Analysis	Model 1		Model 2		Model 3	
Variable	Coefficient	I^2	Coefficient	I^2	Coefficient	I^2
Treat	1.441***	45.70 %	1.441***	43.90 %	1.413***	0.69
Period	−0.106	86.10 %	−0.117	85.70 %	−0.162	83.90 %
Treat × Period	0.74***	0 %	0.824***	0 %	1.361***	37.10 %
Gap: Positive			0.263***	17.30 %		
Gap × Treat × Period			−0.273**	16.50 %		
History					0.116*	74.60 %
Treat × Period × History					−0.349***	72.20 %
Size	0.182***	0 %	0.180***	0 %	0.182***	6.80 %
Lifecycle:						
Decline	0.658***	0 %	0.696***	0 %	0.679***	0 %
Growth	0.214***	0 %	0.236***	0 %	0.226***	0 %
Introduction	0.677***	0 %	0.688***	0 %	0.700***	0 %
Shake-out	0.651***	0 %	0.667***	0 %	0.687***	0 %
Age	0.005	0 %	0.005	0 %	0.006*	0 %
Constant	−8.010***	1.1 %	−8.048***	2.20 %	−8.108***	7.90 %

Note: *** $p<.01$, ** $p<.05$, * $p<.1$.
Source: Authors' analysis using STATA.

the parallel trend assumption, bolstering the credibility of our DiD methodology. Another key assumption of the DiD approach is the common shock assumption. This refers to the possibility of other events occurring during or after the disaster under study that could influence the results (Dimick and Ryan, 2014). By employing multiple treatment studies that encompass various treatment and control groups, as well as different pre- and post-treatment time periods, we mitigate the risk of such common shocks affecting our findings (Meyer, 1995).

We also evaluated the use of Poisson regression for patent counts in our analysis, given its suitability for count data (Cameron and Trivedi, 2013; Deb and Norton, 2018). This model assumes equidispersion, where the count variable's mean and variance are equal. We conducted an overdispersion test, with equidispersion as the null hypothesis. As Table 4 indicates, overdispersion was found in several models, but not in D2, D3, D8, D9, and D10. Since our study does not focus on estimating specific count probabilities, such as the likelihood of zero patents, Poisson regression with random effects is appropriate (Dean, 1992; Wooldridge, 1999), ensuring the validity of our findings across different disaster analyses.

Our study also employed the Hausman test to compare fixed and random effects models (Dogan, 2016; Hussain et al., 2021). Table 4 shows that with p-values above 0.05 for all 19 models, the random effect model is deemed most suitable, validating our methodological approach and effectively capturing the dynamics between disasters and RE innovation.

Continuing with model validity checks, we addressed multicollinearity, where interlinked explanatory variables can skew results (Bölük and Mert, 2014; Graves and Shan, 2014; Hussain et al., 2021). Our Variance Inflation Factor (VIF) analysis, detailed in Table 4 for 19 models, showed the highest average VIF at 1.53, well below the multicollinearity concern threshold of 10 (Majeed and Ozturk, 2020; Shan and Troshani, 2014; Un, 2016). This indicates minimal multicollinearity impact, affirming the integrity and reliability of our econometric approach in exploring the impact of climate change-induced disasters on RE innovation.

5. Discussion and conclusion

5.1. Discussion

This study investigates the impact of climate change-induced disasters on firms' pursuit of RE innovation. Integrating the BTOF with the threat rigidity model, we delve into strategic decision-making in firms confronted with such disasters. Our findings reveal a significant increase in RE innovation post-disaster, especially among firms operating below their aspiration levels. This observation is in line with the BTOF, suggesting that firms underperforming against their targets are more inclined to innovate to improve their situation (Cyert and March 1963; Gaba and Bhattacharya, 2012). This finding not only supports but also extends the BTOF by applying it to the context of environmental crises, offering a fresh lens through which to view firm responses to climate change challenges. This result is consistent with Ma et al. (2024), who found that natural disasters motivate firms to pursue green innovation.

Similarly, Marshall et al. (2021) noted increased investment in green funds post-disaster, indicating that both firms and investors recognize the value of sustainable practices during such events. Moreover, this finding extends the work of Huang et al. (2018) and Krueger et al. (2020), who highlighted the impact of climate risks on corporate performance and decision-making but did not explore the specific role of aspiration levels in shaping these responses. Our study fills this gap by demonstrating how aspiration levels influence firms' behavior in the face of climate change-induced disasters.

In terms of firms with a history of experiencing disasters, our findings reveal a tendency towards reduced investment in RE innovation post-disaster. This observation is in line with the principles of the threat rigidity model, which posits that prolonged or repeated exposure to threats can cause organizations to adopt more rigid, conservative strategies, focusing on immediate survival and efficiency over innovation (Staw et al., 1981). This more cautious approach contrasts with the proactive stance adopted in some other

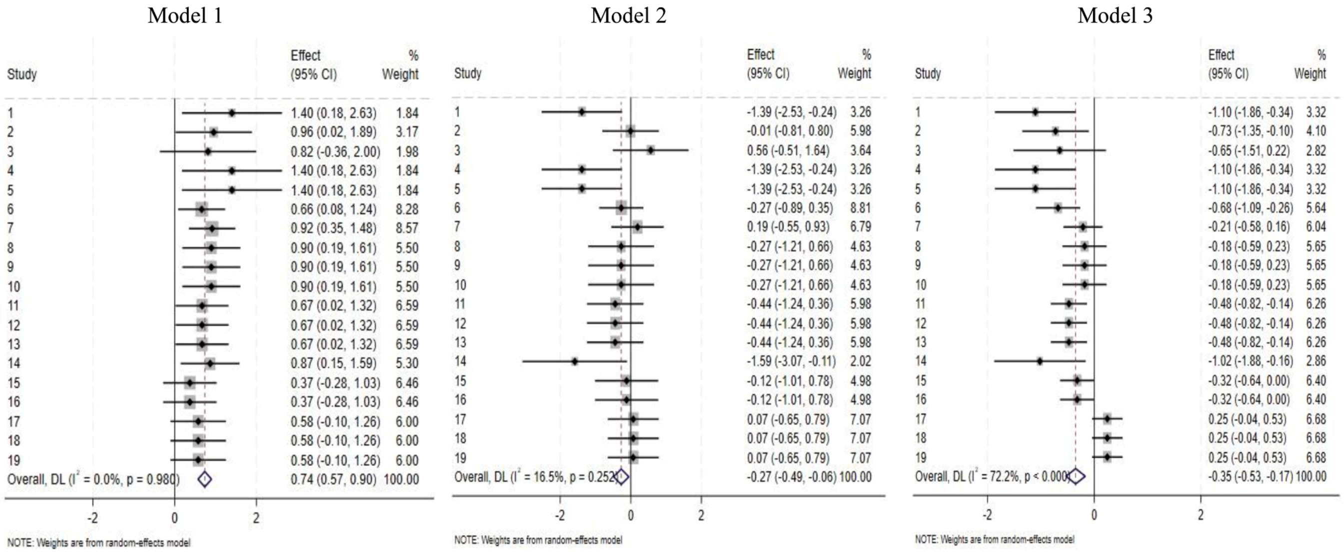


Fig. 2. Forest plots of meta-analyses.
Source: Authors' analysis using STATA.

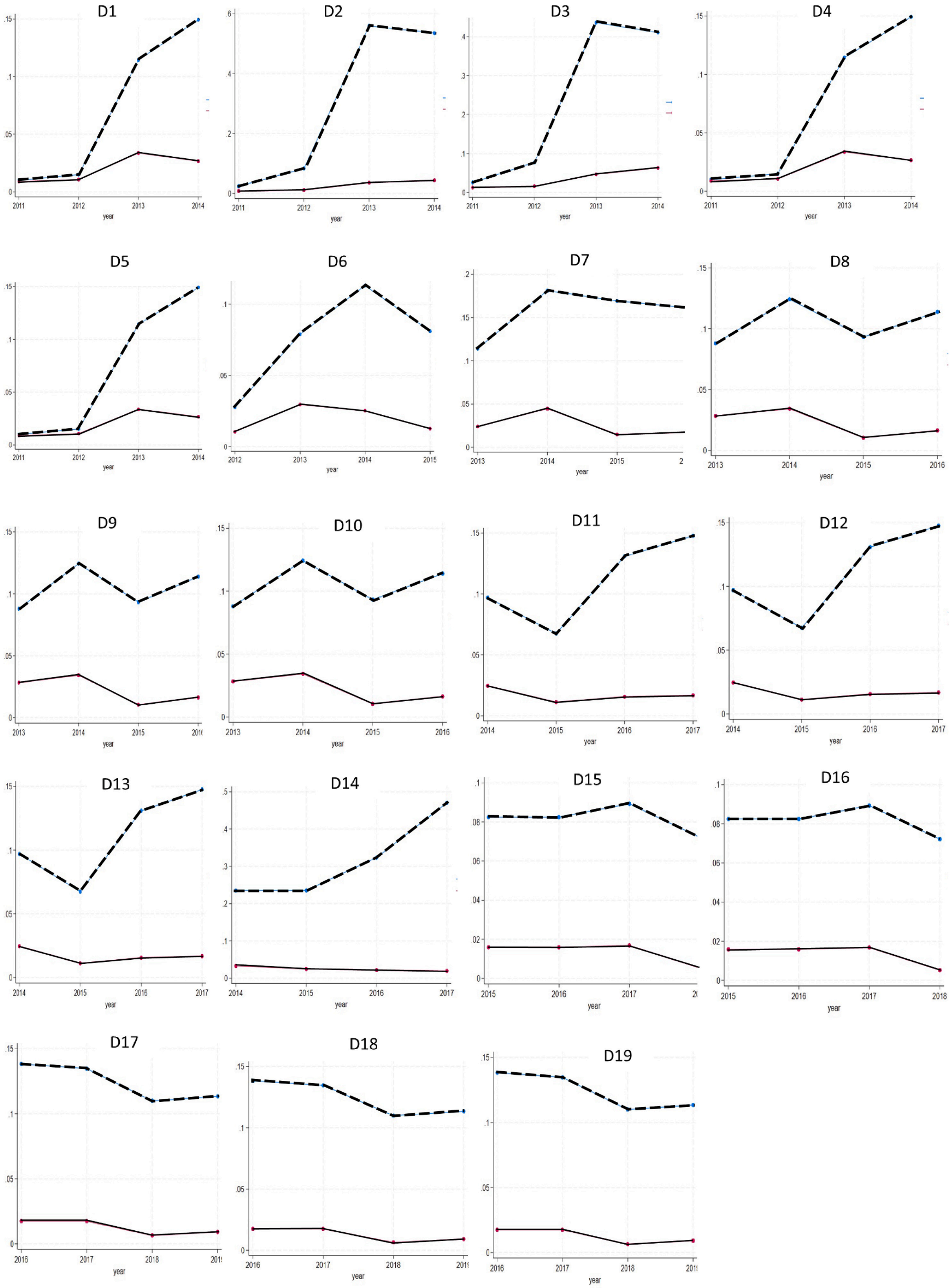


Fig. 3. Parallel trend plots.
Source: Authors' analysis using STATA.

Table 4
Results of robustness tests.

Tests	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19
Overdispersion test (t-value)	2.66**	0.22	0.88	2.66**	2.66**	4.12**	3.91**	0.76	0.76	0.76	5.00**	5.00**	5.00**	2.62**	2.86**	2.86**	7.84**	7.84**	7.84**
Hausman test (Chi-square)	0.59	13.89	−1.05	0.59	0.59	−15	3.711	−0.96	−0.96	−0.96	0.296	0.296	0.296	−1.93	0.454	0.454	−8.93	−8.93	−8.93
VIF (Mean value)	1.53	1.48	1.46	1.53	1.53	1.53	1.49	1.48	1.48	1.48	1.5	1.5	1.5	1.43	1.5	1.5	1.5	1.5	1.5

Note: *** $p<.01$, ** $p<.05$, * $p<.1$.
Source: Authors' analysis using STATA.

studies. For instance, while Ren et al. (2022) suggested that extreme climate events might trigger increased production in specific industries, especially under strict environmental regulations, our findings indicate that the direct experience of disasters can lead firms to prioritize stability over innovation. The integration of the BTOF with the threat rigidity model in this study offers a comprehensive framework for understanding how the performance-aspiration gap and reactions to perceived threats collectively shape a firm's strategic response to climate change impacts. This approach to strategic decision-making in firms with extensive disaster history reflects a prioritization of risk mitigation and resilience. It complements the findings of Marshall et al. (2021) and provides an additional perspective on the varied impacts of climate risks across industries noted by Huang et al. (2018) and Ren et al. (2022).

Our findings also contribute to the literature by highlighting the nuanced relationship between a firm's past experiences and its innovation behavior. For example, Augustine et al. (2019) and Raynard et al. (2020) discussed the role of temporal continuity in shaping firms' responses to climate risks. Our study adds to this discussion by suggesting that firms with a history of natural disasters are likely to draw on these past experiences, leading to a more conservative approach to RE innovation. This insight aligns with the principle of temporal continuity, which posits that firms' risk attitudes and strategic decisions are influenced by their historical experiences (Imas, 2016; Lant and Shapira, 2008).

5.2. *Theoretical implications*

This study contributes to environmental management, strategic decision-making, and organizational behavior by extending the BTOF (Cyert and March 1963) to the context of environmental crises. By applying the BTOF to climate change-induced disasters, the study highlights how the performance-aspiration gap drives firms toward RE innovation. This finding aligns with Mithani et al. (2021), who noted that natural disasters, while threatening, also create innovation opportunities. Our study advances this by showing how climatological disasters influence firms' pursuit of RE innovation, thereby expanding the understanding of how environmental threats influence strategic decisions.

Furthermore, the integration of the threat rigidity model (Staw et al., 1981) provides deeper insight into how historical experiences with natural disasters influence a firm's behavior in response to new environmental challenges. By incorporating the BTOF with the threat rigidity model, this research broadens the understanding of how firms' past encounters with disasters shape their behavior, particularly in pursuing RE innovations. This integration addresses a gap in the literature, as noted by Dunz et al. (2021) and Fabrizi et al. (2018), by demonstrating how performance-aspiration gaps and the experience of threats interact to drive firms' innovation behaviors.

5.3. *Managerial implications*

This research holds significant managerial implications for business leaders. It underscores the importance of considering a firm's history of natural disasters and its performance relative to aspirations in strategic planning. Firms with a history of natural disasters might find it beneficial to develop strategies that balance immediate survival with RE innovation goals. Additionally, the findings suggest that periods following disasters offer opportunities for firms to reassess and enhance their sustainability strategies, particularly in pursuing RE innovations. Furthermore, the study provides valuable insights for firms in building resilience against future environmental threats. Understanding the impact of a firm's history of natural disasters on its innovation propensity can inform more effective risk management and resilience-building strategies.

5.4. *Policy implications*

For policy-makers, the study's findings are instrumental in shaping appropriate policies and incentives. Understanding how firms respond to climate change-induced disasters is vital in developing targeted policies and incentives. In particular, the study reveals that firms performing below their aspiration level are more inclined towards RE innovation. Policy-makers can leverage this insight to create policies that support these firms, thereby encouraging sustainable practices and technological advancements in RE. This approach could include incentives for research and development in renewable technologies or support for smaller firms striving to innovate in the face of environmental challenges. Developing such policies is crucial for fostering a sustainable and resilient business environment.

5.5. *Limitation and future work*

This study provides insights into how climate change-induced disasters affect RE innovation, but it has limitations that suggest directions for future research. A key limitation is the assumption that firms treat all stakeholders equally, without prioritizing specific groups. In practice, firms often prioritize stakeholders based on industry, lifecycle, and external pressures (Kolk and Pinkse, 2007). Future studies could examine how stakeholder prioritization influences firms' RE innovation decisions, enhancing understanding of stakeholder management's role in environmental strategies.

Moreover, while the role of governance and top leadership is acknowledged as significant in the pursuit of innovation, this study did not include governance-related controls in order to focus specifically on the direct effects of climate change-induced disasters. Future research could benefit from incorporating governance variables to explore how leadership and organizational structure influence the pursuit of RE innovation in response to environmental crises. Furthermore, as highlighted by Zaman et al. (2021), institutional investors and equity analysts play a crucial role in shaping firms' behavior, particularly in green-innovative firms.

Incorporating these variables in future studies could provide a more nuanced understanding of how external stakeholders, such as institutional investors, influence the pursuit of RE innovation and its financial outcomes.

Additionally, the study mainly focuses on the impacts of climate change-induced disasters on RE innovation. Future research could explore the broader spectrum of climate change impacts, including nature-driven, policy-driven, and market-driven effects (Zhou and Wen, 2020), offering a more holistic view of the challenges and opportunities for firms. Moreover, the geographic scope of this study is limited to U.S. firms, potentially overlooking the global variance in responses to climate disasters. Expanding the research to include firms from different regions could provide a more global perspective on RE innovation in the face of climate change. Furthermore, the study concentrates on publicly traded U.S. firms, excluding privately held firms that might have different responses to climate change (Mithani et al., 2021). Future research including privately held firms could yield a more comprehensive understanding of the business landscape's response to environmental challenges.

5.6. Conclusion

This study addresses a vital gap in understanding firms' strategic responses to environmental crises, especially in the context of climate change. By integrating the BTOF with the threat rigidity model, our study offers a unique perspective on firms' strategies amid environmental uncertainty and the need for sustainable innovation. The observed increase in RE innovation, particularly among firms below their aspiration levels, highlights the importance of adaptability and the potential for positive environmental impact, even under adversity. This underscores the necessity for businesses to continuously adapt and realign their strategies in response to environmental challenges. Ultimately, this research paves the way for a deeper understanding of the link between environmental crises and corporate innovation, contributing to discussions on sustainability and corporate environmental responsibility.

CRediT authorship contribution statement

Hiva Rastegar: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Writing – original draft. **Aymen Sajjad:** Writing – review & editing, Supervision. **Gabriel Eweje:** Resources, Validation, Writing – review & editing, Supervision. **Kazunori Kobayashi:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Founding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability

Data will be made available on request.

References

Agostino, M., 2024. Extreme weather events and firms' energy practices. The role of country governance. Energy Policy 192, 114235.
Agüero, J.M., 2021. COVID-19 and the rise of intimate partner violence. World Dev. 137, 105217.
Amore, M.D., Bennedsen, M., 2016. Corporate governance and green innovation. J. Environ. Econ. Manage 75, 54–72. https://doi.org/10.1016/j.jeem.2015.11.003.
Augustine, G., Soderstrom, S., Milner, D., Weber, K., 2019. Constructing a distant future: imaginaries in geoengineering. Acad. Manage. J. 62 (6), 1930–1960. https://doi.org/10.5465/amj.2018.0059.
Bae, J.W., Kim, S.J., 2022. How do active firms implementing corporate environmental responsibility take technological approaches to environmental issues? a resource-allocation perspective. Sustainability 14 (14). https://doi.org/10.3390/su14148606.
Bayer, P., Dolan, L., Urpelainen, J., 2013. Global patterns of renewable energy innovation, 1990–2009. Energy Sustainable Dev. 17 (3), 288–295. https://doi.org/10.1016/j.esd.2013.02.003.
Belasen, A.R., Polachek, S.W., 2009. How disasters affect local labor markets: the effects of hurricanes in Florida. J. Human Resour. 44 (1), 251–276.
Bettinazzi, E.L., Massa, L., Neumann, K., 2020. Sustainability as a competitive tool for the brave? Or for the best? A behavioral theory perspective. Organ. Environ. 33 (3), 408–436.
Bölük, G., Mert, M., 2014. Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: evidence from a panel of EU (European Union) countries. Energy 74, 439–446. https://doi.org/10.1016/j.energy.2014.07.008.
Boudreaux, C.J., Jha, A., Escaleras, M., 2022. Weathering the storm: how foreign aid and institutions affect entrepreneurship activity following natural disasters. Entrepreneurship Theory Pract. 46 (6), 1843–1868.
Bromiley, P., 1991. Testing a causal model of corporate risk taking and performance. Acad. Manage. J. 34 (1), 37–59. https://doi.org/10.2307/256301.
Bromiley, P., Harris, J.D., 2014. A comparison of alternative measures of organizational aspirations. Strateg. Manage J. 35 (3), 338–357. https://doi.org/10.2307/24037195.
Brunnermeier, S.B., Cohen, M.A., 2003. Determinants of environmental innovation in US manufacturing industries. J. Environ. Econ. Manage 45 (2), 278–293.
Callaway, B., Sant'Anna, P.H., 2021. Difference-in-differences with multiple time periods. J. Econom. 225 (2), 200–230.
Cameron, A.C., Trivedi, P.K., 2013. Regression Analysis of Count Data, 2nd ed. Cambridge University Press.
Cevik, S., Miryugin, F., 2023. Rogue waves: climate change and firm performance. Comp. Econ. Stud. 65 (1), 29–59.

Chen, W., Miller, K.D., 2007. Situational and institutional determinants of firms' R&d search intensity. Strateg. Manage J. 28 (4), 369–381. https://doi.org/10.2307/2014244610.1002/smj.594.

Chen, Z., Zhou, M., Ma, C., 2022. Anti-corruption and corporate environmental responsibility: evidence from China's anti-corruption campaign. Glob. Environ. Change 72. https://doi.org/10.1016/j.gloenvcha.2021.102449.

COP 28. (2023). Retrieved 06/01/2024 2024 from https://www.cop28.com/en/.

Costantini, V., Crespi, F., Palma, A., 2017. Characterizing the policy mix and its impact on eco-innovation: a patent analysis of energy-efficient technologies. Res. Policy. 46 (4), 799–819. https://doi.org/10.1016/j.respol.2017.02.004.

Cyert, R.M., March, J.G., 1963. A Behavioral Theory of the Firm. Prentice-Hall.

Dang, T.V., Xu, Z., 2018. Market sentiment and innovation activities. J. Financ. Quant. Anal. 53 (3), 1135–1161. https://doi.org/10.1017/S0022109018000078.

Das, T.K., Teng, B.S., 1999. Cognitive biases and strategic decision processes: an integrative perspective. J. Manage. Stud. 36 (6), 757–778.

Dean, C.B., 1992. Testing for overdispersion in Poisson and binomial regression models. J. Am. Stat. Assoc. 87 (418), 451–457.

Deb, P., & Norton, E.C. (2018). *Modeling health care expenditures and use* (Vol. 39). 10.1146/annurev-publhealth040617-013517.

Deeks, J.J., Altman, D.G., Bradburn, M.J., 2001. Statistical methods for examining heterogeneity and combining results from several studies in meta-analysis. Systematic Reviews in Health care: Meta-Analysis in Context. BMJ Publishing Group, pp. 285–315.

Deeks, J.J., Higgins, J.P., Altman, D.G., Cochrane Statistical Methods Group, 2019. Analysing data and undertaking meta-analyses. Cochrane Handbook for Systematic Reviews of Interventions, pp. 241–284.

Dickinson, V., 2011. Cash flow patterns as a proxy for firm life cycle. Account. Rev. 86 (6), 1969–1994. https://doi.org/10.2308/accr-10130.

Dimick, J.B., Ryan, A.M., 2014. Methods for evaluating changes in health care policy: the difference-in-differences approach. JAMA - J. Am. Med. Assoc. 312 (22). https://doi.org/10.1001/jama.2014.16153, 2401-2402-2402.

Dogan, E., Sebri, M., Turkekul, B., 2016. Exploring the relationship between agricultural electricity consumption and output: new evidence from Turkish regional data. Energy Policy 95, 370–377.

Donatti, C.I., Nicholas, K., Fedele, G., Delforge, D., Speybroeck, N., Moraga, P., Zvoleff, A., 2024. Global hotspots of climate-related disasters. Int. J. Disaster Risk Reduct. 108, 104488.

Dong, J.Q., Karhade, P.P., Rai, A., Xu, S.X., 2021. How firms make information technology investment decisions: toward a behavioral agency theory. J. Manage. Inf. Syst. 38 (1), 29–58.

Dunz, N., Naqvi, A., Monasterolo, I., 2021. Climate sentiments, transition risk, and financial stability in a stock-flow consistent model. J. Financ. Stabil. 54. https://doi.org/10.1016/j.jfs.2021.100872.

Energy Information Administration [EIA], 2023. Monthly Energy Review. December. U.S. Energy Information Administration, Washington, DC. Retrieved from. https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf.

Fabrizi, A., Guarini, G., Meliciani, V., 2018. Green patents, regulatory policies and research network policies. Res. Policy 47 (6), 1018–1031. https://doi.org/10.1016/j.respol.2018.03.005.

Faff, R., Kwok, W.C., Podolski, E.J., Wong, G., 2016. Do corporate policies follow a life-cycle? J. Bank. Financ. 69, 95–107.

Fiordelisi, F., Galloppo, G., Paimanova, V., 2023. Climate change shocks and socially responsible investments. Bus. Ethics, Environ. Responsib. 32 (1), 40–56.

Friedlingstein, P., Sullivan, M.O., Jones, M.W., Andrew, R.M., Hauck, J., Olsen, A., Zaehle, S., 2020. Global carbon budget 2020. Earth. Syst. Sci. Data 12, 3269–3340. https://doi.org/10.5194/essd-12-3269-2020.

Frijters, P., Johnston, D.W., Knott, R.J., Torgler, B., 2023. Resilience to disaster: evidence from American wellbeing data. Glob. Environ. Change 79. https://doi.org/10.1016/j.gloenvcha.2023.102639.

Gaba, V., Bhattacharya, S., 2012. Aspirations, innovation, and corporate venture capital: a behavioral perspective. Strat. Entrepreneurship J. 6 (2), 178–199. https://doi.org/10.1002/sej.1133.

George, G., 2005. Slack resources and the performance of privately held firms. Acad. Manage. J. 48 (4), 661–676. https://doi.org/10.5465/AMJ.2005.17843944.

Ghosh, S.K., Ghosh, B.K., 2020. Fossil fuel consumption trend and global warming scenario: energy overview. Glob. J. Eng. Sci. 5 (2), 1–6.

Graves, C., Shan, Y.G., 2014. An empirical analysis of the effect of internationalization on the performance of unlisted family and nonfamily firms in Australia. Fam. Bus. Rev. 27 (2). https://doi.org/10.1177/0894486513491588, 142-160-160.

Greer, C.R., Bruton, G.D., Zachary, M.A., 2022. Patent productivity: strategic human resources and the attention-based view. Int. J. Human Resour. Manage. https://doi.org/10.1080/09585192.2022.2055970.

Greve, H.R., 2003. A behavioral theory of R&D expenditures and innovations: evidence from shipbuilding. Acad. Manage. J. 46 (6), 685–702. https://doi.org/10.5465/30040661.

Habib, A., Hasan, M.M., 2017. Firm life cycle, corporate risk-taking and investor sentiment. Account. Finance 57 (2), 465–497. https://doi.org/10.1111/acfi.12141.

Han, S., 2022. The effect of performance feedback on strategic alliance formation and R&D intensity. Eur. Manage. J. https://doi.org/10.1016/j.emj.2022.03.010.

Hausker, K., Meek, K.R.I.S.T.I.N., Gasper, R., Aden, N., Obeiter, M., 2015. Delivering on the US Climate Commitment: A 10-Point Plan Toward a Low-Carbon Future. World Resources Institute. *May*.

Hoskisson, R.E., Zyung, J., Gambeta, E., Chirico, F., 2017. Managerial risk taking: a multitheoretical review and future research agenda. J. Manage 43 (1), 137–169. https://doi.org/10.1177/0149206316671583.

Howard-Grenville, J., Buckle, S., J., Hoskins, B., J., George, G, 2014. Climate change and management. Acad. Manage. J. 57 (3), 615–623.

Huang, H.H., Kerstein, J., Wang, C., 2018. The impact of climate risk on firm performance and financing choices: an international comparison. J. Int. Bus. Stud. 49 (5), 633–656.

Hussain, S., Nguyen, V.C., Nguyen, H.T., Nguyen, Q.M., Nguyen, T.T., 2021. Macroeconomic factors, working capital management, and firm performance—a static and dynamic panel analysis. Human. Soc. Sci. Commun. 8 (1). https://doi.org/10.1057/s41599-021-00778-x.

Imas, A., 2016. The realization effect: risk-taking after realized versus paper losses. Am. Econ. Rev. 106 (8), 2086–2109.

International Energy Agency [IEA]. (2023). *World energy balances* [data set]. IEA. Retrieved from https://www.iea.org/data-and-statistics/data-product/world-energy-balances#documentation.

IRENA and CPI, 2023. Global Landscape of Renewable Energy Finance 2023. International Renewable Energy Agency, Abu Dhabi.

Johnstone, N., Haščič, I., Popp, D., 2010. Renewable energy policies and technological innovation: evidence based on patent counts. Environ. Resour. Econ.: Off. J. Eur. Assoc. Environ. Resour. Econ. 45 (1), 133–155. https://doi.org/10.1007/s10640-009-9309-1.

Kacperczyk, A., 2009. With greater power comes greater responsibility? takeover protection and corporate attention to stakeholders. In: Strategic Management Journal, 30. John Wiley & Sons, Inc, pp. 261–285. https://doi.org/10.1002/smj.733.

Kim, J., Park, K., 2016. Financial development and deployment of renewable energy technologies. Energy Econ. 59, 238–250. https://doi.org/10.1016/j.eneco.2016.08.012.

Kolk, A., Pinkse, J., 2007. Towards strategic stakeholder management? Integrating perspectives on sustainability challenges such as corporate responses to climate change. Corporate Govern.: Int. J. Bus. Soc. 7 (4), 370–378. https://doi.org/10.1108/14720700710820452.

Krueger, P., Sautner, Z., Starks, L.T., 2020. The importance of climate risks for institutional investors. Rev. Financ. Stud. 33 (3), 1067–1111. https://doi.org/10.1093/rfs/hhz137.

Kunapatarawong, R., Martínez-Ros, E., 2016. Towards green growth: how does green innovation affect employment? Res. Policy 45 (6), 1218–1232. https://doi.org/10.1016/j.respol.2016.03.013.

Lant, T., Shapira, Z., 2008. Managerial reasoning about aspirations and expectations. J. Econ. Behav. Organ. 66 (1), 60–73. https://doi.org/10.1016/j.jebo.2007.03.006.

Lerner, J., Seru, A., 2022. The use and misuse of patent data: issues for finance and beyond. Rev. Financ. Stud. 35 (6), 2667–2704.

Leyva-de la Hiz, D.I., Ferron-Vilchez, V., Aragon-Correa, J.A., 2019. Do firms' slack resources influence the relationship between focused environmental innovations and financial performance? More is not always better. J. Bus. Ethics 159 (4), 1215–1227.

Li, S., Daud Ishola, B., Abbas, S., Subhan, M., Abduvaxitovna Shamansurova, Z., 2023. Building resilience in the face of natural disasters: ICT, fossil fuel use, and sustainable development in an emerging economy. Gondwana Res. 124, 273–289. https://doi.org/10.1016/j.gr.2023.06.018.

Liang, J., Fiorino, D.J., 2013. The implications of policy stability for renewable energy innovation in the United States, 1974–2009. Policy Stud. J. 41 (1), 97–118.

Lin, B., Zhu, J., 2019. Determinants of renewable energy technological innovation in China under CO2 emissions constraint. J. Environ. Manage. 247, 662–671. https://doi.org/10.1016/j.jenvman.2019.06.121.

Lindman, Å., Söderholm, P., 2016. Wind energy and green economy in Europe: measuring policy-induced innovation using patent data. Appl. Energy 179, 1351–1359. https://doi.org/10.1016/j.apenergy.2015.10.128.

Ma, Y., Feng, G.F., Chang, C.P., 2024. From traditional innovation to green innovation: how an occurrence of natural disasters influences sustainable development? Sustainable Dev. 32 (3), 2779–2796.

Majeed, M.T., Ozturk, I., 2020. Environmental degradation and population health outcomes: a global panel data analysis. Environ. Sci. Pollut. Res. 27 (13), 15901–15911. https://doi.org/10.1007/s11356-020-08167-8.

Marshall, B.R., Nguyen, H.T., Nguyen, N.H., Visaltanachoti, N., Young, M., 2021. Do climate risks matter for green investment? J. Int. Financ. Markets, Inst. Money 75. https://doi.org/10.1016/j.intfin.2021.101438.

Meyer, B.D., 1995. Natural and quasi-experiments in economics. J. Bus. Econ. Stat. 13 (2), 151–161. https://doi.org/10.2307/1392369.

Mithani, M.A., 2017. Liability of foreignness, natural disasters, and corporate philanthropy. J. Int. Bus. Stud. 48 (8), 941–963.

Mithani, M.A., Gopalakrishnan, S., Santoro, M.D., 2021. Does exposure to a traumatic event make organizations resilient? Long. Range Plann. 54 (3). https://doi.org/10.1016/j.lrp.2020.102031.

Monasterolo, I., 2020. Climate change and the financial system. Annu Rev. Resour. Economics. 12, 299–320. https://doi.org/10.1146/annurev-resource-110119-031134.

Murillo-Sandoval, P.J., Gjerdseth, E., Correa-Ayram, C., Wrathall, D., Van Den Hoek, J., Dávalos, L.M., Kennedy, R., 2021. No peace for the forest: rapid, widespread land changes in the Andes-Amazon region following the Colombian civil war. Glob. Environ. Change 69. https://doi.org/10.1016/j.gloenvcha.2021.102283.

Nesta, L., Vona, F., Nicolli, F., 2014. Environmental policies, competition and innovation in renewable energy. J. Environ. Econ. Manage 67 (3), 396–411. https://doi.org/10.1016/j.jeem.2014.01.001.

Noailly, J., Smeets, R., 2015. Directing technical change from fossil-fuel to renewable energy innovation: an application using firm-level patent data. J. Environ. Econ. Manage 72, 15–37. https://doi.org/10.1016/j.jeem.2015.03.004.

Oetzel, J., Oh, C.H., 2014. Learning to carry the cat by the tail: firm experience, disasters, and multinational subsidiary entry and expansion. Organ. Sci. 25 (3), 732–756.

Oetzel, J., Oh, C.H., 2021. A storm is brewing: antecedents of disaster preparation in risk prone locations. Strat. Manage. J. 42 (8), 1545–1570. https://doi.org/10.1002/smj.3272.

Osberghaus, D., 2017. The effect of flood experience on household mitigation—evidence from longitudinal and insurance data. Glob. Environ. Change 43, 126–136. https://doi.org/10.1016/j.gloenvcha.2017.02.003.

Perruchas, F., Consoli, D., Barbieri, N., 2020. Specialisation, diversification and the ladder of green technology development. Res. Policy 49 (3). https://doi.org/10.1016/j.respol.2020.103922.

Porto de Albuquerque, J., Cattino, M., Clarke, A., Pajarito Grajales, D., Klonner, C., Rizwan, M., Martins, M.H.D.M., 2023. Dialogic data innovations for sustainability transformations and flood resilience: the case for waterproofing data. Glob. Environ. Change 82. https://doi.org/10.1016/j.gloenvcha.2023.102730.

Raynard, M., Lu, F., Jing, R., 2020. Reinventing the state-owned enterprise? negotiating change during profound environmental upheaval. Acad. Manage. J. 63 (4), 1300–1335. https://doi.org/10.5465/amj.2017.1162.

Ren, X., Li, Y., Shahbaz, M., Dong, K., Lu, Z., 2022. Climate risk and corporate environmental performance: empirical evidence from China. Sustain. Prod. Consum. 30, 467–477. https://doi.org/10.1016/j.spc.2021.12.023.

Roper, S., Tapinos, E., 2016. Taking risks in the face of uncertainty: an exploratory analysis of green innovation. Technol. Forecast. Soc. Change 112, 357–363. https://doi.org/10.1016/j.techfore.2016.07.037.

Rosselló, J., Becken, S., Santana-Gallego, M., 2020. The effects of natural disasters on international tourism: a global analysis. Tour. Manage 79, 104080.

Shan, Y.G., Troshani, I., 2014. Does XBRL benefit financial statement auditing? J. Comput. Inf. Syst. 54 (4). https://doi.org/10.1080/08874417.2014.11645718, 11-21-21.

Shin, H., Ellinger, A.E., Nolan, H.H., DeCoster, T.D., Lane, F., 2018. An assessment of the association between renewable energy utilization and firm financial performance. J. Bus. Ethics 151 (4), 1121–1138. https://doi.org/10.2307/45022718.

Shinkle, G.A., 2012. Organizational aspirations, reference points, and goals: building on the past and aiming for the future. J. Manage 38 (1), 415–455. https://doi.org/10.1177/0149206311419856.

Sinha, A., Tiwari, S., Saha, T., 2024. Modeling the behavior of renewable energy market: understanding the moderation of climate risk factors. Energy Econ. 130, 107290.

Smirnova, O., Strumsky, D., Qualls, A.C., 2021. Do federal regulations beget innovation? Legislative policy and the role of executive orders. Energy Policy 158. https://doi.org/10.1016/j.enpol.2021.112570.

Smulowitz, S.J., Rousseau, H.E., Bromiley, P., 2020. The behavioral theory of the (community-oriented) firm: the differing response of community-oriented firms to performance relative to aspirations. Strat. Manage. J. 41 (6), 1023–1053. https://doi.org/10.1002/smj.3123.

Sodhi, M.S., 2016. Natural disasters, the economy and population vulnerability as a vicious cycle with exogenous hazards. J. Oper. Manage. 45, 101–113. https://doi.org/10.1016/j.jom.2016.05.010.

Staw, B.M., Sandelands, L.E., Dutton, J.E., 1981. Threat rigidity effects in organizational behavior: a multilevel analysis. Adm. Sci. Q. 26 (4), 501–524.

Steffen, B., 2020. Estimating the cost of capital for renewable energy projects. Energy Econ. 88. https://doi.org/10.1016/j.eneco.2020.104783.

Symeou, P.C., Zyglidopoulos, S., Gardberg, N.A., 2019. Corporate environmental performance: revisiting the role of organizational slack. J. Bus. Res. 96, 169–182. https://doi.org/10.1016/j.jbusres.2018.11.019.

Tilcsik, A., & Marquis, C. (2013). Punctuated generosity: how mega-events and natural disasters affect corporate philanthropy in U.S. communities. *Adm. Sci. Q.*, 58 (1), 111–148. 10.1177/0001839213475800.

Truong, C., Trück, S., Mathew, S., 2018. Managing risks from climate impacted hazards – The value of investment flexibility under uncertainty. Eur. J. Oper. Res. 269 (1), 132–145. https://doi.org/10.1016/j.ejor.2017.07.012.

Un, C.A., 2016. The liability of localness in innovation. J. Int. Bus. Stud. 47 (1), 44–67.

United States Patent and Trademark Office [USPTO]. (2024). Patent application data. Retrieved from https://www.uspto.gov/.

Wagner, M., 2011. Corporate performance implications of extended stakeholder management: new insights on mediation and moderation effects. Ecol. Econ. 70 (5), 942–950. https://doi.org/10.1016/j.ecolecon.2010.12.010.

Wiklund, J., Baker, T., Shepherd, D., 2010. The age-effect of financial indicators as buffers against the liability of newness. J. Bus. Ventur. 25 (4), 423–437. https://doi.org/10.1016/j.jbusvent.2008.10.011.

WIPO. (2023). *Global Innovation Index 2023 innovation in the face of uncertainty*. Retrieved from https://www.wipo.int/global_innovation_index/en/2023.

Wooldridge, J.M., 1999. Distribution-free estimation of some nonlinear panel data models. J. Econom. 90 (1), 77–97.

Xu, B., Lin, B., 2018. Assessing the development of China's new energy industry. Energy Econ. 70, 116–131. https://doi.org/10.1016/j.eneco.2018.01.001.

Xu, D., Zhou, K.Z., Du, F., 2019. Deviant versus aspirational risk taking: the effects of performance feedback on bribery expenditure and r&d intensity. Acad. Manage. J. 62 (4), 1226–1251. https://doi.org/10.5465/amj.2016.0749.

Yang, J., Chen, X., 2024. Financial performance feedback, institutional ownership and green innovation: evidence from China. Chinese Manage. Stud. 18 (2), 526–549.

Yang, N., Zhang, Y., Yu, L., Wang, J., Liu, X., 2022. Cross-border mergers and acquisitions, regional cultural diversity and acquirers' corporate social responsibility: evidence from China Listed companies. Int. Rev. Econ. Finance 79, 565–578. https://doi.org/10.1016/j.iref.2022.02.041.

Yu, Y., Zhang, N., 2022. Environmental regulation and innovation: evidence from China. Glob. Environ. Change 76. https://doi.org/10.1016/j.gloenvcha.2022.102587.

Zaman, R., Atawnah, N., Haseeb, M., Nadeem, M., Irfan, S., 2021. Does corporate eco-innovation affect stock price crash risk? Br. Account. Rev. 53 (5), 101031.

Zhou, P., Wen, W., 2020. Carbon-constrained firm decisions: from business strategies to operations modeling. Eur. J. Oper. Res. 281 (1), 1–15. https://doi.org/10.1016/j.ejor.2019.02.050.