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Assessing the Moderating Effect of ESG Investment on Climate Variability Risk and Firm Value Nexus

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Abstract

Purpose: This study investigates how climate variability risk (CVR) influences the firm value (EW) and examines the moderating role of environmental, social, and governance (ESG) investment in mitigating the impact. The objective is to examine whether firms with stronger ESG engagement demonstrate greater resilience to climate-induced uncertainties.

Design: A panel dataset of 1,720 U.S.-listed firms covering the period from 2005 to 2020 is utilized. Both Feasible Generalized Least Squares (FGLS) and Generalized Method of Moments (GMM) techniques are employed to examine heteroscedasticity, endogeneity, and dynamic relationships between the variables.

Findings: Our empirical analysis reveals a significant and negative association between CVR and EW, suggesting that heightened climate uncertainty reduces corporate valuation. In contrast, ESG investment exhibits a positive and significant relationship with EW, underscoring its contribution to sustainable value creation. Furthermore, ESG investment moderates the CVR–EW linkage by diminishing the adverse impact of climate variability risk on firm value.

Research Limitations: The analysis is confined to the U.S.-listed firms, which may limit the applicability of the findings to contexts characterized by different environmental and regulatory structures. Future studies could expand this scope through cross-country comparisons or sector-specific analyses.

Practical Implications: The results underscore the importance for corporate managers, investors, and policymakers to reinforce ESG-driven strategies, as such investments can buffer firms against climate-related risks and support long-term value enhancement.

Originality/Value: This study uniquely incorporates ESG investment as a moderating mechanism within the CVR–EW nexus, offering novel insights into how sustainability-oriented strategies transform climate risk into value-enhancing opportunities in corporate finance.

The findings contribute to the Decision Sciences literature by demonstrating how ESG-based decision frameworks can improve corporate resilience and strategic responses to climate uncertainty, thereby supporting more informed, risk-aware corporate policies.

Keywords: Climate Risk, ESG Investment, Firm Value, GMM; FGLS

JEL Classifications : G32, Q54, M14, Q56

1 Introduction

The uncertainty surrounding climate patterns has emerged as a critical global concern, influencing individuals and multinational corporations across the international arena (Adegbite et al., 2019; Al-Qudah et al., 2022). Severe climatic occurrences including storms, floods, and escalating sea levels, pose substantial threats to businesses by damaging physical assets, disrupting supply chains, and diminishing overall demand and productivity (Alessandri et al., 2012). As economies transition toward a low-carbon model, many firms are facing financial instability, requiring substantial adjustments in regulatory frameworks, market practices, and technological innovation to effectively mitigate climate-related disruptions (Al Ahbabi & Nobanee, 2019). Moreover, empirical evidence reveals a significant association between political instability and climate variability, suggesting that climate-related risks can influence both the operational resilience and strategic decision-making of firms (Anderson & Garcia-Feijoo, 2006; Aouadi & Marsat, 2018). This vague liaison between environmental, political, and economic dimensions underscores the multifaceted nature of climate variability risk (CVR). Consequently, scholars, policymakers, and industry practitioners have increasingly directed their attention toward understanding CVR, recognizing its profound implications for sustainable business performance, financial stability, and long-term economic resilience in a rapidly changing global environment.

Global climatic instability increasingly exposes the U.S. economy to both human and financial risks, thereby threatening societal well-being and business continuity (Arellano & Bond, 1991). Furthermore, accounts of vineyard destruction and dam breaches appearing in phys.org, The Boston Globe, The Kathmandu Post, and Forbes confirm the urgency of addressing climate-induced vulnerability. Despite persistent skepticism, the undeniable urgency of addressing climate variability has become increasingly evident, influencing strategic and operational decisions among both domestic and international enterprises (Adegbite et al., 2019; Aerts et al., 2008). Scientific assessments indicate that the U.S. GDP could decline by nearly 10% if global warming remains unaddressed. The World Economic Forum further recognizes extreme weather events as among the most severe threats to global business operations, estimating that climate-related risks could cost approximately one trillion U.S. dollars, half of which may materialize within the next five years (Bansal & Song, 2017). In response, the United States has committed to investing $1.7 trillion over the next decade to mitigate climate variability and reduce greenhouse gas emissions by half by 2030. Similarly, the European Green Deal introduced by the European Commission aims to achieve a pollution-free economy across EU nations by 2050 (Boulhaga et al., 2023). As corporations increasingly confront climate-related risks, they must also bear the financial and regulatory costs of adopting new technologies and ensuring compliance with environmental standards (Broadstock et al., 2021). Consequently, the growing emphasis on sustainability among stakeholders has intensified scholarly attention toward understanding how climate variability hazards influence investment strategies, pricing behavior, and risk management practices (Adegbite et al., 2019; Awaysheh et al., 2020; Camilleri, 2018).

Scholars have probed how CVR ripples through the economy, showing that it weakens corporate outcomes, increases financial policy uncertainty, and can restrain overall growth (Boulhaga et al., 2023; Camilleri, 2018). Expanding on these macro-level findings, firm-level studies have explored how CVR influences corporate leverage, information efficiency, and financing strategies, as well as how it interacts with political and institutional instability (Cormier & Magnan, 2007). In addition, prior research has examined whether corporate social responsibility (CSR) initiatives can act as a buffer against climate-induced risks, such as declines in stock returns, litigation exposure, and overall firm vulnerability to environmental disruptions (Anderson & Garcia-Feijoo, 2006; Aouadi & Marsat, 2018; Elsayed & Paton, 2005; Estrada et al., 2010). These studies collectively highlight the growing relevance of sustainability-oriented strategies in mitigating climate-related risks. However, despite substantial progress, the direct and systematic link between CVR and firm value (EW) remains insufficiently explored, particularly in the context of U.S.-listed corporations. Therefore, this study aims to bridge this gap by empirically examining how climate variability risk affects EW, offering a more comprehensive understanding of how environmental uncertainty translates into corporate financial performance and long-term value creation.

While extensive research has examined the wider implications of climate variability risk (CVR) for firm performance, financial exposure, and strategic decision-making, several conceptual and empirical voids still persist. Previous studies have predominantly analyzed CSR and ESG activities as standalone drivers of financial outcomes or as instruments for mitigating business risks (Aouadi & Marsat, 2018; Camilleri, 2018). However, limited attention has been given to understanding how ESG investment can function as a moderating channel between CVR and EW. This lack of exploration restricts insights into how firms strategically employ ESG initiatives to offset the adverse financial repercussions of environmental uncertainty. Moreover, much of the existing literature focuses on cross-country or global perspectives, with insufficient emphasis on the U.S. context, where climate variability presents distinctive economic, regulatory, and strategic challenges. To bridge these gaps, the present study investigates the moderating mechanism of investments regarding ESG in the CVR–EW nexus among U.S.-listed firms. Drawing upon real options theory, the resource-based view, and institutional theory, this research develops an integrative framework that elucidates how firms harness ESG investments to strengthen resilience, maintain competitiveness, and foster long-term value creation amid escalating climate-related volatility. In doing so, it advances both theoretical understanding and practical insights beyond the conventional CSR-focused discourse.

ESG programs generally receive positive reception from investors, and yet scholarly debate persists over whether this reception reflects real value creation or temporary market sentiments (Fafaliou et al., 2022). The growing societal demand for corporate sustainability, driven by regulatory pressures, the UN SDGs, and global initiatives such as the Paris Agreement, has intensified this debate. While some scholars report a positive or nonlinear relationship between ESG investments and EW (Figge, 2005; Flammer, 2015; Ortiz Almeyda & Velasco González, 2021), others find weak or even negative financial outcomes (Galbreath, 2010; Garcia-Castro et al., 2010). We argue that ESG investments, unlike conventional CSR approaches, offer a more comprehensive mechanism for addressing long-term performance and risk mitigation (Gillan et al., 2021; Godfrey, 2005). Through better governance, streamlined finances, and technology-driven solutions, ESG initiatives can shrink both direct and indirect costs stemming from climate variability, and they can also make firms more attractive to investors; we therefore explore how such investments change the impact of CVR on EW in the context of the U.S. As the world's largest economy in terms of nominal GDP, the US plays a crucial role in achieving global growth, stability, and environmental sustainability by curbing pollution and greenhouse gas emissions.

Motivated by the growing financial relevance of climate variability, this study seeks to clarify how climate-related uncertainty translates into firm value erosion and whether ESG investment can serve as a strategic buffer. While prior research documents the pricing of climate risks, little is known about the mechanisms through which firms build resilience against such shocks. By integrating ESG investment into the climate risk valuation framework, this study advances academic understanding of sustainability-driven value creation. This study centers on three main lines of inquiry: the link between climate variability risk (CVR) and EW, the effect of ESG investment on EW, and whether ESG alters how CVR influences EW. We assemble a comprehensive sample of 1,720 US-listed companies with annual data from 2005 to 2020, and Feasible Generalized Least Squares (FGLS) and Generalized Method of Moments (GMM) techniques are employed to produce consistent and robust inferences. Our findings reveal that CVR negatively affects EW due to increased uncertainty and potential financial losses associated with climate-related hazards. Conversely, ESG investments positively influence EW by fostering proactive risk management, enhancing corporate reputation, and improving access to sustainable capital. Furthermore, ESG investments strengthen the liaison between CVR and EW, suggesting that firms with higher ESG engagement are better equipped to mitigate climate-related risks and capitalize on sustainability opportunities. We further validate these results through extensive sensitivity and robustness checks, including the decomposition of CVR into physical, regulatory, and opportunity risks, alongside consideration of ESG dimensions associated with CVR. These comprehensive analyses reinforce the reliability and credibility of our conclusions.

This study advances meaningfully to the sustainability and finance literature. First, it empirically examines the effect of climate variability risk (CVR) on firm value (EW) in the United States, thereby filling a significant gap in previous studies that largely analyzed aggregate CO_2 emissions and used generalized measures of firm performance. Second, it explores the impact of ESG investments on EW, offering a more comprehensive and forward-looking perspective that transcends the boundaries of conventional CSR frameworks and integrates ESG dimensions into financial analysis. Third, by integrating ESG investments into the analytical framework and demonstrating their moderating mechanism in the CVR–EW relationship, the study presents a novel and comprehensive perspective on sustainable risk management. Fourth, it advances prior research constrained by accounting-based performance indicators by employing growth option value, derived from an option-based approach, and the Tobin Q model as proxies for EW, thereby enriching the methodological rigor and theoretical depth of corporate finance research. Additionally, statistical challenges are addressed through the use of Feasible Generalized Least Squares (FGLS) and Generalized Method of Moments (GMM) methods, enhancing the robustness of the findings. Taken together, these contributions highlight the study's originality in bridging the fields of sustainability, finance, and risk management by demonstrating how ESG investments transform climate-related risks into value-creating opportunities. Practically, the findings inform managers and investors on how ESG engagement can function not only as compliance, but as a financially material risk-management tool in an era of intensifying climate uncertainty.

The study is highly relevant to Decision Sciences as it provides an analytical framework that supports data-driven decision-making under climate uncertainty, enabling managers and policymakers to design optimal ESG investment strategies that enhance firm value and resilience. It highlights that strategic ESG investments can serve as a valuable enabler, helping firms to mitigate climate-related risks, enhance financial performance, and align with long-term sustainability goals.

2 Theoretical Framework

Real Options Theory, originally introduced by Myers (1977), extends traditional investment decision-making by emphasizing managerial flexibility in responding to uncertainty. It suggests that firms can treat strategic decisions, including sustainability investments, as "options" that provide the right, but not the obligation, to act when future conditions become more favorable. In the context of this study, real options theory supports the argument that ESG investments enable firms to manage the uncertainty posed by climate variability risk. By viewing ESG initiatives as strategic options, firms can mitigate potential losses and capitalize on emerging opportunities related to sustainability transitions. The findings confirm this theoretical premise, as ESG investment significantly moderates the negative effect of climate variability risk on EW. This alignment indicates that firms adopting flexible, sustainability-oriented strategies not only buffer themselves against environmental volatility but also enhance long-term EW through proactive and adaptive decision-making.

The Resource-Based View (RBV), first introduced by Barney (1991), posits that firms gain a sustainable competitive advantage through the development and effective utilization of valuable, rare, inimitable, and non-substitutable (VRIN) resources. From this perspective, ESG investments represent strategic resources that foster reputation, innovation, and stakeholder trust, all of which contribute to superior firm performance. In this study, the positive influence of ESG investment on EW supports RBV's central claim that internal capabilities and intangible assets drive long-term value creation. ESG initiatives enhance operational efficiency, attract green capital, and strengthen stakeholder relations, thus becoming a unique resource that differentiates firms in competitive markets. Furthermore, by integrating ESG principles, firms improve resilience to climate-related risks and regulatory pressures, transforming sustainability practices into a core strategic asset. Therefore, the study's findings affirm RBV by demonstrating that ESG-driven capabilities translate environmental responsibility into measurable financial and competitive advantages.

Institutional Theory, introduced by Meyer and Rowan (1977), explains how organizational behaviors are shaped by external institutional pressures, including regulations, societal expectations, and cultural norms. It posits that firms align their strategies with institutional demands to gain legitimacy and ensure long-term survival. This study's findings align with institutional theory by showing that firms respond to climate variability risk and stakeholder expectations through enhanced ESG engagement. In the U.S.

context, where regulatory frameworks and investor scrutiny around climate and sustainability are intensifying, ESG investment functions as a strategic response to institutional pressures. The positive moderating mechanism of ESG in the CVR–EW relationship demonstrates how compliance with institutional norms not only fulfills external legitimacy requirements but also generates tangible economic benefits. Thus, the findings support the notion that adherence to institutional expectations, through transparent ESG practices, strengthens a firm’s legitimacy, resilience, and value in an increasingly sustainability-driven market environment (Yadav et al., 2025).

3 Literature Review and Hypotheses Development

Research on corporate environmental responsibility has expanded markedly, with many studies focusing on how CVR affects EW (Boulhaga et al., 2023; Cohen, 2023; Godfrey et al., 2009; Hart & Milstein, 2003). Because the IPCC attributes climate change chiefly to human activity, companies are under increased pressure to reduce emissions and plan for climate variability (Cui et al., 2023; Hartzmark & Sussman, 2019; Hausman, 2015). Empirical findings indicate that climate risks alter firms' information efficiency and leverage, and that outcomes improve under rigorous environmental regulation (Cormier & Magnan, 2007). Climate risk is also tied to higher financial policy volatility (Cohen, 2023). U.S. firm-year studies (2002 to 2018) suggest CSR helps to cushion climate impacts, and these results have been validated through multiple econometric strategies (Aksom & Tymchenko, 2020). Meanwhile, firms appear to manage ESG disclosures after natural disasters to sway investors (He et al., 2023). Additionally, investigations into the link between climate risk news and bond returns report mixed and varied outcomes (Jia & Li, 2020).

Drawing on 2012-2021 U.S. firm-level data, Khan et al. (2022) show that CVR erodes EW; moreover, energy sector research similarly ties higher CVR to lower market capitalization, even as dividend yield appears positively associated with EW (Khan et al., 2016). Despite these insights, the relationship between CVR and EW remains largely underexplored, emphasizing the need for further investigation. To address this gap, our study employs a novel CVR metric developed by Aerts et al. (2008), which captures a firm’s exposure to climate-related opportunities, environmental impacts, and regulatory challenges. Moreover, as indicated in prior research, most studies have focused on traditional performance measures such as ROE and ROA, which are constrained by accounting limitations (Kim et al., 2018). This study gauges corporate value with two metrics. As the initial measure in a dual-metric strategy, Tobin’s Q is used because it signals expected investment opportunities (Fafaliou et al., 2022; Kim et al., 2021), and under the real options approach, it reflects both the firm's current business value and the additional value attributable to growth (De Andrés-Alonso et al., 2006; Fafaliou et al., 2022; Klingebiel, 2012; Koller et al., 2019). Naseer et al. (2025) suggest that exposure to climate risk significantly reduces firm market value, with the intensity of this relationship varying across regions and policy environments (e.g., Stern Review, Paris Agreement). Yang et al. (2025) show that firms with credible climate risk disclosures experience higher future valuations, as such transparency reduces information asymmetry and strengthens corporate reputation. Findings of Han et al. (2025) from China demonstrate that enhanced climate risk disclosure not only promotes green innovation but also contributes positively to enterprise value, particularly among financially constrained firms.

ESG investment tends to raise EW, especially among firms with limited financial flexibility. Sustainable finance, therefore, integrates ESG into corporate strategy, and investors who emphasize social responsibility evaluate firms on ESG grounds to infer long-term growth prospects (Khan et al., 2022; Kong et al., 2022; Li et al., 2018). Environmentally, this means assessing emissions, energy use, renewables, pollution control, GHGs, fossil-fuel reliance, and biodiversity; governance covers risk systems, board diversity, governance mechanisms, disclosure compliance, audits, management design, and transparency (Kong et al., 2022; Liang & Renneboog, 2017). Meanwhile, the governance aspect covers a wide array of activities, including risk management practices, board diversity, corporate governance procedures, compliance with disclosure regulations, audit practices, management structure, and transparency (Lins et al., 2017; Magrizos et al., 2021). As such, sustainable finance provides a comprehensive basis for judging firms' enduring financial and social performance. Investor sentiment toward ESG is frequently positive, yet academic consensus is lacking on its effect on firm value (EW) (Fafaliou et al., 2022). Empirical studies range from findings of enhanced value (Figge, 2005; Flammer, 2015), to evidence of nonlinear associations (Ortiz Almeyda & Velasco González, 2021), null results (Galbreath, 2010), and reported underperformance (Garcia-Castro et al., 2010). The growth option value (GOV) notion in recent financial economics work (Magrizos et al., 2021; Mohieldin et al., 2022) conceives firm worth as current assets plus the anticipated value of future growth; real-options theory builds on this and thus emphasizes strategic flexibility and timing for ESG initiatives (Myers, 1977).

Real-options notion assists enterprises to navigate ESG uncertainty and to make resilient choices (Adegbite et al., 2019), and recent work highlights how ESG practices reinforce core operations (Naseer et al., 2024). Still, the impact of ESG on growth-option value has received limited attention despite its strategic importance (Kim et al., 2018), and empirical studies of ESG/CSR effects on financial performance produce mixed results (Ozkan et al., 2023). We therefore use Refinitiv ESG Scores, which draw on sources such as MSCI and Bloomberg, to assess corporate ESG, since these consolidated ratings aid stakeholders in sustainability decision-making (Rahi et al., 2021). Because ESG investments can influence long-term prospects, we posit that they affect EW and thus state our second hypothesis. Evidence also indicates ESG can mitigate firm-level risk (Aksom & Tymchenko, 2020; Boulhaga et al., 2023; Gillan et al., 2021), and in contrast to narrower CSR efforts, ESG provides an integrated route to reduce climate-related risks and boost value via innovation, efficiencies, reputation, risk oversight, capital access, and strategic alignment.

Framed by institutional, stakeholder, and resource-based perspectives (Richardson & Welker, 2001), this paper examines how ESG investments and CVR jointly shape EW. Institutional theory explains pressures to conform to environmental rules and societal expectations (Schuler & Cording, 2006), whereas the resource-based view emphasizes adaptation to sustain competitive advantage (Shahzad et al., 2023; Shiu & Yang, 2017). Stakeholder theory suggests that firms that manage relationships with climate-aware stakeholders can enhance value (Luo & Liao, 2023). Building on evidence that CVR tends to depress EW

(Boulhaga et al., 2023; Godfrey et al., 2009; Hausman, 2015), we use an original CVR indicator (Aerts et al., 2008) and measure value via Tobin's Q and growth-option value. Because the literature yields mixed findings on ESG and valuation (Fafaliou et al., 2022; Figge, 2005; Lins et al., 2017), and since CSR-like investments can function as a buffer against firm-specific risks, we investigate whether ESG offers a comprehensive mitigation approach that can weaken CVR's negative effects and support sustained profitability (Aksom & Tymchenko, 2020; Teng et al., 2021). This theoretically grounded hypothesis serves as the foundation for the remainder of the study, as illustrated in Figure 1.

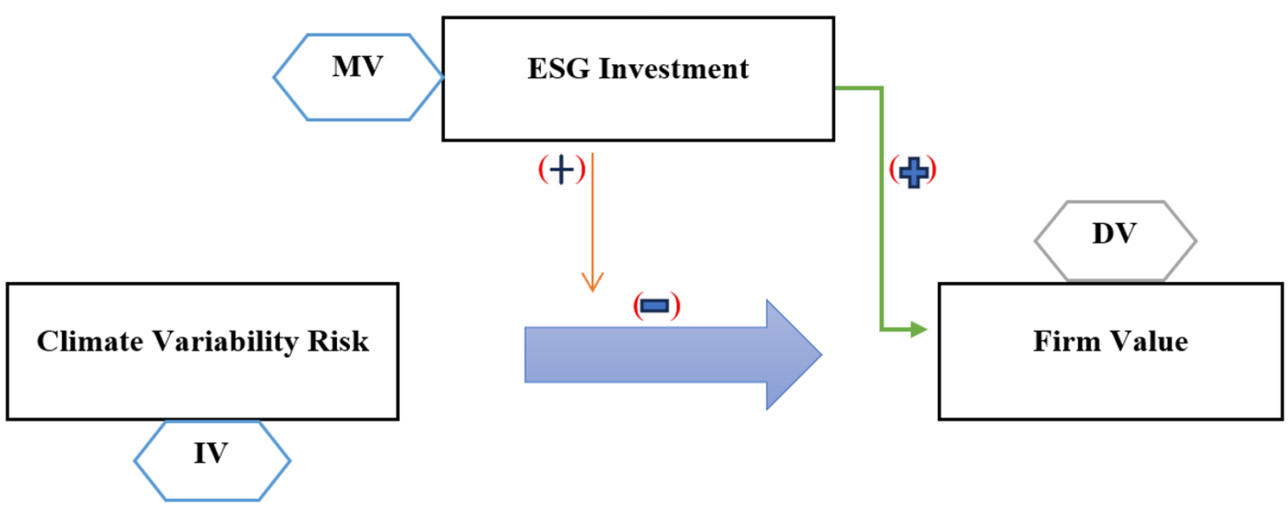
Despite growing attention to environmental and sustainability issues, limited research has jointly examined how climate variability risk and ESG investment interact to influence EW, particularly in the U.S. context. Most prior studies have explored these factors independently or focused on broader measures of corporate performance, leaving a gap in understanding their combined effect on EW. This study fills this gap by investigating the interaction role of ESG investment in the liaison between CVR and EW, providing fresh understandings into how sustainable practices can strengthen corporate resilience to environmental uncertainty. Based on this research gap and the above-mentioned studies, we may hypothesize that

H1: Climate variability risk exerts a significant adverse influence on EW.

H2: ESG investment significantly and positively enhances enterprise valuation.

H3: ESG investment attenuates and reverses the negative effect of climate variability risk on EW.

Figure 1. Conceptual Framework



Note: Figure 1 depicts the conceptual model, highlighting the connections between the independent variable (IV), the dependent variable (DV), and the moderating variable (MV), and showing how they interact with one another.

4 Data and Methodology

4.1 Data

This study uses a panel of 1,720 U.S. publicly traded firms spanning 2005–2020. We selected the U.S. sample because its large economy and role in annual CO_2 emissions make it a focal point for corporate-environment interactions (Aksom & Tymchenko, 2020; Khan et al., 2022). Our inclusion criteria required that firms report governance scores and provide observable disclosures related to climate variability risk, e.g., through earnings releases or investor conference calls, and excluded inactive or delisted entities to reduce survivorship bias. In addition, utilities and financial-sector firms were dropped due to their unique capital structures and sector-specific regulation, and we winsorized the panel to handle extreme values. The analysis relies on firm-level and macro data from CompStat, the WDI, and Refinitiv Eikon.

The study centers on the primary variables of interest, beginning with Climate Variability Risk (CVR), which captures a firm's exposure to climate-related uncertainties. CVR is measured using machine learning-based text analytics on earnings conference call transcripts, identifying the frequency and context of climate risk-related discussions, and thereby reflecting the firm's perceived vulnerability to climate variability. However, firm value is captured through two complementary measures: Tobin's Q (TR), which represents the market valuation of a firm relative to its replacement cost, serving as an indicator of overall market perception and investor confidence; and Growth Option Value (GOV), which quantifies the value of future expansion opportunities, reflecting managerial flexibility and strategic growth potential under uncertainty.

To ensure a comprehensive analysis, the study incorporates a set of control variables capturing firm-specific and macroeconomic conditions. Firm Cash Flow (FOFC) indicates the liquidity available for investment, operations, or debt repayment, providing insight into the firm's financial flexibility. Sales Growth Ratio (SGR) reflects revenue growth over time, signaling the firm's operational performance and expansion potential. Firm Tangibility (TAG) measures the proportion of fixed assets to total assets, highlighting the collateral available for financing and its influence on investment decisions. Firm Leverage (FLEV) represents the debt-to-asset ratio, indicating financial risk and the impact of capital structure on firm stability and valuation.

At the macro level, Inflation Rate (INFR) captures changes in the general price level, which can influence operating costs, investment returns, and real cash flows, while Gross Domestic Product (GDPP) accounts for overall economic activity, shaping market demand and corporate growth opportunities. By integrating these firm-level and macroeconomic controls, the study provides a robust framework for examining how CVR and firm value measures respond to internal financial conditions and external economic fluctuations, offering deeper insights into the financial and strategic implications of climate-related risks.

4.2 Methodology

We applied machine learning techniques to analyze CVR data extracted from earnings conference calls (Aerts et al., 2008). This relationship can be expressed using the following equation:

$$CVR_{i,t} = \frac{1}{B_{i,t}} \sum_{b}^{B_{i,t}} (1[b \ \in C] \times \ 1[b, r \ \in S]) \,, \tag{1}$$

where $CVR_{i,t}$ represents the Climate Variability Risk score for firm i in time t. The term $B_{i,t}$ denotes the total number of bigrams (word pairs) extracted from the earnings conference call transcript of firm i in year t, used to normalize the measure for document length. $1[b \ \in C]$ is an indicator function that equals 1 if bigram b belongs to the predefined climate change vocabulary set C; otherwise, 0. $1[b, r \ \in S]$ equals 1 if bigram b co-occurs with a risk-related term r (e.g., "risk," "uncertainty," "exposure") within the risk vocabulary set S; otherwise, 0. A higher $CVR_{i,t}$ value indicates greater exposure to climate-related risk (Sautner et al., 2023).

We operationalize firm value (EW) using two measures, the first being Tobin's Q (TR), which researchers commonly adopt, and as specified in Equation 2, our method for deriving TR follows established practice (Fafaliou et al., 2022; Khan et al., 2022; Kim et al., 2021; Tong & Reuer, 2006; Trigeorgis & Lambertides, 2014).

$$Q_{i,t} = \frac{Equity\ MV_{i,t} + Liabilities\ MV_{i,t}}{Equity\ BV_{i,t} + Liabilities\ BV_{i,t}}. \tag{2}$$

Second, we derive a real-options-based growth-option metric (GOV), which treats EW as the sum of assets-in-place and the value of future expansion (De Andrés-Alonso et al., 2006; Fafaliou et al., 2022; Klingebiel, 2012; Koller et al., 2019). Following Trigeorgis and Reuer (2017), GOV = (assets-in-place attributable to equity − market capitalization) / market capitalization.

Equation 3 is used to estimate the assets-in-place term.

$$Value\ of\ assets\ in\ place_{i,t} = \frac{Net\ Income_{i,t}}{Ke_{i,t}}. \tag{3}$$

In the subsequent stage, we compute the Growth Option Value (GOV) using the following Equation 4:

$$GOV_{i,t} = \frac{Market\ Capitalization_{i,t} Value\ of\ assets\ in\ place_{i,t}}{Market\ Capitalization_{i,t}}. \tag{4}$$

To determine the value of a firm's equity assets-in-place, this study calculates the present value of net income at time t, assuming perpetual continuation, and discounts it using the cost of equity (K_e). Given that the Capital Asset Pricing Model (CAPM) incorporates market risk, we employ it to estimate the cost of equity (Trigeorgis & Reuer, 2017). Regarding ESG performance, we adopt the company's overall Refinitiv ESG score as a measure (Fafaliou et al., 2022; Rahi et al., 2021). The scoring framework classifies firms as follows: scores from 0 to 0.25 (0–25) reflect poor relative ESG performance and limited transparency in disclosure; scores between 0.51 and 0.75 (51–75) indicate above-average performance and greater disclosure transparency; while scores of 0.76 to 1.00 (76–100) represent excellent relative performance along with a high degree of transparency in ESG reporting. To ensure comparability, all variables are standardized to a uniform scale, and both firm-specific and macroeconomic controls are incorporated across all model specifications, consistent with recent studies.

The econometric models are as follows:

$$TR_{i,t} = \alpha_0 + \beta_1 \mathrm{CVR}_{\mathrm{i,t}} + \delta_1 FOCF_{\mathrm{i,t}} + \delta_2 SGR_{\mathrm{i,t}} + \delta_3 \mathrm{TAG}_{\mathrm{i,t}} + \delta_4 SIZE_{\mathrm{i,t}} + \delta_5 LEV_{\mathrm{i,t}} + \delta_6 \mathrm{INFR}_{\mathrm{i,t}} + \delta_7 \mathrm{GDPP}_{\mathrm{i}} + \gamma_1 Year + \mu_1 Industry + \varepsilon_{\mathrm{i,t}}, \tag{5}$$

$$GOV_{i,t} = \alpha_0 + \beta_1 \mathrm{CVR}_{\mathrm{i,t}} + \delta_1 FOCF_{\mathrm{i,t}} + \delta_2 SGR_{\mathrm{i,t}} + \delta_3 \mathrm{TAG}_{\mathrm{i,t}} + \delta_4 SIZE_{\mathrm{i,t}} + \delta_5 LEV_{\mathrm{i,t}} + \delta_6 \mathrm{INFR}_{\mathrm{i,t}} + \delta_7 \mathrm{GDPP}_{\mathrm{i}} + \gamma_1 Year + \mu_1 Industry + \varepsilon_{\mathrm{i,t}}, \tag{6}$$

where Equations 5 and 6 present the baseline empirical models used to examine how Climate Variability Risk (CVR) affects firm value. The two equations differ only in the way firm value is measured. Specifically, Equation 5 uses Tobin's Q (TR), while Equation 6 uses the Growth Option Value (GOV). In both equations, the dependent variable, $TR_{i,t}$ or $GOV_{i,t}$, represents firm i value in year t. The key explanatory variable is $\mathrm{CVR}_{\mathrm{i,t}}$, which captures the extent to which a firm is exposed to climate variability risk based on textual analysis of earnings conference calls. The coefficient β_1 measures the effect of climate-related risk on firm value. A statistically significant estimate of β_1 indicates that climate variability risk is priced by financial markets.

The models include a comprehensive set of firm-level control variables. FOCF is firm operating cash flow, which reflects internal liquidity and the firm's ability to finance operations without external funds. SGR is the sales growth ratio, captures growth opportunities, and demand expansion. TAG is asset tangibility, which measures the proportion of fixed assets, indicating collateral availability. SZE is firm size, controls for scale effects, while FLEV is financial leverage, captures capital structure, and financial risk. At the macroeconomic level, INFR controls for inflationary conditions that may influence costs and real returns, and GDPP captures the broader economic environment in which firms operate. In addition, year dummy variables are included to absorb common time-specific shocks, while industry dummy variables control for unobserved industry characteristics.

The constant term α_0 represents the baseline level of firm value when all explanatory variables equal zero. Finally, $\varepsilon_{\mathrm{i,t}}$ denotes the error term, capturing unexplained variation. Together, these two equations allow the study to assess whether climate variability risk affects both current market valuation (TR) and future growth opportunities (GOV), while carefully accounting for firm-specific characteristics, macroeconomic conditions, and unobserved heterogeneity across time and industries.

Equations 7 through 11 illustrate the construction of the dynamic panel two-stage GMM models employed in this study to test the hypotheses, thereby examining the relationship between climate variability risk (CVR) and firm value (EW), while placing particular emphasis on the role of ESG investments.

$$TR_{i,t} = \alpha_0 + \beta_1 \mathrm{TR}_{\mathrm{i,(t-2)}} + \beta_2 \mathrm{CVR}_{\mathrm{i,t}} + \delta_1 FOCF_{\mathrm{i,t}} + \delta_2 SGR_{\mathrm{i,t}} + \delta_3 \mathrm{TAG}_{\mathrm{i,t}} + \delta_4 SIZE_{\mathrm{i,t}} + \delta_5 LEV_{\mathrm{i,t}} + \delta_6 \mathrm{INFR}_{\mathrm{i,t}} + \delta_7 \mathrm{GDPP}_{\mathrm{i}} + \gamma_1 Year + \mu_1 Industry + \varepsilon_{\mathrm{i,t}}, \tag{7}$$

$$GOV_{i,t} = \alpha_0 + \beta_1 \mathrm{GOV}_{\mathrm{i,(t-2)}} + \beta_2 \mathrm{CVR}_{\mathrm{i,t}} + \delta_1 FOCF_{\mathrm{i,t}} + \delta_2 SGR_{\mathrm{i,t}} + \delta_3 \mathrm{TAG}_{\mathrm{i,t}} + \delta_4 SIZE_{\mathrm{i,t}} + \delta_5 LEV_{\mathrm{i,t}} + \delta_6 \mathrm{INFR}_{\mathrm{i,t}} + \delta_7 \mathrm{GDPP}_{\mathrm{i}} + \gamma_1 Year + \mu_1 Industry + \varepsilon_{\mathrm{i,t}}, \tag{8}$$

$$TR_{i,t} = \alpha_0 + \beta_1 \mathrm{TR}_{\mathrm{i,(t-2)}} + \beta_2 \mathrm{CVR}_{\mathrm{i,t}} + \beta_3 \mathrm{ESG}_{\mathrm{i,t}} + \delta_1 FOCF_{\mathrm{i,t}} + \delta_2 SGR_{\mathrm{i,t}} + \delta_3 \mathrm{TAG}_{\mathrm{i,t}} + \delta_4 SIZE_{\mathrm{i,t}} + \delta_5 LEV_{\mathrm{i,t}} + \delta_6 \mathrm{INFR}_{\mathrm{i,t}} + \delta_7 \mathrm{GDPP}_{\mathrm{i}} + \gamma_1 Year + \mu_1 Industry + \varepsilon_{\mathrm{i,t}}, \tag{9}$$

$$TR_{i,t} = \alpha_0 + \beta_1 \mathrm{TR}_{\mathrm{i,(t-2)}} + \beta_2 \mathrm{CVR}_{\mathrm{i,t}} + \beta_3 \mathrm{ESG}_{\mathrm{i,t}} + \beta_4 (\mathrm{CVR}_{\mathrm{i,t}} \times \mathrm{ESG}_{\mathrm{i,t}}) + \delta_1 FOCF_{\mathrm{i,t}} + \delta_2 SGR_{\mathrm{i,t}} + \delta_3 \mathrm{TAG}_{\mathrm{i,t}} + \delta_4 SIZE_{\mathrm{i,t}} + \delta_5 LEV_{\mathrm{i,t}} + \delta_6 \mathrm{INFR}_{\mathrm{i,t}} + \delta_7 \mathrm{GDPP}_{\mathrm{i}} + \gamma_1 Year + \mu_1 Industry + \varepsilon_{\mathrm{i,t}}, \tag{10}$$

$$GOV_{i,t} = \alpha_0 + \beta_1 \mathrm{GOV}_{i,(t-2)} + \beta_2 \mathrm{CVR}_{\mathrm{i,t}} + \beta_3 \mathrm{ESG}_{\mathrm{i,t}} + \beta_4 \left(\mathrm{CVR}_{\mathrm{i,t}} \times \mathrm{ESG}_{\mathrm{i,t}}\right) + \delta_1 FOCF_{\mathrm{i,t}} + \delta_2 SGR_{\mathrm{i,t}} + \delta_3 \mathrm{TAG}_{\mathrm{i,t}} + \delta_4 SIZE_{\mathrm{i,t}} + \delta_5 LEV_{\mathrm{i,t}} + \delta_6 \mathrm{INFR}_{\mathrm{i,t}} + \delta_7 \mathrm{GDPP}_{\mathrm{i}} + \gamma_1 Year + \mu_1 Industry + \varepsilon_{\mathrm{i,t}}, \tag{11}$$

where in the models, firms are indexed by i, and time t. Tobin's Q ratio (TR) serves as a measure of a firm's market value, whereas lagged dependent variables are denoted with the subscript $t-2$, and GOV represents growth option value. The analysis employs several additional variables, each with specific acronyms: GDPP for gross domestic product, INFR for inflation, δ for control variables, SIZE for firm size, SGR for sales growth, LEV for financial leverage, CVR for climate variability risk, TAG for asset tangibility, FOCF for firm operating cash flow, and ε for error term.

To construct the Climate Variability Risk (CVR) measure, we applied a machine learning–based text analytics approach to firms' quarterly earnings conference call transcripts. First, textual data were preprocessed through tokenization, lemmatization, and stop-word removal. Second, a dictionary-based supervised learning model was developed to identify terms associated with climate variability, extreme weather, and environmental uncertainty. The model was trained and validated using a manually labeled subset of conference call data to ensure contextual accuracy. Third, we employed term-frequency inverse document frequency (TF-IDF) weighting to quantify the intensity of climate-related discussions, which was then aggregated to construct the firm-level CVR index. Higher values of CVR indicate greater perceived exposure to climate variability and environmental risks.

The empirical analysis is conducted in a structured sequence to ensure robust and credible results. First, we begin with descriptive statistics and correlation analysis to understand the basic distribution and relationships among variables. This preliminary step provides insights into potential multicollinearity or extreme values and informs subsequent modeling choices. Second, we examine the properties of the panel data by conducting stationarity tests. Both first- and second-generation unit root tests are employed to assess whether variables are stationary over time (Cheng et al., 2021, 2022; Hui et al., 2017). Table A1 reports the results of panel unit root tests based on both first-generation (ADF–Fisher) and second-generation (IPS W-statistic) approaches to account for cross-sectional independence and dependence, respectively. The findings indicate that most variables are stationary at conventional significance levels, while the remaining variables become stationary after first differencing. These results confirm that all series are integrated at acceptable orders, thereby ruling out spurious regression and validating the reliability of the subsequent panel estimations.

While spurious regression is a valid concern in panel settings where variables exhibit unit root or near–unit root behavior (Wong et al., 2024), this risk is mitigated in the present study through both diagnostic testing and model choice. As reported in Table A1, panel unit root tests indicate that the key variables are either stationary in levels or become stationary after first differencing, suggesting no evidence of non-stationary stochastic trends driving the estimated relationships. Moreover, the use of a dynamic two-step system GMM framework further alleviates concerns of spurious regression by estimating the model in differences and levels simultaneously, while employing internally generated instruments. This approach effectively controls for unobserved heterogeneity, persistence in firm value measures, and potential endogeneity, thereby ensuring that the reported results reflect genuine economic relationships rather than spurious correlations.

Third, we address potential heteroskedasticity, serial correlation, and cross-sectional dependence by applying the Feasible Generalized Least Squares (FGLS) method, which provides efficient and robust estimates in the presence of these common panel data issues (Velte, 2017). To assess linearity in the estimated models, this study employs the Ramsey RESET F-test, where the null hypothesis is that the functional form of the model is correctly specified and linear in parameters. As reported in Table A2, the F-statistics for Tobin's Q (TR) and Growth Option Value (GOV), as well as for all explanatory variables, are statistically insignificant (p-values > 0.10), indicating a failure to reject the null hypothesis of linearity. Accordingly, "ND" (not detected) denotes that no evidence of functional form misspecification or nonlinearity is found, which supports the adequacy and validity of the linear model specification used in this study (Hui et al., 2017). Fourth, to account for unobserved heterogeneity, endogeneity, and dynamic adjustment effects, we employ the Generalized Method of Moments (GMM) (Aksom & Tymchenko, 2020; Wang et al., 2003). This approach incorporates lagged dependent variables to capture adjustment dynamics, controls for firm fixed effects to address time-invariant characteristics, and generates internal instruments to correct for potential reverse causality. GMM is particularly useful in studying relationships where firm behavior and economic conditions are simultaneously determined, ensuring consistent and unbiased estimates.

Fifth, quantile regression is conducted across the 50th, 75th, and 90th percentiles to explore heterogeneity in the dependent variable, providing insights into how effects differ across the distribution of firm responses (Weber, 2014). Finally, a series of diagnostic tests validates the model. The Arellano–Bond test results reported in Table 5 indicate the presence of first-order serial correlation AR(1) in the differenced residuals, which is expected in dynamic panel GMM estimations, while the AR(2) test statistics are statistically insignificant across all model specifications. This confirms the absence of second-order serial correlation, validating the consistency of the two-step GMM estimates. Moreover, the Hansen and Sargan test p-values suggest that the instrument set is valid and not over-identified. These steps collectively ensure that the methodology addresses potential nonlinearity, spurious regression, and heterogeneity issues, thereby enhancing the robustness and credibility of the empirical results. Tables A1 and A2 can be found in the Appendix section.

5 Findings and Discussion

Table 1. Summary Statistics

Variable	Observation	Mean	Std.	Min.	Max.	VIF	1/VIF
TR	19,440	2.610	2.010	0.522	9.210		
GOV	19,440	0.870	0.710	0.099	8.341		
CVR	19,440	0.039	0.040	0.000	0.075	2.120	0.482
ESG	19,440	0.399	0.220	0.000	0.941	1.080	0.917
TAG	19,440	6.801	5.004	2.101	8.108	1.060	0.978
FOCF	19,440	0.101	0.079	0.090	0.406	2.590	0.420
SIZE	19,440	8.019	6.089	6.101	23.301	1.380	0.763
SG	19,440	2.496	1.004	0.840	7.011	1.400	0.722
LEV	19,440	0.247	0.259	0.000	0.811	2.090	0.502
INFR	19,440	3.850	2.460	1.420	7.030	1.280	0.833
GDPP	19,443	− 0.060	3.150	2.090	5.900	2.050	0.511
Mean VIF						1.970	

Note: The Authors' own calculations. **Acronyms:** Tobin's Q Ratio (TR); Growth Option Value (GOV); Climate Variability Risk (CVR); Assets Tangibility (TAG); Operating Cash Flow (OCF); Firm Size (SIZE); Sales Growth (SG); Financial Leverage (LEV); Inflation Rate (INFR); GDP per Capita Growth (GDPP); Environmental, Social, and Governance (ESG).

Table 1 provides descriptive statistics for the key variables in this study, based on 19,440 firm-year observations. The Tobin Q ratio (TR), representing EW, has a mean of 2.610 and a standard deviation of 2.010, indicating considerable variation in firm valuation. Growth option value (GOV), capturing the potential future growth of firms, averages 0.870, reflecting moderate expansion opportunities. Climate variability risk (CVR) is low on average at 0.039, suggesting limited risk exposure for most firms, while the ESG index has a mean of 0.399, indicating generally moderate ESG performance. Tangibility (TAG) and operating cash flow (FOCF) show substantial variation, with mean values of 6.801 and 0.101, respectively. Firm size (SIZE) and sales growth (SG) display broad distributions, highlighting differences in operational scale and performance dynamics. Financial leverage (LEV) averages 0.247, reflecting moderate reliance on debt financing. Macroeconomic factors such as inflation rate (INFR) and GDP per capita growth (GDPP) exhibit expected variation. The variance inflation factor values are all below 10, suggesting minimal multicollinearity and supporting reliable regression analysis.

Table 2. Pairwise Correlation

	FR	ESG	TAG	FOFC	SIZE	SG	LEV	INFR	GDPP
1	1.000								
2	0.188*	1.000							

3	0.121*	0.588***	1.000						
4	−0.113*	− 0.415***	− 0.257**	1.000					
5	−0.321***	0.391***	0.244**	0.435***	1.000				
6	0.290***	− 0.287**	− 0.297**	− 0.336***	− 0.416***	1.000			
7	0.227**	0.321***	0.323***	− 0.320***	0.413***	− 0.501***	1.000		
8	−0.164*	0.198**	0.210**	0.212**	0.401***	− 0.101*	− 0.112*	1.00	
9	−0.152*	− 0.122*	− 0.261**	− 0.233**	0.316***	− 0.117*	0.050	− 0.10	1

Note: *** p<0.01, ** p<0.05, * p<0.1. Acronyms: Tobin's Q Ratio (TR); Growth Option Value (GOV); Climate Variability Risk (CVR); Assets Tangibility (TAG); Operating Cash Flow (OCF); Firm Size (SIZE); Sales Growth (SG); Financial Leverage (LEV); Inflation Rate (INFR); GDP per Capita Growth (GDPP); Environmental, Social, and Governance (ESG).

Table 2 reports the pairwise correlations among the main variables employed in this study. Overall, the results indicate that most correlations are moderate to low, suggesting that multicollinearity is not a major concern and that the data are suitable for regression analysis. The ESG index shows a strong positive correlation with tangibility (TAG, 0.588) and financial leverage (LEV, 0.321), indicating that firms with higher tangible assets and greater leverage are more likely to demonstrate strong ESG performance. Similarly, firm size (SIZE) is positively associated with ESG (0.391) and other firm-level characteristics, reflecting the tendency of larger firms to adopt more formalized governance and sustainability practices. Financial performance indicators, such as operating cash flow (FOCF), exhibit negative correlations with ESG (−0.415) and other firm-level measures, suggesting that cash-rich firms may not always prioritize ESG initiatives to the same extent as firms focused on long-term sustainability. Sales growth (SG) and financial leverage (LEV) also display expected patterns of association, with moderate negative correlations between SG and LEV (−0.501) and negative relationships with ESG and FOCF, reflecting potential trade-offs between growth, financing, and sustainability practices. Macroeconomic variables, including inflation (INFR) and GDP per capita growth (GDPP), show generally weak correlations with firm-level measures, indicating that broader economic conditions are largely independent of firm-specific financial and ESG characteristics. Notably, SIZE, LEV, and TAG show moderate intercorrelations, but none are so high as to pose serious multicollinearity concerns. These results collectively indicate that the dataset is well-suited for multivariate analysis. The moderate correlations observed suggest meaningful relationships between ESG performance, firm-level financial indicators, and macroeconomic conditions while avoiding excessive overlap among variables. Therefore, this correlation structure provides a robust foundation for examining the impacts of ESG engagement, climate-related risks, and firm characteristics on corporate environmental behavior.

5.1 Regression Techniques

To guard against misspecification and spurious results, we first subjected the data to a battery of diagnostic and post-estimation procedures (see Table 3). Next, we fitted the baseline regression to validate our hypotheses, and under the assumption of no panel prior influence, we applied the Breusch-Pagan (LM) test to determine whether a pooled OLS approach would suffice or whether panel techniques were required. The significant p-value from the Breusch–Pagan test indicated that panel estimation was preferable. Following the rejection of the null hypothesis in the Hausman test, we adopted a fixed-effects model and computed both fixed and random effects for comparison. The Modified Wald and Wooldridge tests confirmed the presence of heteroskedasticity and serial correlation in the models, which were addressed by employing a robust fixed-effects specification.

Table 3. FEM

FE Robust	Direct effect				Moderating Mechanism	
Variables	TR (1)	GOV (2)	TR (3)	GOV (4)	TR (5)	GOV (6)
	TR	GOV	TR	GOV	TR	GOV
CVR	− 0.0503*** (0.0179)	− 0.0406** (0.0203)	− 0.0551*** (0.0218)	− 0.0526** (0.0213)	− 0.0447*** (0.0138)	− 0.0492** (0.0246)
ESG			0.0681*** (0.0143)	0.0456** (0.0228)	0.0674*** (0.0131)	0.0615*** (0.0208)
CVR* ESG					0.0064** (0.0032)	0.0047* (0.0025)
TAG	− 0.0348* (0.0025)	− 0.0602** (0.0301)	− 0.5106*** (0.0202)	− 0.0026** (0.0013)	− 0.0521*** (0.0033)	− 0.0705 (0.4207)
FOCF	0.1809*** (0.0297)	2.5023 (2.0809)	2.5002 (2.0804)	0.0294*** (0.0099)	0.0565*** (0.0271)	0.0952 (0.0523)
SIZE	− 0.0783*** (0.0032)	− 2.5010*** (0.2400)	0.5709*** (0.0080)	0.0079*** (0.0011)	0.0023*** (0.0002)	− 0.3089*** (0.0111)
SG	0.1170*** (0.0049)	0.6550*** (0.0405)	0.563*** (0.0414)	0.0173*** (0.0015)	0.0042 (0.0044)	0.0003*** (0.0000)
LEV	− 0.0301*** (0.0103)	0.0370 (0.7207)	0.2608 (0.7025)	− 0.0137*** (0.0036)	0.126*** (0.0094)	− 0.0223 (0.0234)
INFR	− 0.0045 (0.0063)	− 1.1430 (1.1460)	0.7407 (0.5433)	− 0.0030 (0.0055)	− 0.0101 (0.0149)	− 0.0834*** (0.4401)
GDPP	0.6004*** (0.0239)	− 8.643*** (1.680)	−10.1911*** (1.6834)	− 0.1053*** (0.0080)	− 0.0700*** (0.0219)	2.1001*** (0.596)
Constant	0.693 (1.0119)	− 0.602 (0.049)	− 0.0007*** (0.0000)	− 0.050*** (0.0000)	− 0.0242** (0.0121)	− 0.0813*** (0.0362)
Observation	19,443	19,443	19,443	19,443	19,443	19,443
Industry/year cluster	✔	✔	✔	✔	✔	✔
adj. R2	0.1590	0.2210	0.2860	0.2140	0.2590	0.2890
F-test	35.0***	27.1***	47.4***	17.7***	117.0***	467.7***
Breusch–Pagan χ2	434.46***	934.06***	534.96***	1134.46***	834.48***	1434.46***
Hausman Test χ2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Modified Wald test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wooldridge test	F=314.420***	F=513.210***	F=453.250***	F=627.220***	F=109.420***	F=541.370***
Wald test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Table 3 presents the results of panel fixed-effects regressions. The dependent variable is Tobin's Q Ratio (TR) in columns (1), (3), and (5), and Growth Option Value (GOV) in columns (2), (4), and (6). *** p<0.01, ** p<0.05, * p<0. Acronyms: Tobin's Q Ratio (TR); Growth Option Value (GOV); Climate Variability Risk (CVR); Assets Tangibility (TAG); Operating Cash Flow (OCF); Firm Size (SIZE); Sales Growth (SG); Financial Leverage (LEV); Inflation Rate (INFR); GDP per Capita Growth (GDPP); Environmental, Social, and Governance (ESG). **Source:** Author's Own Collection.

Table 3 presents the results of this robust fixed-effects approach, offering empirical insights into the relationship between firm-level CVR, TR, and GOV. These statistics unveil an inverse and significant effect of CVR on TR and GOV, supporting H1. Specifically, Columns 1 and 2 show that a one-unit increase in CVR corresponds to decreases of −0.050 and −0.040 in TR and GOV, respectively, while holding other variables constant, which aligns with the conclusions reported by He et al. (2023).

Next, we examine the effect of ESG investments on TR and GOV. As shown in Table 3, Columns 3 and 4, ESG investments are associated with improvements in TR and GOV, and these effects are positive and statistically significant. The statistics can be supported by prior literature (Fafaliou et al., 2022; Rahi et al., 2021; Shahzad et al., 2023), thereby providing empirical support for H2. To test our third hypothesis (H3), we introduce the interaction term between CVR and the ESG index (CVR*ESG) in Columns 5 and 6. The findings reveal that this interaction exerts a positive influence on EW, indicating that ESG investments can lessen the adverse effects of climate variability risk on TR and GOV, which confirms our hypothesis.

Our findings underscore the advantages that ESG investments can offer to firms that are particularly susceptible to climate variability risk, demonstrating that active engagement in ESG initiatives can enhance firm value (Boulhaga et al., 2023; Khan et al., 2022). In all empirical models, we included relevant control variables, and the results reveal that certain factors negatively influence TR and GOV, including TAG, SIZE, LEV, and INFR, whereas others exert a positive effect, such as SGR, FOCF, and GDPP. Across all specifications, CVR consistently demonstrates an inverse impact on TR and GOV. Additionally, the significant F-test results for each fixed-effect model indicate that the models are properly specified. Previous corporate finance research identifies multiple determinants of TR and GOV, including climate risk (Fafaliou et al., 2022), and our modeling aligns with these studies by incorporating both firm-level and macroeconomic factors (Kim et al., 2021). To enhance reliability, we mitigated potential confounding variables, applied a one-year lag to all variables, and report clustered standard errors in parentheses.

Table 4. FGLS

FGLS	Direct effect				Moderating Effect	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
	TR	GOV	TR	GOV	TR	GOV
CVR	− 0.0631*** (0.0242)	− 0.0570** (0.0305)	− 0.0509*** (0.0231)	− 0.0459*** (0.0071)	− 0.0524*** (0.0191)	− 0.0344*** (0.0020)
ESG			0.0779*** (0.0126)	0.0642*** (0.0216)	0.0712*** (0.0222)	0.0470*** (0.0231)
CVR* ESG					0.0121*** (0.0024)	0.0102*** (0.0019)
TAG	− 0.0090*** (0.0037)	− 0.0006*** (0.0000)	− 0.0813*** (0.0362)	0.0080*** (0.0062)	− 0.0010*** (0.0000)	− 0.0026*** (0.0011)
FOCF	− 0.0031*** (0.0008)	− 0.0006*** (0.0000)	− 0.0305 (0.0061)	− 0.0040** (0.0020)	− 0.0004** (0.0002)	− 0.0091*** (0.0033)
SIZE	0.0039** (0.0021)	0.0108** (0.0004)	− 0.0090 (0.0093)	− 0.0300*** (0.0003)	− 0.0006** (0.0003)	− 0.0108*** (0.0054)

SG	0.0016***	0.0038***	0.0008**	0.0043***	0.0214	0.0108
	(0.0004)	(0.0017)	(0.0004)	(0.0081)	(0.0228)	(0.0155)
LEV	− 0.0010**	− 0.0040**	− 0.0301***	− 0.0090***	− 0.0108	− 0.0031***
	(0.0004)	(0.0020)	(0.0061)	(0.0037)	(0.0115)	(0.0014)
INFR	− 0.0521***	− 0.0090***	− 0.0007***	− 0.0007***	− 0.050***	− 0.0242**
	(0.0058)	(0.0007)	(0.0100)	(0.0000)	(0.0000)	(0.0119)
GDPP	0.0315**	− 0.0018	− 0.0309***	− 0.0003***	− 0.0004	− 0.0065***
	(0.0152)	(0.0011)	(0.0083)	(0.0001)	(0.0004)	(0.0029)
Constant	− 3.720***	− 0.0060**	0.693	− 0.602	− 1.909***	− 0.0652
	(1.036)	(0.0030)	(1.0119)	(0.049)	(0.2304)	(3.0188)
Industry / Year FE	✔	✔	✔	✔	✔	✔
Cluster	✔	✔	✔	✔	✔	✔
Observation	19,440	19,440	19,440	19,440	19,440	19,440
Wald Chi^2	36.14***	16.20***	76.03***	46.07***	53.15***	73.14***

Note: Table 4 presents the results of Feasible Generalized Least Squares. The dependent variable is Tobin's Q Ratio (TR) in columns (1), (3), and (5), and Growth Option Value (GOV) in columns (2), (4), and (6). *, **, and *** indicate significance at 10%, 5%, and 1%. Acronyms: Tobin's Q Ratio (TR); Growth Option Value (GOV); Climate Variability Risk (CVR); Assets Tangibility (TAG); Operating Cash Flow (OCF); Firm Size (SIZE); Sales Growth (SG); Financial Leverage (LEV); Inflation Rate (INFR); GDP per Capita Growth (GDPP); Environmental, Social, and Governance (ESG). **Source:** Author's own statistics.

While fixed-effects estimators with robust functions address issues such as heteroskedasticity and serial correlation, they may not completely capture cross-sectional dependence. Therefore, this study employs the FGLS approach, which simultaneously corrects for heteroskedasticity, serial correlation, and cross-sectional dependence (Velte, 2017). The FGLS outcomes, presented in Table 4 (Columns 1–2), remain consistent with the baseline estimations. Supporting H1, the negative and significant coefficients for CVR (−0.0621 and −0.0570) indicate that higher climate variability risk leads to a decline in firm value, measured through TR and GOV, consistent with the findings of He et al. (2023). Furthermore, the results in Columns 3–4 reveal that ESG investments exert a positive and significant influence on TR and GOV. This outcome aligns with previous evidence showing that firms with stronger ESG engagement tend to achieve superior financial performance and market reputation (Fafaliou et al., 2022; Rahi et al., 2021; Shahzad et al., 2023). To assess H3, the interaction term (CVR*ESG) is introduced. The coefficients of 0.0121 and 0.0102 reported in Columns 5–6 are positive and significant, suggesting that ESG initiatives help counterbalance the adverse impact of CVR on TR and GOV. Collectively, these results confirm H3 and underscore the strategic role of ESG practices in enhancing corporate resilience and long-term value creation, particularly for firms exposed to intensifying climate-related risks (Boulhaga et al., 2023).

5.2 GMM

This study recognizes the potential for endogeneity, including reverse causality, in regression estimation. Even with the inclusion of multiple control variables, certain unobserved factors, such as behavioral effects or broader macro-level climate variability attitudes, could influence both CVR and firm value. To address these concerns, we apply the GMM, a robust econometric technique renowned for correcting endogeneity and reverse causation while simultaneously generating instrumental variables (Wang et al., 2003).

Table 5. GMM

Two-stage GMM	Direct effect				Moderator's Mechanism	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
	TR	GOV	TR	GOV	TR	GOV
L2.TR	−0.0366*** (0.0102)		−0.0336*** (0.0114)		− 0.0264*** (0.0116)	
L2.GOV		−0.0770*** (0.0312)		−0.0041** (0.0014)		0.0564*** (0.0212)
CVR	−0.0449*** (0.0221)	−0.0361*** (0.0111)	−0.0463*** (0.0125)	−0.0319*** (0.0108)	− 0.0445*** (0.0221)	0.0331*** (0.0103)
ESG			0.0689*** (0.0310)	0.0523*** (0.0181)	0.0541*** (0.0138)	0.0474** (0.0241)
CVR* ESG					0.0292*** (0.0042)	0.0138*** (0.0067)
TAG	−0.0027*** (0.0016)	−0.0038*** (0.0001)	− 0.0008 (0.0008)	− 0.0065 (0.0041)	− 0.0301*** (0.0071)	−0.0104** (0.0057)
FOCF	0.3892*** (0.0445)	−0.0033*** (0.0001)	−0.0086*** (0.0010)	0.0091*** (0.0004)	0.00926*** (0.00088)	0.0092*** (0.0010)
SIZE	−0.0923*** (0.0102)	−0.1250*** (0.0258)	−0.0574*** (0.0121)	−0.0444*** (0.0144)	− 0.0153*** (0.0008)	−0.0108*** (0.0049)
SG	0.0124*** (0.0058)	0.0095*** (0.0031)	0.0011 (0.0012)	0.0029 (0.0018)	0.0579*** (0.0024)	0.0008 (0.0057)
LEV	−0.0096*** (0.0016)	0.1011*** (0.0105)	0.0202*** (0.0019)	−0.0182*** (0.0007)	− 0.0127*** (0.0095)	0.0041*** (0.0015)
INFR	−0.0125*** (0.0042)	−0.1081*** (0.0194)	− 0.0035 (0.0040)	−0.0132*** (0.0026)	− 0.0581 (0.0358)	− 0.0136 (0.0199)
GDPP	−0.0125*** (0.0042)	0.0123 (0.0261)	0.0169*** (0.0065)	− 0.0048* (0.0025)	− 0.0334*** (0.0067)	− 0.1300* (0.0802)
Constant	0.0581*** (0.0024)	−7.0915*** (0.0397)	0.0072 (0.0140)	1.0072*** (0.0145)	− 3.689*** (0.2033)	−4.0658*** (0.0183)
Industry Year/ FE	✔	✔	✔	✔	✔	✔
Number of ids	1771	1771	1771	1771	1771	1771
AR (1)-1st differences	0.001	0.002	0.003	0.001	0.031	0.001
AR (2) – 1st differences	0.329	0.311	0.301	0.147	0.241	0.
Sargan Test (P-value)	0.081	0.120	0.198	0.101	0.149	0.123
Hansen test (P-value)	0.155	0.111	0.149	0.123	0.109	0.088

Note: Table 5 presents the results of the Generalized Method of Moments. The dependent variable is Tobin's Q Ratio (TR) in columns (1), (3), and (5), and Growth Option Value (GOV) in columns (2), (4), and (6). *, **, and *** indicate significance at 10%, 5%, and 1%. Acronyms: Tobin's Q Ratio (TR); Growth Option Value (GOV); Climate Variability Risk (CVR); Assets Tangibility (TAG); Operating Cash Flow (OCF); Firm Size (SIZE); Sales Growth (SG); Financial Leverage (LEV); Inflation Rate (INFR); GDP per Capita Growth (GDPP); Environmental, Social, and Governance (ESG).

The GMM results, presented in Table 5, Columns 1 and 2, show statistically significant negative coefficients for CVR, confirming that higher climate variability risk reduces TR and GOV, which aligns with our primary hypothesis. Columns 3 and 4 reveal that ESG investments exert a strong and positive influence on TR and GOV, supporting H2 and highlighting their potential benefits. Additionally, the interaction term (CVR*ESG index) significantly and positively moderates the CVR–TR and GOV relationship, further validating H3, as shown in Table 5, Columns 5–6. The second-order Autoregressive (AR (2)) test confirms the absence of residual autocorrelation, ensuring model reliability. In summary, our analysis employs rigorous econometric methods, including FGLS, GMM, and fixed-effect robust models, to address heteroskedasticity, serial correlation, and endogeneity, providing robust insights into the relationships among CVR, ESG investments, and TR and GOV. Our findings highlight three key points: (1) CVR exhibits a notable and negative association with EW; (2) ESG investments positively influence TR and GOV; and (3) ESG investment moderates the negative effect of CVR on TR and GOV, thereby enhancing EW.

First, our findings consistently confirm H1, showing that higher CVR reduces enterprise value, which aligns with prior research suggesting that climate-related expenses can depress corporate value (Boulhaga et al., 2023; Khan et al., 2022; Xie et al., 2019; Zhang & Shuang, 2021). Second, examining the role of ESG investments, our results consistently demonstrate a positive effect on TR and GOV across all estimation methods (fixed-effect robust, FGLS, and GMM), confirming H2, and echoing prior studies (Rahi et al., 2021; Sautner et al., 2023; Shahzad et al., 2023). ESG investments enhance TR and GOV through reputation improvement, attraction of investors and customers, and fostering productivity and innovation.

Finally, we investigate the moderating influence of ESG investments on the CVR–TR and GOV relationship. The interaction term (CVR*ESG index) exhibits a significant positive effect, indicating that ESG initiatives can lessen the detrimental impact of CVR on TR and GOV. In particular, these investments not only strengthen corporate value but also help reduce CVR. This suggests that climate-focused financial policies, including green tax incentives and subsidies, may encourage firms and investors to adopt more sustainable practices. Consistent with prior research (Gillan et al., 2021; Godfrey, 2005), ESG investments act as comprehensive risk management tools, complementing traditional CSR strategies by addressing long-term performance and risk reduction. In essence, the results underscore that adopting robust ESG practices is not merely a social obligation but a strategic lever for long-term success. Enterprises that integrate stakeholder-focused sustainability actions into their operations tend to build stronger credibility, attractive financial and public confidence, elevate their market image, and strengthen their competitive position, factors that collectively drive higher profitability and firm value.

This study makes several important contributions to the emerging literature on climate risk, ESG investment, and firm value. First, unlike existing studies that mainly examine the direct effects of climate risk or ESG performance in isolation, this paper integrates climate vulnerability, climate policy uncertainty, and ESG investment within a unified valuation framework, allowing a more complete understanding of how climate-related shocks transmit into corporate value. Second, the study advances the literature by explicitly testing the moderating role of ESG investment, showing not only whether ESG matters, but how it conditions the impact of climate risk and uncertainty on firm valuation, an aspect that remains underexplored in prior work. Third, by employing firm-level panel evidence and interaction mechanisms, the paper moves beyond descriptive ESG assessments and provides causal-oriented insights into resilience-building through ESG channels. Finally, this research contributes methodologically by linking climate vulnerability metrics with financial valuation outcomes, offering a novel perspective for both academics and practitioners on how strategic ESG investment can function as a risk-hedging tool in the presence of climate uncertainty.

6 Conclusion

This study investigates how climate variability risk (CVR) influences EW, with a predominant focus on the moderating mechanism of ESG investments. Using a balanced panel of 1,720 U.S.-listed enterprises spanning from 2005 to 2020, our study integrates both firm-specific and macro-level perspectives in the analysis. The measure of EW is derived from Tobin's Q ratio (TR) and growth option value (GOV), while climate variability risk is estimated through a machine learning approach that captures fluctuations in climate-related patterns and exposures. ESG investment is assessed by using Refinitiv's comprehensive ESG score, reflecting firms' overall sustainability engagement and disclosure quality. To ensure methodological rigor, the study employs feasible generalized least squares (FGLS), dynamic-panel generalized method of moments (GMM), and panel fixed effects estimators. The empirical results reveal three key insights. First, climate variability risk exerts a significant negative impact on EW, implying that greater exposure to climate fluctuations reduces EW. Second, ESG investments exhibit a strong positive effect on both growth opportunities and overall EW, suggesting that responsible corporate practices enhance firm performance and resilience. Third, ESG engagement mitigates the adverse influence of climate variability risk on EW, highlighting its moderating and protective role. Robustness tests using alternative estimation techniques confirm the stability and reliability of these findings.

6.1 Policy Recommendations

This study yields actionable understandings for U.S. policy makers, corporate executives, and investors. First, the documented negative effect of CVR on EW implies that regulators and firms should prioritize forward-looking risk reduction measures and resilience planning, since such interventions can help to prevent value erosion. Second, the positive association between ESG considerations and EW shows that integrating sustainability criteria into corporate strategy and capital allocation delivers measurable benefits, and firms should therefore embed ESG governance and investment decision processes. Third, investors can incorporate CVR and ESG metrics into their due diligence and portfolio selection, because doing so improves risk assessment and supports long-term value preservation. Moreover, these findings offer guidance for refining policy frameworks to align with the U.S. regulatory environment and market conditions, promoting investment in sustainable corporate practices and effective climate risk management. Specifically, U.S. policymakers should strengthen disclosure requirements related to climate risk and ESG reporting to enhance transparency and investor confidence. Regulatory bodies, i.e., the Securities and Exchange Commission (SEC), could integrate ESG risk assessment into corporate governance standards to encourage sustainable business practices. Moreover, firms operating in high-emission industries should align their strategies with national climate goals and green finance initiatives.

Encouraging tax incentives and sustainability-linked financing could further motivate corporations to invest in ESG-driven resilience and long-term value creation.

From an academic standpoint, this endeavor adds to the understanding of how climate variability risk (CVR) affects EW (EW), thereby enriching the existing scholarly literature. Methodologically, the research introduces an innovative approach by employing machine learning algorithms to extract climate risk information from corporate conference calls, thereby offering a more comprehensive assessment of climate-related risks. The empirical results provide robust support for the model regarding climate, predominantly within the context of US-listed enterprises. Findings reveal that CVR exerts a significant and negative influence on EW, aligning with established theoretical frameworks and reinforcing evidence that CVR may unpleasantly affect financial statistics. Furthermore, the study highlights that ESG investments operate as a moderating mechanism that counterbalances the negative valuation effects of CVR, indicating that consistent engagement in sustainability initiatives can fortify firm value resilience in changing climatic conditions.

6.2 Limitations and Future Avenues

This research has some limitations. Since the analysis focuses exclusively on the U.S.-listed enterprises, the results may not be directly applicable to firms operating in other economies with different regulatory frameworks and environmental conditions. Future studies could broaden the scope by examining multinational data sets, incorporating additional firm- or sector-specific variables, and employing alternative approaches to measure both climate risk and ESG performance, thereby offering a more holistic understanding of these liaisons.

References

Adegbite, E., Guney, Y., Kwabi, F., & Tahir, S. (2019). Financial and corporate social performance in the UK listed firms: the relevance of non-linearity and lag effects. *Review of Quantitative Finance and Accounting*, *52*, 105-158. https://doi.org/10.1007/s11156-018-0705-x

Aerts, W., Cormier, D., & Magnan, M. (2008). Corporate environmental disclosure, financial markets and the media: An international perspective. *Ecological Economics*, *64*(3), 643-659. https://doi.org/https://doi.org/10.1016/j.ecolecon.2007.04.012

Aksom, H., & Tymchenko, I. (2020). How institutional theories explain and fail to explain organizations. *Journal of Organizational Change Management*, *33*(7), 1223-1252. https://doi.org/10.1108/JOCM-05-2019-0130

Al Ahbabi, A. R., & Nobanee, H. (2019). Conceptual building of sustainable financial management & sustainable financial growth. *Available at SSRN 3472313*. https://dx.doi.org/10.2139/ssrn.3472313

Alessandri, T. M., Tong, T. W., & Reuer, J. J. (2012). Firm heterogeneity in growth option value: The role of managerial incentives. *Strategic Management Journal*, *33*(13), 1557-1566. https://doi.org/10.1002/smj.1992

Al-Qudah, A. A., Al-Okaily, M., & Alqudah, H. (2022). The relationship between social entrepreneurship and sustainable development from economic growth perspective: 15 'RCEP'countries. *Journal of Sustainable Finance & Investment*, *12*(1), 44-61. https://doi.org/10.1080/20430795.2021.1880219

Anderson, C. W., & Garcia-Feijoo, L. (2006). Empirical evidence on capital investment, growth options, and security returns. *The journal of finance*, *61*(1), 171-194. https://doi.org/10.1111/j.1540-6261.2006.00833.x

Aouadi, A., & Marsat, S. (2018). Do ESG controversies matter for firm value? Evidence from international data. *Journal of business ethics*, *151*, 1027-1047. https://doi.org/10.1007/s10551-016-3213-8

Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies*, *58*(2), 277-297. https://doi.org/10.2307/2297968

Awaysheh, A., Heron, R. A., Perry, T., & Wilson, J. I. (2020). On the relation between corporate social responsibility and financial performance. *Strategic Management Journal*, *41*(6), 965-987. https://doi.org/10.1002/smj.3122

Bansal, P., & Song, H.-C. (2017). Similar but not the same: Differentiating corporate sustainability from corporate responsibility. *Academy of Management Annals*, *11*(1), 105-149. https://doi.org/10.5465/annals.2015.0095

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99-120. https://doi.org/10.1177/014920639101700108

Boulhaga, M., Bouri, A., Elamer, A. A., & Ibrahim, B. A. (2023). Environmental, social and governance ratings and firm performance: The moderating role of internal control quality. *Corporate Social Responsibility and Environmental Management*, *30*(1), 134-145. https://doi.org/10.1002/csr.2343

Broadstock, D. C., Chan, K., Cheng, L. T., & Wang, X. (2021). The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China. *Finance research letters*, *38*, 101716. https://doi.org/10.1016/j.frl.2020.101716

Camilleri, M. A. (2018). Closing the loop for resource efficiency, sustainable consumption and production: a critical review of the circular economy. *International Journal of Sustainable Development*, *21*(1-4), 1-17. https://doi.org/10.1504/IJSD.2018.100802

Cheng, Y., Hui, Y., Liu, S., & Wong, W.-K. (2022). Could significant regression be treated as insignificant: An anomaly in statistics? *Communications in Statistics: Case Studies, Data Analysis and Applications*, *8*(1), 133-151. https://doi.org/10.1080/23737484.2021.1986171

Cheng, Y., Hui, Y., McAleer, M., & Wong, W.-K. (2021). Spurious relationships for nearly non-stationary series. *Journal of Risk and Financial Management*, 14(8), 366. https://doi.org/10.3390/jrfm14080366

Cohen, G. (2023). The impact of ESG risks on corporate value. *Review of Quantitative Finance and Accounting*, *60*(4), 1451-1468. https://doi.org/10.1007/s11156-023-01135-6

Cormier, D., & Magnan, M. (2007). The revisited contribution of environmental reporting to investors' valuation of a firm's earnings: An international perspective. *Ecological economics*, *62*(3-4), 613-626. https://doi.org/10.1016/j.ecolecon.2006.07.030

Cui, X., Wang, C., Sensoy, A., Liao, J., & Xie, X. (2023). Economic policy uncertainty and green innovation: Evidence from China. *Economic Modelling*, *118*, 106104. https://doi.org/https://doi.org/10.1016/j.econmod.2022.106104

De Andrés-Alonso, P., Azofra-Palenzuela, V., & De La Fuente-Herrero, G. (2006). The real options component of firm market value: The case of the technological corporation. *Journal of Business Finance & Accounting*, *33*(1-2), 203-219. https://doi.org/10.1111/j.0306-686x.2005.00654.x

Elsayed, K., & Paton, D. (2005). The impact of environmental performance on firm performance: static and dynamic panel data evidence. *Structural Change and Economic Dynamics*, *16*(3), 395-412. https://doi.org/https://doi.org/10.1016/j.strueco.2004.04.004

Estrada, I., de la Fuente, G., & Martín-Cruz, N. (2010). Technological joint venture formation under the real options approach. *Research Policy*, *39*(9), 1185-1197. https://doi.org/https://doi.org/10.1016/j.respol.2010.05.015

Fafaliou, I., Giaka, M., Konstantios, D., & Polemis, M. (2022). Firms' ESG reputational risk and market longevity: A firm-level analysis for the United States. *Journal of Business Research*, *149*, 161-177. https://doi.org/https://doi.org/10.1016/j.jbusres.2022.05.010

Figge, F. (2005). Value-based environmental management. From environmental shareholder value to environmental option value. *Corporate Social Responsibility and Environmental Management*, *12*(1), 19-30. https://doi.org/10.1002/csr.74

Flammer, C. (2015). Does Corporate Social Responsibility Lead to Superior Financial Performance? A Regression Discontinuity Approach. *Management Science*, *61*(11), 2549-2568. https://doi.org/10.1287/mnsc.2014.2038

Galbreath, J. (2010). Sustainable development in business: a strategic view. In *Theory and practice of corporate social responsibility* (pp. 89-105). Springer. https://doi.org/10.1007/978-3-642-16461-3_6

Garcia-Castro, R., Ariño, M. A., & Canela, M. A. (2010). Does social performance really lead to financial performance? Accounting for endogeneity. *Journal of business ethics*, *92*, 107-126. https://doi.org/10.1007/s10551-009-0143-8

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. https://doi.org/10.1016/j.jcorpfin.2021.101889

Godfrey, P. C. (2005). The relationship between corporate philanthropy and shareholder wealth: A risk management perspective. *Academy of management review*, *30*(4), 777-798. https://doi.org/10.5465/amr.2005.18378878

Godfrey, P. C., Merrill, C. B., & Hansen, J. M. (2009). The relationship between corporate social responsibility and shareholder value: An empirical test of the risk management hypothesis. *Strategic management journal*, *30*(4), 425-445. https://doi.org/10.1002/smj.750

Han, L., Liu, T., Lu, H., & Zhang, W. (2025). Climate risk disclosure, green innovation and enterprise value. *Finance Research Letters*, *72*, 106553. https://doi.org/https://doi.org/10.1016/j.frl.2024.106553

Hart, S. L., & Milstein, M. B. (2003). Creating sustainable value. *Academy of Management Perspectives*, *17*(2), 56-67. https://doi.org/10.5465/ame.2003.10025194

Hartzmark, S. M., & Sussman, A. B. (2019). Do investors value sustainability? A natural experiment examining ranking and fund flows. *The Journal of Finance*, *74*(6), 2789-2837. https://doi.org/10.1111/jofi.12841

Hausman, J. (2015). Specification tests in econometrics. *Applied Econometrics*, *38*(2), 112-134.

He, F., Ding, C., Yue, W., & Liu, G. (2023). ESG performance and corporate risk-taking: Evidence from China. *International Review of Financial Analysis*, *87*, 102550. https://doi.org/https://doi.org/10.1016/j.irfa.2023.102550

Hui, Y., Wong, W.-K., Bai, Z., & Zhu, Z.-Z. (2017). A new nonlinearity test to circumvent the limitation of Volterra expansion with application. *Journal of the Korean Statistical Society*, *46*(3), 365-374. https://doi.org/10.1016/j.jkss.2016.11.006

Jia, J., & Li, Z. (2020). Does external uncertainty matter in corporate sustainability performance? *Journal of Corporate Finance*, *65*, 101743. https://doi.org/https://doi.org/10.1016/j.jcorpfin.2020.101743

Khan, M., Serafeim, G., & Yoon, A. (2016). Corporate Sustainability: First Evidence on Materiality. *The Accounting Review*, *91*(6), 1697-1724. https://doi.org/10.2308/accr-51383

Khan, M. A., Riaz, H., Ahmed, M., & Saeed, A. (2022). Does green finance really deliver what is expected? An empirical perspective. *Borsa Istanbul Review*, *22*(3), 586-593. https://doi.org/https://doi.org/10.1016/j.bir.2021.07.006

Kim, K.-H., Kim, M., & Qian, C. (2018). Effects of corporate social responsibility on corporate financial performance: A competitive-action perspective. *Journal of management*, *44*(3), 1097-1118. https://psycnet.apa.org/doi/10.1177/0149206315602530

Kim, S., Lee, G., & Kang, H. G. (2021). Risk management and corporate social responsibility. *Strategic Management Journal*, *42*(1), 202-230. https://doi.org/10.1002/smj.3224

Klingebiel, R. (2012). Options in the Implementation Plan of Entrepreneurial Initiatives: Examining Firms' Attainment of Flexibility Benefit. *Strategic Entrepreneurship Journal*, *6*(4), 307-334. https://doi.org/https://doi.org/10.1002/sej.1142

Koller, T., Nuttall, R., & Henisz, W. (2019). Five ways that ESG creates value. *The McKinsey Quarterly*.

Kong, X., Zhang, X., Yan, C., & Ho, K.-C. (2022). China's historical imperial examination system and corporate social responsibility. *Pacific-Basin Finance Journal*, *72*, 101734. https://doi.org/https://doi.org/10.1016/j.pacfin.2022.101734

Li, Y., Gong, M., Zhang, X.-Y., & Koh, L. (2018). The impact of environmental, social, and governance disclosure on firm value: The role of CEO power. *The British Accounting Review*, *50*(1), 60-75. https://doi.org/https://doi.org/10.1016/j.bar.2017.09.007

Liang, H., & Renneboog, L. (2017). On the foundations of corporate social responsibility. *The Journal of Finance*, *72*(2), 853-910. https://doi.org/10.1111/jofi.12487

Lins, K. V., Servaes, H., & Tamayo, A. (2017). Social capital, trust, and firm performance: The value of corporate social responsibility during the financial crisis. *the Journal of Finance*, *72*(4), 1785-1824. https://doi.org/10.1111/jofi.12505

Luo, Y., & Liao, W.-C. (2023). Does ESG Guide Chinese Stock Investment with Economic Policy Uncertainty in Trade War. *Available at SSRN 4631649*. https://dx.doi.org/10.2139/ssrn.4631649

Magrizos, S., Apospori, E., Carrigan, M., & Jones, R. (2021). Is CSR the panacea for SMEs? A study of socially responsible SMEs during economic crisis. *European Management Journal*, *39*(2), 291-303. https://doi.org/10.1016/j.emj.2020.06.002

Meyer, J. W., & Rowan, B. (1977). Institutionalized Organizations: Formal Structure as Myth and Ceremony. *American Journal of Sociology*, *83*(2), 340-363. https://doi.org/10.1086/226550

Mohieldin, M., Wahba, S., Gonzalez-Perez, M. A., & Shehata, M. (2022). SDGs and the 2030 Agenda: On Crisis and Opportunity. In *Business, Government and the SDGs: The Role of Public-Private Engagement in Building a Sustainable Future* (pp. 1-17). Springer. https://doi.org/10.1007/978-3-031-11196-9_1

Myers, S. C. (1977). Determinants of corporate borrowing. *Journal of Financial Economics*, *5*(2), 147-175. https://doi.org/https://doi.org/10.1016/0304-405X(77)90015-0

Naseer, M. M., Guo, Y., & Zhu, X. (2025). When climate risk hits corporate value: The moderating role of financial constraints, flexibility, and innovation. *Finance Research Letters*, *74*, 106780. https://doi.org/https://doi.org/10.1016/j.frl.2025.106780

Naseer, M. M., Khan, M. A., Bagh, T., Guo, Y., & Zhu, X. (2024). Firm climate change risk and financial flexibility: Drivers of ESG performance and firm value. *Borsa Istanbul Review*, *24*(1), 106-117. https://doi.org/https://doi.org/10.1016/j.bir.2023.11.003

Ortiz Almeyda, M., & Velasco González, M. D. P. (2021). The value of a firm’s engagement in ESG practices: Are we looking at the right side? https://doi.org/10.1016/j.lrp.2021.102143

Ozkan, A., Temiz, H., & Yildiz, Y. (2023). Climate Risk, Corporate Social Responsibility, and Firm Performance. *British Journal of Management*, *34*(4), 1791-1810. https://doi.org/https://doi.org/10.1111/1467-8551.12665

Rahi, A. F., Akter, R., & Johansson, J. (2021). Do sustainability practices influence financial performance? Evidence from the Nordic financial industry. *Accounting Research Journal*, *35*(2), 292-314. https://doi.org/10.1108/ARJ-12-2020-0373

Richardson, A. J., & Welker, M. (2001). Social disclosure, financial disclosure and the cost of equity capital. *Accounting, organizations and society*, *26*(7-8), 597-616. https://doi.org/10.1016/S0361-3682(01)00025-3

Sautner, Z., Van Lent, L., Vilkov, G., & Zhang, R. (2023). Firm-Level Climate Change Exposure. *The Journal of Finance*, *78*(3), 1449-1498. https://doi.org/https://doi.org/10.1111/jofi.13219

Schuler, D. A., & Cording, M. (2006). A corporate social performance–corporate financial performance behavioral model for consumers. *Academy of management Review*, *31*(3), 540-558.

Shahzad, K., Shah, S. Q. A., Lai, F.-W., Jan, A. A., Shah, S. A. A., & Shad, M. K. (2023). Exploring the nexus of corporate governance and intellectual capital efficiency: from the lens of profitability. *Quality & Quantity*, *57*(3), 2447-2468. https://doi.org/10.1007/s11135-022-01472-z

Shiu, Y. M., & Yang, S. L. (2017). Does engagement in corporate social responsibility provide strategic insurance-like effects? *Strategic management journal*, *38*(2), 455-470. https://doi.org/10.1002/smj.2494

Teng, X., Wang, Y., Wang, A., Chang, B.-G., & Wu, K.-S. (2021). Environmental, social, governance risk and corporate sustainable growth nexus: Quantile regression approach. *International Journal of Environmental Research and Public Health*, *18*(20), 10865. https://doi.org/10.3390/ijerph182010865

Tong, T. W., & Reuer, J. J. (2006). Firm and industry influences on the value of growth options. *Strategic organization*, *4*(1), 71-95. https://dx.doi.org/10.2139/ssrn.858164

Trigeorgis, L., & Lambertides, N. (2014). The Role of Growth Options in Explaining Stock Returns. *Journal of Financial and Quantitative Analysis*, *49*(3), 749-771. https://doi.org/10.1017/S0022109014000118

Trigeorgis, L., & Reuer, J. J. (2017). Real options theory in strategic management. *Strategic management journal*, *38*(1), 42-63. https://doi.org/10.1002/smj.2593

Velte, P. (2017). Does ESG performance have an impact on financial performance? Evidence from Germany. *Journal of global responsibility*, *8*(2), 169-178. https://doi.org/10.1108/JGR-11-2016-0029

Wang, H., Barney, J. B., & Reuer, J. J. (2003). Stimulating firm-specific investment through risk management. *Long range planning*, *36*(1), 49-59. https://doi.org/10.1016/S0024-6301(02)00203-0

Weber, O. (2014). Environmental, Social and Governance Reporting in China. *Business Strategy and the Environment*, *23*(5), 303-317. https://doi.org/https://doi.org/10.1002/bse.1785

Wong, W.-K., Cheng, Y., & Yue, M. (2024). Could regression of stationary series be spurious? *Asia-Pacific Journal of Operational Research*, 2440017. https://doi.org/10.1142/S0217595924400177

Xie, J., Nozawa, W., Yagi, M., Fujii, H., & Managi, S. (2019). Do environmental, social, and governance activities improve corporate financial performance? *Business Strategy and the Environment*, *28*(2), 286-300. https://doi.org/https://doi.org/10.1002/bse.2224

Yadav, A., Gyamfi, B. A., Agozie, D. Q., Asongu, S. A., & Behera, D. K. (2025). Unveiling the Dynamics of Green Innovation on ESG Performance: The Role of Financial Distress and the Impact of the Paris Agreement. *Thunderbird International Business Review*. https://doi.org/https://doi.org/10.1002/tie.70042

Yang, B., Zhu, C., Xiang, C., & Cao, Y. (2025). Honesty pays off: Climate risk disclosure credibility and firm value. *Finance Research Letters*, *86*, 108414. https://doi.org/https://doi.org/10.1016/j.frl.2025.108414

Zhang, J., & Shuang, Z. (2021). Socially responsible investment and firm value: The role of institutions. *Finance Research Letters*, *41*, 101806. https://doi.org/10.1016/j.frl.2020.101806

Appendix

Table A1. Panel Stationarity Tests Under Cross–Sectional Dependence and Independence

Variables	1st Generation	2nd Generation
	ADF-Fisher	IPS W-Statistic
TR	-13.04***	21.18***
GOV	-8.96***	-3.58***
Independent Variables		
CVR	-12.11***	-12.65***
Moderating Variables		
ESG Investments	-21.52***	-3.11***
Firm-Specific		
TAG	-6.47***	13.02***
FOCF	3.68	-8.71***
SIZE	-6.21***	-2.48***
SG	-17.39***	-12.36***
LEV	-9.72***	-8.76***
Macroeconomic		
INFR	-6.58***	-1.83**
GDPP	-3.55***	-6.69**

Note: Table A1 presents the results of panel data stationarity evaluations using both first- and second-generation unit root tests. The ADF–Fisher and IPS W-statistics indicate that the variables exhibit stationarity when assuming cross-sectional independence. To account for potential interdependencies among cross-sections, second-generation unit root tests were also applied. Overall, the results verify that each variable is integrated at a suitable order for panel analysis, ensuring the validity and robustness of the forthcoming regression estimations.
Source: Author's Own Calculations.

Table A2. Normality and Linearity Diagnostics of Models' Residuals

Variables	Jarque-Bera	Probability	Results	F. Stat.	Probability
TR	1.934	0.380	ND	2.115	0.127
GOV	2.472	0.290	ND	1.983	0.142
Independent Variables					
CVR	1.682	0.431	ND	1.746	0.173
Moderating Variables					
ESG Investments	3.024	0.221	ND	2.238	0.118
Firm-Specific					
TAG	1.318	0.517	ND	1.685	0.184
FOCF	2.705	0.259	ND	1.926	0.149
SIZE	1.557	0.458	ND	1.789	0.168
SG	2.389	0.303	ND	2.015	0.137
LEV	1.921	0.382	ND	1.967	0.146
Macroeconomic					
INFR	2.612	0.271	ND	1.842	0.159
GDPP	1.764	0.414	ND	1.978	0.145

Source: Authors' Own Calculations. ND stands for not detected.

Table A3. List of Abbreviations

Tobin Q Ratio	TR
Growth Option Value	GOV
Climate Variability Risk	CVR
Assets Tangibility	TAG
Operating Cash Flow	OCF
Firm Size	SIZE
Sales Growth	SG
Financial Leverage	LEV
Inflations Rate	INFR
GDP Per Capita Growth	GDPP
Environmental, Social, and Governance	ESG