



**University of  
Sheffield**

**Three Essays on Corporate Climate  
Activism of Non-financial Firms**

*by*

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degree of Doctor of Philosophy

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## Declaration

I declare that this PhD thesis is the result of my independent effort and original work, except where specific references are cited in the text. I remain fully mindful of the University of Sheffield's guidelines on the use of unfair means ([www.sheffield.ac.uk/ssid/unfair-means](http://www.sheffield.ac.uk/ssid/unfair-means)). The essays written for this thesis have not been submitted elsewhere for any type of qualification or degree. However, essays of this thesis have been submitted to scholarly journals and presented at various PhD seminars and international conferences. I also confirm that generative AI or AI-facilitated applications have only been used in the thesis writing process in order to improve the readability and clarity of the thesis language. Finally, I do not apply any kind of AI tool to analyze empirical data and draw insights from the data used in this research.

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## Abstract

This PhD thesis investigates the climate activism of non-financial firms. It focuses on UK and US firms to examine whether and how climate activism influences firm-level substantive environmental performance measures as well as financial outcomes. This thesis comprises three standalone essays. Taken together, it offers new insights into the climate activism of non-financial firms that are exposed to direct and indirect carbon emissions. Below is a summary of each essay.

The first essay examines the effect of climate risk governance and green transformation initiatives on carbon mitigation performance. Based on a unique dataset of compliant non-financial carbon-sensitive UK-listed firms, this essay provides evidence that climate risk governance mechanisms and green transformation initiatives enhance actual carbon performance by lowering actual carbon emissions. Further analysis shows that the combined effect of climate risk governance and green transformation initiatives helps attain sustained carbon mitigation performance. To put it plainly, the combined effect of both drivers indicates the quality of institutional transformation that is responsible for reducing carbon emissions. This study has significant implications for board members, CEOs, regulators, and other stakeholders regarding reforms in governance mechanisms and sustainable transformation.

Utilizing the non-financial components of the S&P 500 index, the second essay provides novel empirical evidence that climate risk governance is associated with environmental innovation. We find that firms with resilient climate risk governance appear to engage more in eco-driven innovative approaches to lower environmental costs and the burden on customers. This essay also demonstrates the channel through which climate risk governance supports environmental innovation. The empirical outcomes of this study contribute to the global debate on eco-friendly innovations that encourage sustainable business avenues and help limit the adverse impact of climate change.

The third essay looks into the effects of firm-level actual environmental investment, a fundamental aspect of tangible environmental engagement and risk management, on firm financing decisions and the cost of debt in US firms. Reusing the sample employed in the second essay, this study shows that firms that spend on environmental initiatives tend to boost their use of financial leverage. We also find evidence that a higher level of environmental investment is negatively related to the cost of debt. However, this negative association between environmental investment and the cost of debt financing is more pronounced for small firms as opposed to their larger counterparts. The empirical outcomes of this essay provide noteworthy insights for socially responsible investors, executive management, and regulators regarding firm-level substantive environmental engagements and financing decisions.

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## List of Acronyms

CDP	Carbon Disclosure Project
CEO	Chief Executive Officer
COD	Cost of Debt
CO <sub>2</sub>	Carbon Dioxide
CRG	Climate Risk Governance
CSR	Corporate Social Responsibility
DID	Difference-in-Differences
ESG	Environmental, Social, and Governance
FE	Fixed Effects
FTSE	Financial Times Stock Exchange
GHG	Greenhouse Gas
GMM	Generalized Method of Moments
GRI	Global Reporting Initiatives
GTI	Green Transformation Initiatives
IPCC	Intergovernmental Panel on Climate Change
IV	Instrumental Variable
MTB	Market to Book
NASDAQ	National Association of Securities Dealers Automated Quotations
NYSE	New York Stock Exchange
OLS	Ordinary Least Squares
TCFD	Task Force on Climate-Related Financial Disclosure
PSM	Propensity Score Matching
ROA	Return on Assets
ROE	Return on Equity
RBV	Resource-Based View
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNGC	United Nations Global Compact

## Chapter 1

# Introduction

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## 1.1 Background

As stated in a report from the United Nations<sup>1</sup>, 2023 was the warmest year ever recorded since modern recordkeeping commenced in 1850. Regrettably, the last decade (2014–2023) has been characterized by the ten warmest years in the 174-year record<sup>2</sup>. As a result, in our atmosphere, CO<sub>2</sub> and other harmful gases reached a record-breaking level. In this regard, the Paris Agreement 2015, a legally binding international consensus, has primarily intended to quicken global realization and response to mitigate the climate change risk. In line with this, the agreement set plans for gripping the unpleasant temperature rise well below 2 degrees Celsius and making concerted efforts to lower such an increase even up to 1.5 degrees Celsius (Rogelj et al., 2016). Countries accordingly submitted their anticipated Nationally Determined Contributions (NDCs) that indicate their effort for climate change actions in the period after 2020. According to Deutch (2020), a 45% reduction in carbon emissions by the year 2030 and a net-zero status target by the end of 2050 are still achievable. However, as of today, the efforts made by the government, public, and private sectors in relation to ongoing targets and ambitions tend to be inadequate.

The rapid surge in CO<sub>2</sub> emissions over the past couple of decades has resulted in global warming; this situation has sparked extensive policy debates globally (Churchill et al., 2019). Accordingly, to limit the adverse effects of climate change and ensure environmental safety and a more habitable world, we must prioritize the fields of related research, collaboration, investment, transformation, and adaptation. There is no denying that the success of all the efforts relies heavily on the actions of major corporations in developed nations and the main contributors to pollution. Hence, it is crucial that international bodies, governments, civil societies, environmentalists, and NGOs work closely together to meet the milestones (Haque and Ntim, 2022). Given this context, it is intriguing to examine and understand how carbon-sensitive business enterprises attempt to address climate change issues and environmental nightmares. This thesis, spread into three particular essays, focuses on the environmental engagements of non-financial firms that are accountable for direct and indirect emissions.

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<sup>1</sup> <https://www.un.org/sustainabledevelopment/climate-change/> (Accessed on July 10, 2024)

<sup>2</sup> <https://www.metoffice.gov.uk/> (Accessed on July 18, 2024)

## 1.2 Gaps in Related Literature

Existing literature leaves critical gaps in understanding how different governance mechanisms impact carbon performance. The mixed outcomes observed raise important questions about the overall efficacy of traditional governance mechanisms (Haque, 2017; Haque and Ntim, 2020; Luo, 2019; Moussa et al., 2019). It is argued that these mechanisms often fall short of adequately addressing the scope of climate-related commitments and sustainable business practices (Bui et al., 2020; Luo and Tang, 2020). In contrast, a climate-focused governance framework is increasingly essential, as it enables firms to navigate the multifaceted challenges posed by climate change while balancing regulatory compliance, environmental protection, and sustainable operations (Albitar et al., 2022; Bui et al., 2020). However, the extent to which such frameworks substantively influence carbon mitigation performance remains unclear, warranting further investigation. Moreover, the literature predominantly centers on carbon reduction initiatives, which, despite their prevalence, have often failed to significantly enhance actual carbon performance (Haque, 2017; Haque and Ntim, 2020; Moussa et al., 2019). Prior studies frequently emphasize symbolic measures that lack transformative potential (Haque, 2017; Moussa et al., 2019). The lack of knowing tangibly verifiable transformative initiatives hinders the ability to accurately assess a firm's commitment to implementing meaningful changes and progress in reducing carbon footprints. Building on the above, the first empirical essay aims to address these important unresolved research gaps by proposing two rigorous determinants of actual carbon mitigation performance.

Increasing socio-environmental pressures and global awareness of climate change have led to the emergence of climate-focused board processes in executive decision-making (Gerged et al., 2021). It is also argued that boards prioritizing climate-focused governance and sustainability are better equipped to mitigate greenwashing practices (Bui et al., 2020), reduce the adverse impacts of climate change (Galbreath, 2010), and capitalize on opportunities tied to environmentally responsive business models (Drobotz et al., 2023). As observed, the extant literature on climate governance primarily focuses on carbon disclosure (Bui et al., 2020) and organizational commitments to climate change (Albitar et al., 2023). Despite this, the relationship between climate risk governance and one critical element of sustainable business—environmental innovation—remains unknown. This raises the question of whether climate risk governance significantly drives firm-level environmentally friendly innovation. Therefore, empirical essay two seeks to explore this gap in the related literature.

Earlier literature accentuates the strategic importance of environmental investment as a potential driver for not only substantive environmental performance but also firm financing decisions and financial resilience (Atif et al., 2022; Pekovic et al., 2018). Despite its considered significance, the existing literature lacks a comprehensive investigation into the impact of environmental investment—a more tangible and substantial indicator of firm-level environmental activism—on financial leverage decisions. While a limited number of studies have explored the relationship between environmental, social, and governance (ESG) factors or other measures of environmental performance and firm financial leverage (e.g., Fernández-Cuesta et al., 2019; Kalash, 2021), the conventional reliance on ESG metrics or disclosure-based environmental performance measures does not always capture genuine environmental engagement. These commonly used measures are susceptible to greenwashing practices, where firms misrepresent their environmental commitment (Mahoney et al., 2013). Such misrepresentation can result in equity mispricing (Lin et al., 2023), raising concerns about the reliability and applicability of ESG data and causing controversy around its use (Yu et al., 2020). Further, a growing body of research has also looked at the link between environmental performance and the cost of capital (e.g., El Ghoul et al., 2018; Eliwa et al., 2021; Fonseka et al., 2019). However, it remains unclear whether environmental investments made by firms influence the cost of debt. Addressing the gaps in the related literature outlined above, the third and final empirical essay seeks to establish a link between environmental investment and firm financial leverage. It also attempts to explore the potential relationship between environmental investment and the cost of borrowing.

## 1.2 Essay One

It is argued that typical governance attributes may not be sufficient to translate climate activism into the board's decision-making process (Arena et al., 2018; Bui and de Villiers, 2017; Bui et al., 2020). Setting that aside, the majority of climate protection initiatives appear to reflect process-based carbon performance only (Haque, 2017; Haque and Ntim, 2020; Orazalin et al., 2023). Therefore, considering both streams, the first essay of this thesis aims to shed light on a governance framework that explicitly concentrates on climate change issues to enhance actual carbon performance. Next, this essay outlines a series of initiatives, collectively defined as green transformation initiatives, to provide a comprehensive picture of the substantive efforts to fight climate change in general and improve carbon performance in particular. Finally, this essay also analyzes the collaborative effect of climate risk governance and green transformation initiatives, which might reflect the firm-level quality of transformation. Accordingly, it demonstrates how the firm-level quality of transformation improves actual carbon performance. Taken together, the purpose of the first essay is to provide empirical evidence to address the following three questions: i) Does climate risk governance drive substantive carbon mitigation performance by minimizing actual carbon emissions? ii) Do the green transformation initiatives improve carbon performance by reducing actual carbon emissions? iii) Does the interaction term between climate risk governance and green transformation initiatives strengthen carbon mitigation performance by lowering actual emissions?

UK carbon-driven firms are now more committed than ever before to reducing carbon footprints and achieving the 2050 net-zero objectives in response to the national climate change strategy. To begin with, we look at 600 constituents of the FTSE All-Share Index based on the following three criteria: i) The firms publish yearly sustainability or environmental impact reports; ii) They have board-level environmental or sustainability committees. After excluding the banks and related financial institutions and the missing values, we eventually observe that 276 firms comply with one or both of the set conditions. Thus, the first essay utilizes 276 UK-listed compliant firms for the period between 2011 and 2020 to examine whether climate risk governance and green transformation initiatives drive substantive carbon performance. The selection of the study period from 2011 to 2020 is based on two primary reasons. First, in the last decade, the entire world has faced massive environmental challenges that necessitate substantial environmental accountability. Second, during this period, the executive

management of firms sensitive to carbon emissions has become increasingly vigilant about climate change issues.

### 1.3 Essay Two

It is evident that implementing environmentally sustainable creative processes, accompanied by socially responsible business practices, may significantly help reduce carbon emissions and protect the climate (Asongu and Odhiambo, 2021; Costantini et al., 2017). Adopting eco-friendly innovation measures within a firm creates a creative atmosphere, allowing it to develop environmentally efficient and viable technologies to limit unfavorable environmental liabilities to its customers, business partners, other stakeholders, and society as a whole. In the second essay, we aim to present climate risk governance as a robust determinant of firm-level environmentally safe and sound innovations. This essay attempts to find the answer to the main research question: Can climate risk governance affect environmental innovation? It also aims to seek an answer to the following: Is there a mechanism by which climate risk governance can facilitate eco-friendly innovation? Environmental innovation differs from conventional innovation in that its main goal is to enhance environmentally safe business practices (Zhang and Walton, 2017). Accordingly, in the second essay, we attempt to show whether and how climate risk governance drives firm-level eco-innovation. There is a widespread belief that environmentally friendly innovations are strongly associated with both environmental spending and research and development (R&D) activity (Raymond and St-Pierre, 2010). Hence, this study reveals a mechanism, i.e., environmental investment, through which climate risk governance strengthens firm-level capacity and the scope of environmental innovation. We rely on the S&P 500 capital market index, which encompasses the largest publicly quoted firms. Firms with significant market capitalization are normally exposed to a variety of state-imposed directives and societal expectations to take the lead in implementing climate change initiatives and responsibly engage in environmental innovation. This study, based on two already mentioned reasons, has chosen the data period from 2011 to 2021 to gather the required data and conduct empirical analysis. In addition, the rationale for selecting 2011 as the beginning year is to rule out the influence of the global financial crisis. Overall, to investigate this empirically, this essay employs a panel of 4378 firm-year observations derived from 398 non-financial S&P 500 constituents between 2011 and 2021.

## 1.4 Essay Three

In the third and final essay, we shift our focus from environmental outcomes to firm financial outcomes. Prior research has largely paid attention to assessing the effect of environmental performance on firm financial performance (Zhou et al., 2023) and financial leverage (Kalash, 2021). In the same vein, a handful of studies show how carbon emissions and sustainability performance affect the cost of borrowing (such as Eliwa et al., 2021; Li et al., 2014). However, thus far, there has been an absence of a focused study in the extant literature that examines the effect of environmental spending, an essential component of environmental activism and risk management, on capital structure decisions and the cost of borrowing. Taking the above arguments into account, this essay aims to deal with the following two questions: i) Does investing in environmental activities increase the firm's financial leverage? ii) Does investing in environmental initiatives lower the cost of debt capital? Accordingly, this essay empirically analyzes the influence of firm-level actual environmental investment on firm financing decisions and the cost of debt. The study uses 4,376 firm-year observations from the non-financial S&P 500 constituents that are sensitive to both direct and indirect emissions between 2011 and 2021. As indicated earlier, S&P 500 firms are considered global exemplars of sustainability and environmental performance. This essay regards 2011 as the beginning year for data collection. First, it will help preclude the potential effect of the global financial crisis and its subsequent consequences, thereby confirming the consistency and acceptability of the empirical analysis. Second, in developed countries, considerable progress has been made in corporate environmental activism in the form of environmental disclosure practices, sustainability performance, and the advent of regulatory requirements.

Of particular note, in all three essays, banks and other financial institutions are omitted from our final sample because they are not subject to direct carbon emissions and are responsible for only a limited magnitude of indirect emissions. Furthermore, the regulatory framework imposed on these institutions leads to corporate governance practices different from those of non-financial firms (Luo and Tang, 2020; Orazalin, 2020).

## 1.5 Main Findings and Contributions to Literature

In the first essay, we offer two rigorous determinants of carbon mitigation performance (CMP) within the UK context. This essay uses a sample of 276 carbon-sensitive, non-financial UK-listed firms from 2011 to 2020. It is based on a multi-theoretical framework that combines the predictions of agency theory, neo-institutional theory, and the resource-based view. Our findings indicate that CRG significantly enhances CMP by effectively reducing carbon emissions. Additionally, we provide evidence that GTI is negatively associated with carbon emissions, demonstrating that firms adopting higher levels of transformation initiatives can achieve optimized, substantive CMP. Importantly, our empirical analysis reveals that the combined effect of CRG and GTI ( $CRG \times GTI$ ) further strengthens CMP. This synergy suggests that the integrated implementation of CRG and GTI encourages improved institutional transformation processes, eventually contributing to sustained CMP. To address potential endogeneity concerns and mitigate sample selection bias, we employ a range of identification strategies, including instrumental variable (IV) analysis using two-stage least squares (2SLS) regressions, difference-in-differences (DiD) analysis as a quasi-natural experiment, and the Heckman two-stage selection model. We also conduct additional robustness checks using an alternative outcome variable and estimation methods. Our results remain robust across these identification strategies and additional analyses.

In the second empirical essay, we look at the link between climate risk governance (CRG) and environmental innovation. We examine this by using a sample of 4,378 firm-year observations from 398 non-financial firms in the S&P 500 index between 2011 and 2021. Drawing on the resource-based view and agency theory, our findings demonstrate a significant positive association between CRG and environmental innovation. This relationship is notably stronger for larger firms with a robust focus on climate risk governance compared to smaller firms. To address potential endogeneity concerns, we employ instrumental variable (IV) analysis and propensity score matching (PSM), confirming the robustness of our results. Channel analysis further reveals that CRG mechanisms drive firm-level environmental expenditures, which subsequently increase the capacity and potential for environmental innovation. In order to mitigate sample selection bias, we utilize the two-stage Heckman selection model. In addition, we conduct robustness checks using various estimation techniques, including fixed-effects (FE) models and generalized method of moments (GMM) regressions. Alternative measures

for the outcome variable are also explored. Overall, the baseline estimates remain consistent and robust across all analyses.

In the third and final essay, using a panel of 4,376 firm-year observations from non-financial S&P 500 firms over the period 2011–2021, we provide evidence that firms' spending on environmental activities is positively associated with their use of financial leverage. We argue that firms demonstrating a commitment to environmental safety and investment in environmental activities are more attractive to lenders. Further analysis reveals that increased environmental investment is linked to a lower cost of borrowing. Our findings remain robust after addressing potential endogeneity concerns through instrumental variable (IV) analysis and propensity score matching (PSM) methods. To mitigate sample selection bias, we also employ the Heckman two-stage selection model. Moreover, we conduct robustness checks and apply alternative estimation techniques to validate our results. Overall, the baseline estimates remain consistent and resilient across all identification strategies, sub-samples, and additional analyses.

This thesis primarily contributes to the literature related to climate governance. Besides, it expands the body of knowledge related to environmental sustainability and carbon performance. In addition, this thesis also extends the existing corporate capital structure literature. All three essays in this thesis have made specific contributions to the relevant literature, which are listed below:

The first essay enriches the existing climate change and carbon-related literature by showing a groundbreaking pathway through which climate-focused governance maximizes carbon mitigation performance by minimizing actual carbon emissions. Moreover, this study accounts for a long-term perspective and also includes the governance measures that explicitly address the shortcomings of the previous research (Bui et al., 2020) in constructing the climate risk governance index. Next, this research contributes distinctly to the existing literature by introducing a set of activities targeted toward green transformation. Unlike previous symbolic measures (for instance, Haque, 2017; Luo and Tang, 2020; Moussa et al., 2019) based on dummy variables, GTI aims for a structural shift toward sustainable business, environmental safety, and net zero status. The GTI index incorporates novel, hand-collected data based on an exhaustive content analysis of environmental and sustainability reports, making the transformation initiatives tangibly verifiable rather than mere lip service. Overall, GTI is regarded as robust and practical because it evaluates firm responses across three levels,

indicating the extent of the actual transformation. Further, this study reveals empirical evidence that the stronger the combination of CRG and GTI, the greater the quality of firm-level transformation and the greater the carbon performance. Unlike previous studies, this research presents a new understanding of the combined impact of climate-based governance and green transformation, emphasizing the quality and extent of firm-level transformation, which is responsible for sustained actual carbon performance. Finally, this study also delivers additional insight into extant literature as it employs quasi-natural experimentation using the Difference-in-Differences (DID) estimation technique to assess the effect of a climate accord, specifically the Paris Agreement 2015, on firm-level climate risk governance practices and green transformative actions with the aim of improving carbon performance.

In the second essay, an original empirical analysis of the nexus between climate risk governance and environmental innovation has been performed. A narrow body of research has analyzed the effect of climate-related governance mechanisms on carbon disclosures (Bui et al., 2020) and commitments towards climate protection (Albitar et al., 2023). Nevertheless, eco-friendly innovation, a fundamental and more plausible instrument for reducing carbon footprints, bringing sustainability to current business models, and ensuring environmental safety, has not been addressed in the discussion. Hence, our empirical results are crucial to the environmental innovation literature. Next, by applying channel analysis, this study presents unique empirical evidence that climate risk governance facilitates environmentally sustainable innovations through the mechanism of environmental investment. Therefore, this finding contributes to the current body of knowledge (Alam et al., 2022; Li et al., 2020; Lyandres and Palazzo, 2016), implying that the pursuit of climate risk governance encourages firm-level expenditure on environmental initiatives, thereby increasing firm-level scope and capacity for environmental innovation. Furthermore, this study also conducts a subsample analysis on large and small firms to gain deeper insights. This further analysis extends the extant literature by presenting empirical evidence that the influence of climate risk governance on eco-innovation is more noticeable for large firms relative to their smaller counterparts.

The third and final essay adds to the extant literature, offering new evidence of the relationship between environmental investment and firm financial leverage. Environment-related investment is a crucial and visible indicator of environmental activism and performance. This type of important investment decision is predicted to have an impact on firm financing decisions, which has been addressed in this study. Hence, this empirical evidence extends the current body of knowledge concerning corporate capital structure (Fernández-Cuesta et al., 2019; Kalash, 2021; Nakamura, 2011; Shu et al., 2023). Moreover, this study also presents a novel analysis to ascertain whether and how spending on environmental initiatives affects the cost of debt. Therefore, the empirical result of this investigation makes a valuable contribution to the related literature (El Ghouli et al., 2018; Eliwa et al., 2021; Jung et al., 2018; Nandy and Lodh, 2012). Finally, this study represents the first empirical investigation from the US context, exploring the intricate association between environmental investment, firm financial leverage, and the cost of borrowing. This research adds to the current understanding of firm financing decisions by focusing on non-financial firms within the S&P 500 that are responsible for both scope one and scope two carbon emissions.

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Chapter 2

# Theoretical Framework

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## 2.1 Background

The purpose of the three standalone essays in this thesis is to investigate (i) whether climate risk governance and green transformation initiatives impact carbon mitigation performance; (ii) whether corporate climate risk governance affects firm-level eco-innovation; and (iii) whether there exists an association between environmental investment, firm financing choices, and the cost of borrowing. Following related empirical research on corporate governance mechanisms, boardroom attributes, and environmental outcomes, the three essays in this thesis are grounded in pertinent social science and management theories. In the first essay, agency theory, resource-based view, and neo-institutional theory have been employed within a multi-theoretical framework. The reason for relying on a multi-theoretical model is that one specific theoretical viewpoint lacks sufficient clarity to provide a more understandable theoretical underpinning for how climate risk governance and green transformation, as well as a combination of both variables, might influence actual carbon performance. In the second essay, the empirical investigation draws on the resource-based view and agency theory to support the potential link between climate risk governance and eco-innovation. Finally, the third essay builds on the trade-off theory of firm-level financing decisions to explain the impact of environmental investment on firm financial leverage and the cost of debt financing. The following discussion, based on literature-driven arguments, focuses on all the theories that are applied to explain the intricate association among the key variables of interest and support the development of hypotheses. Figure 1 outlines the overall theoretical framework pertinent to three empirical essays.

## 2.2 Agency Theory

According to agency theory, managers are designated as agents, and it is assumed that their interests may differ from those of the owners, i.e., shareholders. This is why the interests of principals are not in persistent conformity with those of agents. Therefore, a clash of interests stands among the interests of shareholders and the priorities of management (Fama and Jensen, 1983; Jensen and Meckling, 1976). As observed, a large body of available corporate governance literature has built on the extensively prevalent agency theory (for instance, Haque, 2017; Liao et al., 2015; Luo et al., 2012; Matsumura et al., 2014; Rankin et al., 2011; Taurigana and Chithambo, 2015; Ziegler et al., 2011). Climate protection initiatives and

climate-focused governance mechanisms necessitate long-term investments and related commitments, often without the prospect of immediate financial returns. Consequently, corporate managers with self-serving interests may be unwilling to allocate significant cash flows to such initiatives (Liao et al., 2015). Agency theory provides a framework for understanding this scenario, as it emphasizes the importance of implementing measures to limit informational asymmetry and mitigate conflicts of interest. For example, agency theory emphasizes the importance of monitoring roles within the board structure, particularly the formation and functioning of a subcommittee dedicated to environmental or sustainability issues. Moreover, according to the agency theory-driven governance model, compensation policy is viewed as a critical tool for minimizing agency problems and increasing firm performance. Thus, executive compensation linked to environmental or ESG performance is also in line with the predictions of agency theory (Cordeiro and Sarkis, 2008; Haque, 2017). In addition, external control instruments, such as government-advised reporting responsibilities or other regulatory directives, work effectively as predicted by this theory (Taurigana and Chithambo, 2015). Taken together, this study incorporates sustainability reporting, firm-level awareness of climate risk and opportunities, a corporate sustainability or environmental committee, plus sustainability or ESG-linked executive compensation to construct the overall climate risk governance index, following agency theory-based insights in the first two essays of this thesis. To sum up, agency theory reflects on the concerns emerging from the probable conflict of interests between outside shareholders and managers, as well as how to foster a robust governance structure and the required compliance.

### 2.3 Resource-based View

The resource-based view dates back to Wernerfelt (1984), who posits that firms might be considered a mixture of resources, and the effective management of the available resources is vital to gaining competitive advantage. Accordingly, the internal resources (a combination of both tangible and intangible resources) of a firm are the main source of long-term competitive edge (Barney, 1991). Grant (1991) also argues that businesses need to concentrate on recognizing, nurturing, and leveraging their distinctive resource base to develop strategies that align with their internal strengths. Hence, it is fair to consider that understanding the firm's resources allows for resilient decision-making and strategic planning (Grant, 1991). In related literature, the resource-based view has been extensively drawn upon as a theoretical underpinning. For example, Bear et al. (2010) support the notion that firms with the availability

of both tangible and intangible resources hold firm capabilities to achieve green climate-focused targets. Moreover, following the resource provisioning functions of corporate boards, de Villiers et al. (2011) investigate the impact of board dynamics on environmental performance from the US perspective. Likewise, Mallin and Michelon (2011) examine whether and how board characteristics are associated with corporate social performance. Luo et al. (2013) also argue that financial resources are essential to limiting and controlling carbon emissions, in support of the theoretical insights of boards' resource-based view. It is claimed that firms tend to leverage their resources to develop distinctive capabilities and proficiency that are instrumental to achieving a sustainable competitive benefit (Alam et al., 2019; Atif et al., 2022; Orazalin et al., 2023). Qiu et al. (2016) also contend that firms with an abundant mix of resources and know-how appear to considerably engage in corporate environmental and social projects. Likewise, Luo et al. (2013) investigate the link between internal resource constraints and carbon disclosure propensity, documenting that financial constraints may impede firm-level carbon disclosure efforts. However, due to greenwashing and other symbolic climate-based commitments (Bowen and Aragon-Correa, 2014; Bui et al., 2020; Haque, 2017), it is not always possible for all firms to secure a competitive advantage by developing dynamic internal capabilities and thereby ensuing environmental outcomes in a substantive manner, such as actual carbon performance and environment-friendly innovation. Hence, we argue that firms can achieve substantial environmental outcomes and maximize their long-term competitive advantage with the support of climate-focused governance that emphasizes managerial intent, firm-level actions, consistent compliance, and operational resilience.

Overall, climate-responsive governance at the firm level is linked to its resource-oriented approach (Backman et al., 2017). In the current context, we assume that the climate risk governance mechanisms align with firm-level resource provisioning to optimize their effectiveness. Therefore, in the first and second essays, the availability of resources (both tangible and intangible) acts as a cornerstone for the smooth functioning of strategic decisions and attaining substantive environmental performance when aligned appropriately with a resilient climate governance framework. The resource-based perspective helps to explain the complex affiliation not only between climate risk governance structure and actual carbon performance but also between climate risk governance and firm-level environmental innovation. In addition, we draw on the predictive power of the resource-based view, which advocates for the right use of necessary and intricate resources to adopt and reinforce green transformation initiatives to improve actual carbon performance.

## 2.4 Neo-institutional Theory

Firms adhere to the norms, directives, and anticipations of different institutions and stakeholders to safeguard and maintain their legitimacy, according to institutional theoretical insights (Berrone and Gomez-Mijia, 2009; DiMaggio and Powell, 1983). DiMaggio and Powell (1983) postulate three variants of institution-level isomorphism that illustrate the effect of institutional and societal pressure on businesses. Three variants of institutional isomorphism are summarized below:

First, coercive/regulative isomorphism is categorized as the mechanism by which institutional forces commonly exert direct (i.e., environmental regulations, governance guidelines) and indirect (i.e., expectations of the broader society for climate protection activism) pressure on firms to choose specific business standards and models that eventually lead to increased legitimacy and accountability. Second, cognitive/mimetic isomorphism is the mechanism by which firms respond to unpredictable events by imitating other firms' best practices, which appear to become more rational and effective (DiMaggio and Powell, 1983). Third, normative isomorphism is expected to hold whenever strong managerial networks and corporate social connections impact business processes and standards. In addition to recognizing the notable propositions of DiMaggio and Powell (1983); Oliver (1991) advocates a significant addition to the institutional theoretical framework by specifying a typology of a firm's strategic behavior in reaction to pressures to conform to institutional and societal expectations. It represents the basis for the institutional transformation (DiMaggio and Powell, 1983). Scott (2001) further extends the institutional theory (DiMaggio and Powell, 1983), arguing that firms' reactions to the three types of institutional isomorphism are propelled by two specific underlying motives, i.e., legitimacy-based motive and efficiency-based motive. In this way, following DiMaggio and Powell's (1983) predictions about institutional theory, Scott (2001, 2008) introduces the concept of neo-institutional theory.

As previously stated, in the first essay, we use GTI as a driver of carbon mitigation performance. To determine green transformation, we capture firm-level, actual initiatives based on hand-collected data. In doing so, we shed light on the firms' more substantive approach, which goes beyond mere process-driven arrangements. Therefore, institutional isomorphism with an efficiency motive is fundamental in explaining the association between GTI and carbon

mitigation performance. However, as observed, since many firms may prioritize superior symbolic initiatives to attract stakeholders and investors (Delmas et al., 2013; Haque, 2017), they often try to resort to the legitimacy motive (Haque and Ntim, 2020). By prioritizing only impression management, these firms implement carbon reduction measures or related activism that tend to be purely ornamental, with very little impact on substantive carbon performance. In contrast, in the first essay, institutional isomorphism with efficiency motive provides a more pertinent theoretical argument to justify the complex association between GTI and substantive carbon performance, as well as the moderating role of CRG in enhancing the negative relationship between GTI and carbon mitigation performance. In short, we posit that neo-institutionalism provides a more nuanced theoretical perception, specifically about how firms resort to the efficiency motive to adopt green transformative initiatives that help improve actual carbon performance.

## 2.5 Trade-off Theory

Lastly, in the third and final essay, we analyze whether spending on environmental engagements affects a firm's financial leverage and the cost associated with borrowing money. To explain the nexus among the test variables, we focus on the trade-off theory of firm financing choices, which is recognized as one of the fundamental concepts within the domain of corporate finance. In conformity with the trade-off theory of capital structure, firms intend to determine their capital structure by striking a balance between marginal benefits and the cost of borrowing (Bradley et al., 1984; Graham, 2003; Nguyen and Phan, 2020). On the contrary, the pecking order concept of corporate capital structure decisions posits that corporations give priority to and rank their choices when it comes to financing sources (Allen, 1993; Myers and Majluf, 1984). This concept is rooted in the premise that firms prioritize using their internal sources, such as retained earnings, rather than seeking external funding, and if external funding becomes necessary, they prefer debt over equity financing. However, in terms of the trade-off theory, one of the major advantages of incurring debt obligations is the tax-shield benefit. The interest costs on borrowing are tax-deductible, which lowers a firm's taxable profit and, therefore, its tax-related liability. This generates a significant incentive for firms to employ debt capital to take advantage of a reduced overall tax burden. It is argued that firm-level investment in environmentally sustainable projects is predicted to increase long-term shareholder wealth by generating multiple new business opportunities, strengthening the firm's environmental

reputation, and enhancing energy efficiency (de Villiers et al., 2011; Liao et al., 2015; Matsumura et al., 2014).

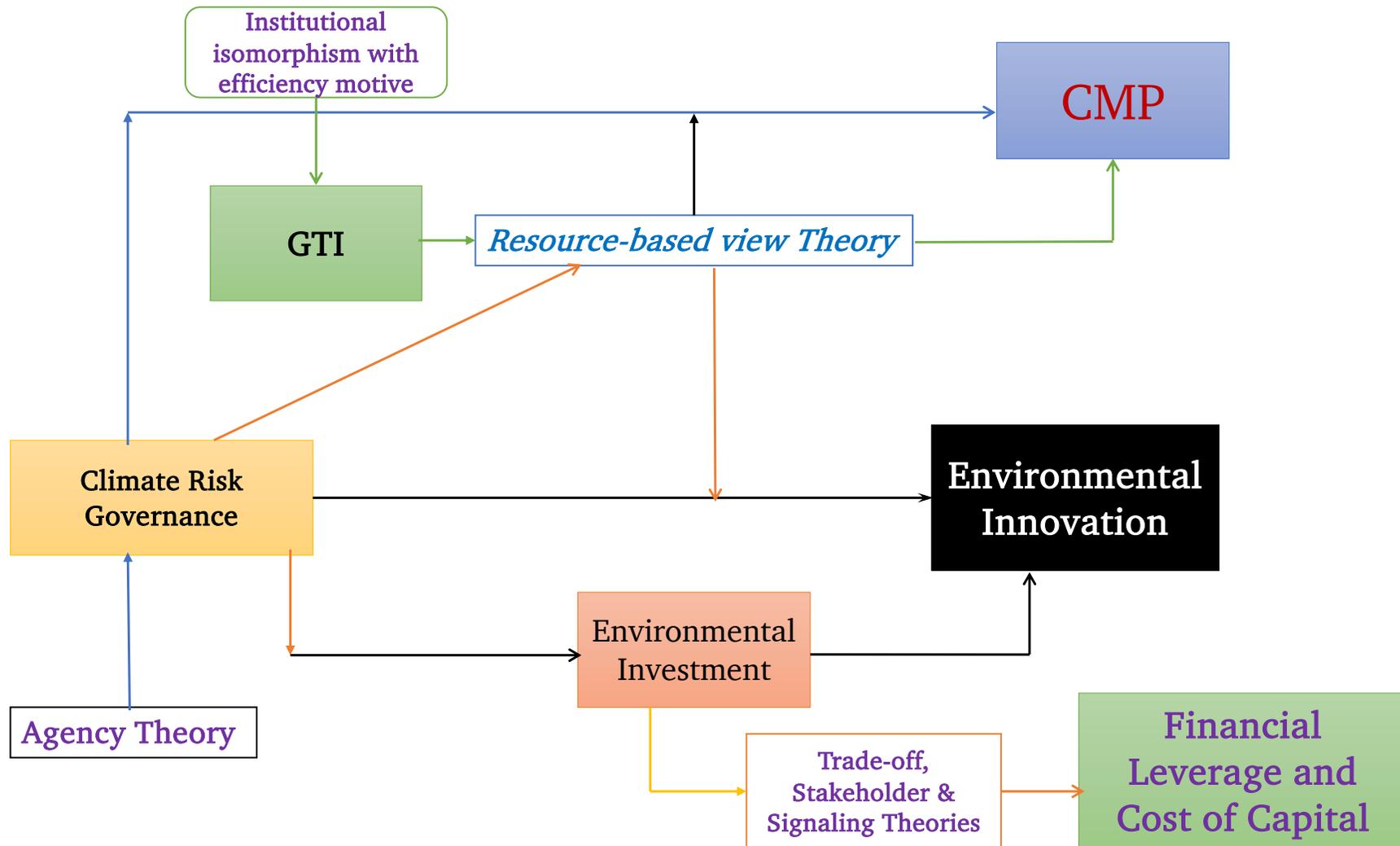
## 2.6 Stakeholder and Signaling Theories

Stakeholder theory highlights the significance of addressing the needs and interests of all stakeholders in a business rather than focusing exclusively on maximizing shareholder value. Stakeholders include anyone impacted by the firm's actions, such as employees, customers, suppliers, investors, communities, and the environment (Freeman, 2010). This theory posits that long-term success and sustainability rely on balancing and managing these diverse interests. In the realm of corporate finance and environmental investments, stakeholder theory suggests that firms that engage in socially responsible practices—like reducing their environmental impact—can strengthen relationships with key stakeholders. This can lead to reduced risks, improved reputation, and financial benefits. However, if stakeholders perceive environmental initiatives as mere greenwashing or if the firm has a history of environmental controversies, such investments may not yield more favorable financing terms (Lyon and Montgomery, 2015).

Signaling theory posits that firms communicate their intrinsic attributes or intentions via visible behaviors or signals. Signals are considered trustworthy only when they are expensive, thus successfully differentiating high-quality participants from low-quality ones (Spence, 1973). Signaling theory has been extensively used across several fields, including corporate strategy, organizational behavior, and environmental policy. Signaling theory predicts, in the context of environmental investment, that firms with superior environmental performance in mind will make visible and expensive environmental investments to show their genuine commitment to sustainability efforts, reduce the impact of the environment, and set themselves apart from their competitors.

Based on the above reasoning, in the present context, a theoretical approach informed by multiple theoretical perspectives—the trade-off theory, stakeholder theory, and signaling theory—is essential to comprehensively capture the cost-benefit dynamics of environmental investment and its explanatory power regarding financial leverage and the cost of debt.

Figure 01: The theoretical framework of this thesis



Source: Author's Proposition

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## Chapter 3

# Empirical Essay One

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# Climate Risk Governance, Green Transformation Initiatives, and Carbon Mitigation Performance<sup>3</sup>

## Abstract

This study investigates the effects of climate risk governance and green transformation initiatives on carbon mitigation performance. Using a sample of 276 compliant non-financial UK-listed firms from 2011 to 2020, we find that climate risk-focused governance mechanisms and green transformation initiatives aimed at structural transformation improve carbon performance by minimizing actual carbon emissions. Further, we reveal that the interaction between climate risk governance and green transformation initiatives—an indication of the quality of sustainable institutional transformation to address the impact of climate change—helps realize sustained carbon mitigation performance. The results of our study remain consistent after a battery of robustness checks and identification strategies. This study has important implications for executive management, policymakers, and other stakeholders with regard to governance structure reforms and green transformation at the firm level.

Keywords: Climate risk governance, Green transformation initiatives, Sustainability, Carbon mitigation performance

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<sup>3</sup> A shortened version of this essay has been recommended for revision and resubmission (R&R) to the *Journal of International Accounting, Auditing, and Taxation* (JIAAT) [ABS-3].

## 1. Introduction

Climate change, with an explicit focus on carbon mitigation on a global scale, is widely recognized as a major political and corporate concern at present (Mahmoudian et al., 2023). Following the 2015 Paris Climate Accord, COP26 and COP27 were attempts to draw global attention to the challenges of climate change. In recent years, climate governance and green transformation have emerged as key areas of research interest, with carbon emissions and climate change receiving attention from regulators, environmentalists, climate scientists, campaigners, members of corporate boards, and academics. Academic debate has highlighted issues surrounding the role of governance structures in devising climate and carbon strategies, as well as their impact on actual carbon mitigation performance (CMP). In this connection, the related literature reports inconclusive results regarding the implications of conventional governance systems for carbon performance (Haque, 2017; Luo, 2019; Moussa et al., 2019). Thus, the conventional governance measures do not seem to adequately incorporate climate-related commitments or management actions (Bui et al., 2020; Luo and Tang, 2020). Furthermore, the existing literature on carbon or climate-related disclosures generally argues that disclosures do not always guarantee substantive carbon performance (Luo, 2019; Braam et al., 2016; Shrivastava and Addas, 2014; de Villiers and van Staden, 2006). Alrazi et al. (2016) demonstrate that the governance mechanism concerning climate change works well in a holistic framework and facilitates prompt executive decisions. Nonetheless, past studies do not offer sufficient insights into climate-focused corporate governance, except for Bui et al. (2020), who examine the effects of climate governance measures on carbon disclosure. Therefore, the question of whether and how appropriate board-level climate activism could support carbon mitigation performance remains unanswered.

Motivated by this vital yet unresolved research question, we present a unique climate risk governance (CRG) framework alongside green transformation initiatives (GTI), a set of initiatives targeting environmentally sustainable transformation, by analyzing the individual impact of each determinant and their joint effect on actual carbon performance in the context of the UK. Furthermore, this study examines how the interaction term between CRG and GTI, a reflection of overall institutional transformation, might affect carbon performance. We know

that the UK Climate Change Act of 2008<sup>4</sup> puts forth a legally mandated aim of reducing carbon emissions by at least 80% relative to the levels recorded in 1990. Hence, we have taken compliant UK firms into account because they are subject to regulatory supervision as per the government's plan for carbon reduction. More importantly, over the years, these firms have played a leading role relative to other competing firms in implementing significant changes to their business practices in response to the ambitious national climate change policy. Hence, drawing on a multi-theoretical model driven by the predictions of agency, resource-based view, and neo-institutional theories and employing a total of 2050 observations derived from 276 compliant carbon-sensitive, non-financial UK-listed firms from 2011 to 2020, we find that CRG significantly improves CMP by reducing carbon emissions. Further, we show that GTI is negatively associated with carbon emissions, suggesting that firms that pursue a higher level of transformation initiatives can optimize substantive CMP. Our empirical analysis also reveals that an interaction variable between CRG and GTI (CRG\*GTI) strengthens CMP. This indicates that the interaction between CRG and GTI enables firms to enhance the quality of their institutional transformation, which ultimately helps to maintain sustained CMP. To address potential endogeneity concerns and sample selection bias, we employ appropriate identification strategies, such as instrumental variable analysis (IV), using 2SLS regressions, difference-in-difference (DiD) analysis, a quasi-natural experiment, and Heckman's two-stage model for sample selection bias. We also run additional analyses with an alternative outcome variable, sub-samples, and other estimation methods. Our baseline findings hold across the identification strategies and robustness checks.

Our study is positioned at the crossroads of two research paths in the extant literature employing typical board characteristics to predict climate change or carbon disclosure and carbon performance. The first path relies on carbon or climate change disclosure (for instance, Abbasi et al., 2024; Rankin et al., 2011; Liao et al., 2015; Jaggi et al., 2018; Elsayih et al., 2018; Wang et al., 2021). Since climate disclosure can be used as a greenwashing instrument to enhance corporate legitimacy and attain stakeholder acceptance (e.g., Mahoney et al., 2013; Haque, 2017), a critical question that remains unanswered is the extent to which carbon disclosure relates to carbon performance, and this study aims to address this. The second path concerns process-driven and/or actual carbon performance (e.g., Moussa et al., 2019; Luo and Tang, 2020). Interestingly, the typical governance variables in these studies focus on process-

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<sup>4</sup> <https://www.gov.uk/guidance/climate-change>

based carbon performance, which tends to be inadequate for explaining actual carbon performance. Thus, in contrast to this widely prevalent governance–disclosure–performance linkage that reports contradictory results, we take a novel angle by integrating the two research paths to investigate whether CRG accompanied by GTI helps firms to enhance their substantive carbon performance.

To the best of our knowledge, our study is the first in the climate change and carbon performance literature to offer two rigorous and dynamic CMP drivers. This study makes three important contributions to the literature. First, it introduces a unique CRG index that differs substantially from what was found in the existing literature (see Section 4.2.2.i and Appendix Table A2 for details). We address the shortcomings of the previous study by emphasizing uniformity and incorporating relevant components into the index. Our results show a strong negative relationship between the CRG index and CMP. Our findings are consistent with the arguments of agency theory in that the monitoring roles arising from a firm's economic perspectives—with awareness, compliance, reporting, incentives, and assurance—encourage firms to emphasize climate-focused governance mechanisms for superior firm-level environmental outcomes (i.e., carbon performance). In addition, when aligned appropriately with the available firm-level resources, climate risk governance is effective in influencing substantive carbon performance. Although Bui et al. (2020)<sup>5</sup> examine the relationship between climate governance measures and carbon disclosure by U.S. firms, our study differs from theirs significantly.

Second, this study makes a unique contribution to the extant literature by introducing an index of GTI. Based on a review of the related literature and numerous UN directives (see Section 4.2.2.ii and Appendix Table A3 for details), this study identifies a set of actions called GTI. Unlike other researchers' symbolic measures (e.g., Haque, 2017; Haque and Ntim, 2020), GTI implies a persistent structural shift toward an environmentally sustainable and carbon-neutral future. In several ways, GTI is anticipated to add unique value to the emerging literature as a

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<sup>5</sup> This study differs significantly from that of Bui et al. (2020) in three important ways. First, there are marked differences between the governance measures in this study and those in Bui et al. (2020); see discussions in section 4.2.2.i). Second, unlike Bui et al. (2020), we investigate the relationship between CRG and CMP. Third, unlike previous researchers, we document new insights into the interaction of climate-focused governance and green transformation to identify the extent and quality of the institutional transformation for sustained CMP.

driver of CMP. Firstly, GTI is more robust and practical because it considers the firm responses spread over three levels, reflecting the extent of the implementation. Secondly, the GTI index incorporates novel, hand-collected data based on an exhaustive content analysis of annual reports and sustainability reports, making the transformation initiatives tangibly verifiable and dynamic. Thus, the initiatives denote a transformative status, which is more plausible than the typical symbolic carbon reduction or climate change initiatives. Thirdly, the total score for the GTI indicates the firm's success in transitioning from a non-green operational status to a greener and more sustainable status in pursuit of reduced carbon emissions.

Finally, this is the first study to integrate two dynamic drivers through CRG-GTI interaction and examine the effect it might have on CMP. We investigate whether the interaction between CRG and GTI serves as a gateway to long-standing sustainability and carbon mitigation for both high-carbon and low-carbon emitting firms. We show that the interaction between CRG and GTI evidences firm-level capacity and reveals the overall quality of institutional transformation towards improved and sustained CMP. In other words, the greater the extent or quality of the transformation at the firm level, the lower the CO<sub>2</sub> emissions, and ultimately, the better the actual carbon performance. No attempt has been made in the extant literature to integrate climate governance and green transformation. The most relevant studies that analyze the impact of an interaction variable are those by Ntim and Soobaroyen (2013), Haque and Ntim (2018), and Haque and Ntim (2020). However, in the existing literature, no attempt has been made to integrate a climate governance framework and green transformative actions for the structural shift of a firm's operation. As a result, our perspective on an integrated effort between CRG and GTI can provide an all-encompassing system for sustained carbon mitigation performance.

The remainder of this work is structured in the following manner: Section two focuses on theory, provides a review of the existing literature, and constructs the hypotheses. Section four presents the data and empirical models, as well as a discussion of the empirical results. Lastly, section five concludes the essay by highlighting the contributions and policy suggestions.

## 2. Theory, Related Literature, and Development of Hypotheses

In this section, we shed light on agency, the resource-based view, and neo-institutional theories to develop the theoretical foundation of this study. The resource-based view suggests that firms with both tangible and intangible resources are better able to meet climate-focused targets. Previous studies have shown that board dynamics impact environmental performance and resource-provisioning functions at the firm level (de Villiers et al., 2011; Bear et al., 2010). Agency theory argues that the interests of principals may not align with agents', and the monitoring role ensures smooth governance (Fama and Jensen, 1983; Jensen and Meckling, 1976). With respect to institutional theory, DiMaggio and Powell (1983) propose three versions of institutional isomorphism that explain the impact of institutional or social pressure on businesses. Isomorphism is a restraining process by which an institution changes to follow other peer institutions confronting similar environmental circumstances. This theory also explains how regulatory bodies and other stakeholders shape and influence corporate environmental responsibilities across both developed and emerging economies (Dögl and Behnam, 2015). Further, drawing on the institutional theory posited by DiMaggio and Powell (1983), Scott (2001) argues that firms' responses to the three forms of institutional isomorphism are influenced by two primary motives: the intention to earn legitimacy and the pursuit of efficiency.

However, it is often argued that no single theory will be adequate to explain the intricate affiliation among the main variables of interest (Moussa et al., 2019; Xue et al., 2019). Moreover, every theoretical perspective has some limitations. For example, institutional isomorphism gives little attention to the disparities between principals and managers in their interests and priorities or to the availability of firms' physical resources. Resource-based view concentrates exclusively on the effects of firms' internal motivations, such as their resources and capabilities, while disregarding the external pressures from stakeholders with varied interests and regulatory directives. Likewise, even though agency theory focuses on the concerns resulting from prospective conflicts of interest among managers and shareholders (Jensen and Meckling, 1976; Eisenhardt, 1989), it is confined to emphasizing the monitoring roles of the board processes (Moussa et al., 2019). Considering the predictive power of relevant theoretical understanding, we draw on a multi-theoretical model for the following reasons.

First, a review of neo-institutional theory indicates that firms' reactions to regulative, cognitive, and normative social or institutional pressures are often prompted by two motives: legitimization (ornamental or symbolic) and efficiency (tangible or substantive) (Scott, 2001). With the legitimization motive, firms may symbolically conform to regulatory requirements, which can help them uphold and restore corporate legitimacy (Haque and Ntim, 2022; Ntim, 2016; Oliver, 1991). Symbolic actions, such as announcing climate-based targets, donating to environmental agencies or activists, and committing to carbon reduction, are unlikely to improve efficiency (Haque and Ntim, 2022). In contrast, an efficiency motive indicates that firms may engage in climate-change activism to protect their stakeholders' interests (Aguilera et al., 2007). Therefore, Neo-institutional theory, with its efficiency-based motive, provides a relevant theoretical argument to our research context for firms to deal with regulatory requirements and stakeholders' expectations by implementing substantive initiatives for green transformation. It is predicted that firms will be unable to limit their actual carbon footprints if they are heavily reliant on symbolic measures (persistent greenwashing attempts) and prioritize the legitimization motive. In contrast, efficiency-driven firms appear to be pursuing genuine climate-change actions for a structural shift to sustainable business (i.e., GTI) to maximize their carbon performance by minimizing actual carbon emissions over time.

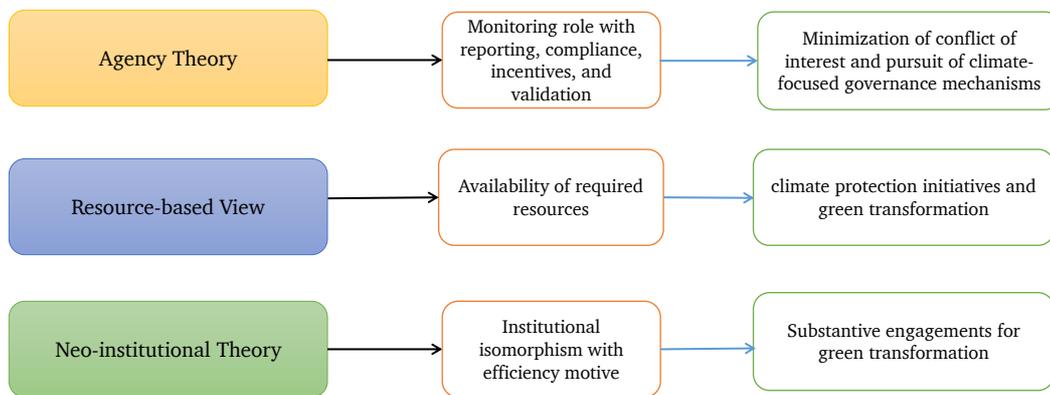
Second, consistent with the resource-based perspective, firms could attain a substantial level of competitive edge by utilizing their resources for environmental activities that result in financial and non-financial benefits, in contrast to firms with resource constraints (Alam et al., 2019; Atif et al., 2021; Safiullah et al., 2021; Orazalin et al., 2023). Furthermore, it is claimed that corporate governance in climate-related undertakings is largely associated with the resource-based view (Backman et al., 2017). We, therefore, build on the predictive power of the resource-based view, which advocates for firms to deploy valuable resources and capabilities in the presence of a strong CRG structure and implement green transformative initiatives for actual carbon performance.

Third, according to agency theory, environmental or related committees are assumed to deliver better monitoring functions (Peters and Romi, 2013). It also suggests that managers tend to engage in increased compliance, systematic reporting, and external assurance to reduce information asymmetry between internals, outside shareholders, regulators, and other stakeholders (Healy and Palepu, 2001; Liao et al., 2015; Simnett et al., 2009). Further, the agency theory-driven governance model suggests that the provision of monetary benefits can

be an essential mechanism for minimizing conflicts of interest and ultimately improving monitoring tasks. Thus, an ESG-based executive compensation strategy is expected to mitigate agency complications in governance (Mahoney and Thorn, 2006). Overall, we draw on resource-based views, agency theory, and neo-institutional theory to explain the intricate association between CRG, GTI, and CMP based on applicability and literature-driven arguments. Figure 2 illustrates the theoretical model, while Figure 3 shows the hypotheses of this study.

Figure 2: A multi-theoretical model to explain the nexus between CRG, GTI, and CMP

### Multi-theoretical Framework



Source: Author's Proposition

Earlier studies, on the one hand, have focused extensively on the effect the governance attributes have on firm-level environmental initiatives and their resulting outcomes (Kiliç and Kuzey, 2019; Liao et al., 2015; Hollindale et al., 2019). However, they have paid little attention to evaluating actual carbon performance, which is a practical and substantial measure of environmental performance. On the other hand, a growing body of literature explores various conventional corporate governance characteristics to examine their effect on actual carbon performance (i.e., Luo and Tang, 2020; Moussa et al., 2019; Haque, 2017). Nevertheless, conventional governance measures, such as board size, board independence, and CEO-Chair separation, tend to be inadequate in reflecting on aspects of the boardroom that are more pertinent and resilient for environmental engagements and climate-oriented actions. This is because related literature on conventional governance measures provides mixed evidence. For

instance, Haque (2017) shows a positive relationship between governance attributes and process-based carbon performance from the UK context, while they do not find any significant association between governance attributes and actual carbon performance. In contrast, Altunbas et al. (2022) provide evidence that gender diversity mitigates climate change by reducing actual carbon emissions. Interestingly, Luo and Tang (2020) reveal that the overall quality of the governance structure, rather than the individual governance mechanisms, plays a crucial role in influencing both process-oriented and actual carbon performance. Moreover, looking at another stream of research with regard to carbon disclosure-performance behavior, Luo and Tang (2014b) examine the relationship between carbon disclosure behavior and actual carbon performance, revealing that superior performers tend to disclose more carbon-related information. In contrast to Luo and Tang's (2014b) findings, Luo (2019) presents evidence of a negative relationship between carbon disclosures and actual performance. Despite these inconsistent findings, the prior literature frequently overlooks the need for more robust and climate-focused governance mechanisms to increase climate activism and actual carbon performance, since climate-focused governance could narrow the gap between carbon disclosure and actual performance (Bui et al., 2020).

A limited body of research indicates that climate change governance measures, as opposed to conventional governance mechanisms, are more effective in promoting climate protection activism (Arena et al., 2018; Bui and de Villiers, 2017). In this regard, Alrazi et al. (2016) and Ntim and Soobaroyen (2013) emphasize that strong climate governance mechanisms may deter high polluters from making extensive disclosures to conceal poor performance and evade responsibility. Bui et al. (2020) further document a positive relationship between climate-related governance measures and the carbon disclosure behavior of S&P 500 firms. In addition, it has been argued that executive management tends to prefer symbolic activism to substantive environmental performance. So, a greenwashing (or impression management) hypothesis might prompt managers to adopt process-driven carbon performance that does not affect substantive carbon performance (Boiral and Hras-Saizarbitoria, 2017; Haque and Ntim, 2020). In response to this issue, Bui et al. (2020) suggest that corporate climate-focused governance, which prioritizes climate change and sustainability, could potentially prevent greenwashing attempts. In line with the above reasoning, climate risk governance (CRG), which integrates climate change concerns into the board process through increased awareness, compliance, incentives, reporting, and validation, appears to be a resilient solution to addressing the shortcomings of conventional governance mechanisms in the pursuit of maximizing actual

carbon performance. As a result, CRG could play a critical role in improving carbon mitigation performance (CMP) by effectively reducing actual carbon emissions, leading us to propose the following hypothesis:

H<sub>1</sub>: *Ceteris paribus*, CRG enhances CMP by reducing actual carbon emissions.

To achieve meaningful progress in the context of lowering and controlling carbon emissions, a deep-rooted reassessment of how firms approach structural change is required. Bui and Villiers (2017) underscore the significance of absolute reduction targets, managerial support, and dedicated resource allocation for effective CO<sub>2</sub> control. Smith et al. (2022) further support this stance, emphasizing the critical role of robust and resilient emission management strategies in attaining sustainability goals. However, the efficacy of current carbon-reduction frameworks, including those facilitated by CDP questionnaires, has come under scrutiny. Despite their widespread adoption, these initiatives often fall short of proving tangible progress or implementing climate protection measures (Orazalin et al., 2023). This uncertainty surrounding firms' actual carbon reduction efforts highlights the need for a more robust assessment mechanism and efficiency-driven efforts. Furthermore, it is common to demonstrate environmental and social responsibility to external stakeholders through symbolic actions to earn legitimacy only (Comyns and Figge, 2015). Likewise, symbolic engagement in carbon reduction, as observed by Haque (2017) and Haque and Ntim (2020), has become a prevalent strategy among many firms that seek to align with societal and regulatory expectations by rendering lip service. As a result, the reliance on process-oriented constructs based on a simple box-ticking strategy for carbon reduction or climate activism points out the limitations of existing approaches to explaining structural transformation.

In response to these challenges, we posit that green transformation initiatives are a more viable alternative. This is because the GTI score more accurately represents the extent to which a firm has implemented the selected transformative initiatives. In contrast to conventional carbon reduction measures, GTI encompasses a spectrum of firm-level initiatives aimed at structural business transformations (Wang et al., 2023). By transcending symbolic actions, GTI offers a more refined understanding of firms' commitment and substantive efforts to carbon reduction, environmental protection, and long-term sustainability. Drawing from neo-institutional theory and the resource-based view, we argue that firms responsible for both scope one and scope two emissions would benefit from adopting GTI to enhance carbon mitigation performance (CMP). Accordingly, we develop the following hypothesis that considers GTI as a determinant of

carbon mitigation, which might help improve carbon performance by reducing actual carbon emissions.

H<sub>2</sub>: *Ceteris paribus*, GTI improves CMP by reducing actual carbon emissions.

The extant literature predominantly suggests that governance characteristics may affect the relationship between process-based carbon or environmental performance and financial outcomes while having minimal influence on explaining actual carbon performance. However, it does not address the moderating role of climate-focused governance attributes in shaping the association between carbon performance and climate change initiatives in any form. For instance, Ntim and Soobaroyen (2013) find that the interaction between conventional governance characteristics and CSR is positively linked to firm value. Haque and Ntim (2018) also report that the interaction between the Climate Change Act and board independence is positively related to symbolic carbon performance. Furthermore, Haque and Ntim (2020) provide evidence from the European perspective that an interaction variable combining executive incentives and ESG-driven compensation only increases symbolic carbon performance. Previous studies, however, have not investigated the role of climate governance in this regard. Moreover, we note a dearth of research evaluating whether climate governance can simulate the relationship between GTI and actual carbon performance. Again, earlier studies recommend that climate governance can play a vital role in reinforcing firm-specific initiatives to improve actual carbon performance (Bui et al., 2020; Ntim and Soobaroyen, 2013). In particular, Bui et al. (2020) show a relationship between climate governance and carbon disclosure. Sullivan and Gouldson (2017) also argue that governance characteristics, carbon mitigation initiatives, and substantive environmental performance are interconnected. Thus, we argue that when supported by a firm-level CRG framework, the GTI appears to be responsible for sustained carbon performance by minimizing actual carbon emissions.

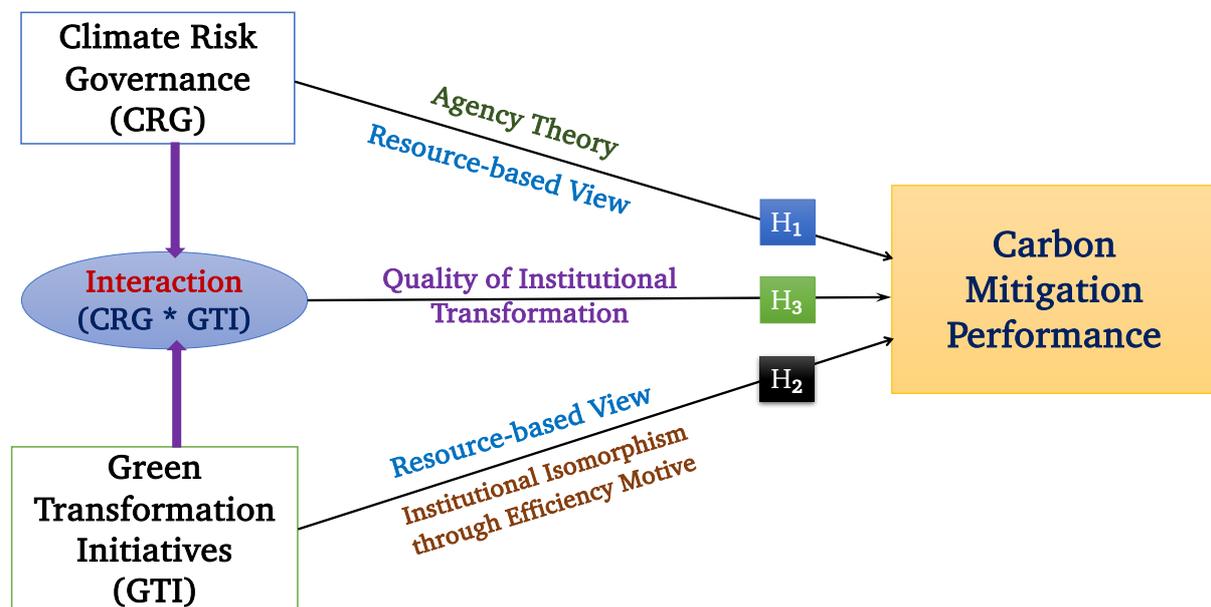
From the theoretical standpoint, the resource-based view suggests that firms develop their distinct capabilities (tangible or intangible) and internal strength to shape their performance and competitiveness (Barney, 2001). This approach has an intra-organizational focus and further argues that performance originates from better use of firm-specific resources (Barney, 1991; Wernerfelt, 1984). We, in this way, argue that a robust climate-focused governance framework—characterized by heightened awareness of climate-related issues, clear reporting responsibilities, a dedicated board-level ESG committee, effective compliance mechanisms, and strong external assurance—optimizes the use of a firm's resources to enhance substantive

environmental performance. Moreover, institutional theory suggests how organizations can make the most of their abilities and survive in a competitive environment by satisfying their stakeholders through efficiency-driven substantive actions. This understanding also indicates that institutional forces will shape and influence firms' activism and, hence, their social and environmental performance (Ntim and Soobaroyen, 2013). Neo-institutional theory concerns the processes by which rules and regulatory directives become a driver of legitimacy, efficiency, and consistency in compliance (Kostova et al., 2008; Scott, 2004; Tolbert and Zucker, 1999). The availability of resources can support innovative approaches, whereas resource constraints are likely to hinder innovation and the adoption of specific climate-based actions (Albitar et al., 2022). Taken together, theoretical predictions help us understand that firms that respond genuinely and substantively to social expectations, stakeholder concerns, and institutional pressures emphasize efficiency. In this context, compliant, carbon-sensitive firms are likely to adopt efficiency-driven approaches to advance green initiatives for transformation. Therefore, a resilient CRG framework that guides and ensures the best possible use of available resources, combined with the efficiency-oriented GTI, can enhance the overall transformative quality and capacity of a firm for its sustained carbon mitigation performance.

Overall, climate-focused governance mechanisms can guide compliant firms in aligning their practices with institutional forces while ensuring optimal use of available resources. A comprehensive transformation, driven by an efficiency-oriented approach that avoids legitimacy-driven symbolic actions, can be achieved through a well-structured climate risk governance (CRG) framework and the pursuit of green transformative initiatives. This approach (CRG\*GTI) focuses on ensuring the quality of institutional transformation in achieving long-term sustainability and net-zero status. We, therefore, propose an interaction between CRG and GTI that reflects overall firm-level capacity and the quality of institutional transformation required to enhance CMP. In other words, we argue that CRG might strengthen the association between GTI and CMP, leading to the development of the third hypothesis outlined below:

H<sub>3</sub>: *Ceteris paribus*, CRG moderates the relationship between GTI and carbon mitigation performance (through an interaction between CRG and GTI) by reducing actual carbon emissions.

Figure 3: Hypotheses of essay one



Source: Author

### 3. Data and Method

#### 3.1 Data

Due to the UK government’s proactive and forward-looking climate-change policy, UK-listed firms are at the forefront of climate activism and disclosure practices (Luo and Tang, 2014a). Therefore, consistent with prior studies (i.e., Liao et al., 2015; Tauringana and Chithambo, 2015; Haque, 2017; Haque and Ntim, 2018), we focus on UK firms. To begin with, we look at the FTSE-600 index components to identify the compliant UK firms. We then filter 600 FTSE All-Share Index components according to whether they publish sustainability reports or they have board-level environmental or ESG-based sustainability committees, as a specialized committee and/or a published sustainability or ESG impact report can indicate climate activism and concern over sustainability issues. We detect 444 firms that meet at least one of the conditions. Finally, out of these 444 firms, 276 are found to be compliant non-financial firms that are responsible for both scope one and scope two emissions, while banks and other financial institutions are dropped from the sample.<sup>6</sup> Our reasons for choosing the study period

<sup>6</sup> Banks and other financial institutions are excluded from our sample because they are not directly responsible for carbon emissions. Moreover, due to their regulatory frameworks, banks and other financial institutions follow somewhat different governance mechanisms (Luo and Tang, 2020; Orazalin, 2020).

of 2011–2020 are twofold. First, over the past decade, the world has faced increasingly severe and adverse environmental challenges. Second, during this period, the executive management of carbon-sensitive firms has shown greater awareness of climate change issues than previously seen. For GTI, we use hand-collected, unique data from compatible UK firms. To conduct the GTI scoring, we draw company-published reports such as sustainability reports, corporate environmental reports, and annual reports, when necessary. In addition, we obtain CRG and carbon emissions data from the Refinitiv Eikon DataStream (formerly Thomson Reuters) Asset4 database. See Appendix Table A1, Panel A, for the sample distribution spread over 10 industries, and Panel B for the sample selection process.

### 3.2 Empirical Models

This study employs univariate and multivariate analyses to investigate the effects of CRG and GTI on CMP. The univariate analysis involves descriptive statistics, while for the multivariate analysis, we use fixed-effects panel data estimators to run baseline tests.<sup>7</sup> Hsiao (2007) contends that panel data methods generate more accurate and efficient inferences by limiting the issues that may stem from unobservable or omitted variables. In addition, these models capture unobserved heterogeneity over time and among individual items (Hsiao, 2007).

First, empirical model 1 takes CRG<sup>8</sup> as its main explanatory variable in order to test H<sub>1</sub>:

$$CMP_{it} = \beta_0 + \beta_1 CRG_{it} + \beta_2 \text{Board Independence}_{it} + \beta_3 \text{Board Size}_{it} + \beta_4 \text{R\&D Intensity}_{it} + \beta_5 \text{Leverage}_{it} + \beta_6 \text{Firm Size}_{it} + \beta_7 \text{Profitability}_{it} + u_{it} \quad (1)$$

As it stands, the CMP of firm *i* in the year *t* is regarded as a function of CRG, together with a range of firm-specific control variables, as specified above. Finally, the error component *u* is added to the regression model.

Second, to test H<sub>2</sub>, empirical model 2 incorporates GTI,<sup>9</sup> accompanied by the same set of control variables:

$$CMP_{it} = \beta_0 + \beta_1 GTI_{it} + \beta_2 \text{Board Independence}_{it} + \beta_3 \text{Board Size}_{it} + \beta_4 \text{R\&D Intensity}_{it} + \beta_5 \text{Leverage}_{it} + \beta_6 \text{Firm Size}_{it} + \beta_7 \text{Profitability}_{it} + u_{it} \quad (2)$$

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<sup>7</sup> The Hausman test result suggests that FE specification is appropriate for our empirical analysis.

<sup>8</sup> Appendix Table A2 highlights all the components of the climate risk governance (CRG) framework.

<sup>9</sup> Appendix Table A3 lists all the green transformation initiatives (GTI).

Third, we encompass both of our main variables of interest in order to regress CMP:

$$CMP_{it} = \beta_0 + \beta_1 CRG_{it} + \beta_2 GTI_{it} + \beta_3 \text{Board Independence}_{it} + \beta_4 \text{Board Size}_{it} + \beta_5 \text{R\&D Intensity}_{it} + \beta_6 \text{Leverage}_{it} + \beta_7 \text{Firm Size}_{it} + \beta_8 \text{Profitability}_{it} + u_{it} \quad (3)$$

Finally, to examine H<sub>3</sub>, the following empirical model includes both the test variables and an interaction term comprising them:

$$CMP_{it} = \beta_0 + \beta_1 CRG_{it} + \beta_2 GTI_{it} + \beta_3 CRG * GTI_{it} + \beta_4 \text{Board Independence}_{it} + \beta_5 \text{Board Size}_{it} + \beta_6 \text{R\&D Intensity}_{it} + \beta_7 \text{Leverage}_{it} + \beta_8 \text{Firm Size}_{it} + \beta_9 \text{Profitability}_{it} + u_{it} \quad (4)$$

### 3.2.1. Dependent Variable

The most critical determinant of climate change is carbon emissions. According to Velte et al. (2020), CO<sub>2</sub> emissions are characterized as an inverted measure of carbon performance. Among other researchers, they consider actual carbon emissions<sup>10</sup>—as opposed to symbolic and process-oriented carbon performance—to be a genuine performance indicator. In reality, the intensity of carbon emissions in the atmosphere matters, while symbolic actions and reduction commitments do not. Hence, the carbon mitigation outcome works best as a substantive performance measure.

Therefore, we focus on the actual carbon performance. We follow Liao et al. (2015), Haque (2017), Moussa et al. (2019), Haque and Ntim (2020), and Downar et al. (2021) in using the natural logarithm of total carbon emissions (in tons) by including scope 1 and scope 2 emissions as a proxy of CMP. However, we do not include scope 3 carbon emissions to calculate total carbon emissions, as there is missing data for most of our sample firms. The higher the CO<sub>2</sub> released into the atmosphere by a firm, the poorer its performance.

### 3.2.2. Independent Variables

#### 3.2.2.i. Climate-Risk Governance (CRG)

It is assumed that the integration of climate change concerns into executive decisions through climate-centric governance instruments reinforces engagement in responsible business

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<sup>10</sup> Carbon emissions are the primary driver of climate change because CO<sub>2</sub> is the most significant determinant of global warming. As a result, many prior studies utilize carbon emissions as a proxy to gauge environmental performance (i.e., Lee and Min, 2015; Xu and Lin, 2015; Du et al., 2019; Tobelmann and Wendler, 2020).

practices. Burke et al. (2017) and Peters and Romi (2013) claim that sustainability committees and other climate-centric governance instruments are effective mechanisms for managing relevant stakeholder interests and boosting sustainability performance. The existing literature on corporate governance provides inadequate evidence of climate actions. For example, Moussa et al. (2019) find evidence of an association between boards' environmental orientation and the carbon performance of US firms. However, the study does not emphasize environmental committees or other salient climate-related determinants in capturing the environmental orientation of the boardroom, focusing instead on traditional governance variables such as multiple directorships, board independence, gender diversity, and the financial expertise of the audit committee.

Thus far, only Bui et al. (2020) have attempted to establish a linkage between climate governance measures and carbon disclosure by U.S. firms. They show that, unlike conventional governance mechanisms, climate governance attributes reveal firms' commitment to ensuring transparency in reporting and dealing with sustainability concerns in more plausible ways. However, the composite index employed in their study regarding climate governance lacks uniformity because it assigns unequal weights to incomparable elements, such as dummy variables and some other weighted components in the same index. We overcome the shortcomings of these previous studies by emphasizing uniformity and incorporating relevant elements from the extant literature. Thus, our CRG index is substantially different from the one found in the extant literature. Our CRG index comprises five indicator variables, with the score falling between 0 and 5. We evaluate Cronbach's alpha<sup>11</sup>, a widely used reliability coefficient, to measure the internal consistency and homogeneity of the CRG index. The reliability coefficient ( $\alpha = 0.8009$ ) demonstrates good internal consistency for the CRG index. This value surpasses the commonly accepted minimum of 0.7, indicating that the scale items are consistent and reliable. Therefore, the components of the CRG index are deemed suitable for analysis without requiring any modifications. The discussion below sheds light on each of the CRG components:

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<sup>11</sup> Cronbach's alpha values range from 0 to 1, with a minimum threshold of 0.6 to 0.7 commonly required to confirm consistency. It is generally accepted that a value exceeding 0.70 indicates good reliability.

A board's comprehension of climate change risks, opportunities, and regulatory requirements serves as the foundation of effective climate governance. Climate change presents both potential threats and business opportunities, necessitating that boards remain well-informed and proactive in their approach. The climate-conscious board must understand these evolving factors and guide strategic decision-making accordingly. Accordingly, following Bui et al. (2020), firms demonstrating awareness of these commercial risks and opportunities are assigned a value of 1, while those lacking such awareness receive a value of 0.

Existing literature suggests that executive compensation might affect firms' environmental performance. For instance, Campbell et al. (2007) propose that strategically designed sustainable compensation policies can motivate executives to engage more actively in environmental initiatives, ultimately enhancing corporate environmental outcomes. Following Haque and Ntim (2020) this study includes sustainability-linked incentives for executives as a component of the CRG framework. Accordingly, firms that offer executive incentives or compensation for significant climate-related actions are assigned a value of 1, while those that do not receive a value of 0.

Earlier studies indicate that the presence of corporate environmental committees within a board is positively associated with the likelihood of sustainability and CO<sub>2</sub> disclosure (Liao et al., 2015; Peters and Romi, 2013). While independent directors may lack the authority to compel executives to allocate substantial long-term resources to carbon mitigation, board-level sustainability or environmental committees play a crucial role in embedding environmental strategies within an organization (Albitar et al., 2023). Additionally, Ioannou et al. (2016) suggest that specialized committees enhance the management and oversight of climate-related issues. Therefore, the climate risk governance index incorporates the existence of a board-level environmental or ESG-related committee.

Sustainability reporting has gained significant attention over the past two decades, particularly in high-pollution regions. Firms increasingly publish ESG, and sustainability reports to enhance transparency and demonstrate their commitment to addressing climate-related challenges (Dhaliwal et al., 2011). These reports provide detailed insights into resource allocation and strategic responses to climate risks. Firms with significant Scope 1 and Scope 2 emissions face particular pressure to disclose their sustainability efforts due to regulatory requirements and stakeholder expectations. Such reporting not only reflects a firm's long-term commitments to attaining decarbonization but also communicates actual climate activism to

society and stakeholders. Therefore, in line with Al-Shaer (2020), the climate risk governance index includes sustainability reporting as a component.

We finally consider the external assurance of sustainability, ESG, or environmental reports as a component of the CRG framework. This external validation not only enhances the credibility of climate activism but also mitigates the risk of greenwashing in disclosure and compliance processes. Consistent with Simnett et al. (2009) and Moroney et al. (2012), we incorporate external assurance into our index. Firms that obtain external assurance or audits for their reports or disclosures receive a score of one, while those without such validation receive zero. Overall, the climate risk governance index focuses on five firm-specific governance mechanisms designed to address climate change and sustainability, with a higher climate governance score reflecting stronger climate activism by the firm (see Appendix Table A2 for the list of variables constructing the CRG index).

#### 3.2.2.ii. Green-Transformation Initiatives (GTI)

According to the United Nations Global Compact and the United Nations Framework Convention on Climate Change (UNFCCC), green and carbon-free corporate actions unquestionably lay the ground for a healthier, more resilient, and safer future for the world. GTI is the cornerstone of green and carbon-free corporate actions. It is comprised of systematic and consistent corporate undertakings toward an organized structural transformation. Drawing on the hand-collected data from the most compliant 276 firms, we incorporate 16 initiatives into the index to signify the extent of a company's pursuit of green transformation to achieve net-zero status. This index contains green pursuits from different dimensions of a particular firm that reflect climate protection and carbon-reduction initiatives to replace conventional arrangements and transform from its non-green operational status into a greener one with the lowest possible carbon emissions. To configure the GTI construct as a potential driver of CMP, we accumulate the 16 initiatives described above in Appendix Table A3. Based on the implemented level of transformation with respect to each initiative, we follow Wiseman (1982) in assigning numerical values in the following manner:

- 0 = Not implemented at all
- 1 = Moderate level of transformation/General indication of any transformation initiative using non-quantifiable evidence/without number values
- 2 = Broad level of transformation/Detailed indication of any transformation activity with quantitative focus/with number values

Thus, the total possible score of a firm stands between 0 and 32. (See Appendix Table A3 for the list of the variables constructing the GTI.) We also test Cronbach's alpha to measure the internal consistency and homogeneity of the GTI index. Our GTI index exhibits excellent reliability, with a Cronbach's alpha value of 0.8986. This high score not only exceeds the threshold of 0.7 but also confirms the scale's suitability for analysis without the need for adjustments.

### 3.2.2.iii Control Variables

Based on a review of prior literature, we chose two sets of control variables. First, we incorporate a couple of conventional governance-related controls, and second, we include other firm-specific financial controls. For governance-related controls, we use the board size, which is calculated as the number of directors serving on the board (Kang et al., 2007; Lim et al., 2007). Following the related literature (i.e., Haque and Ntim, 2020; Bui et al., 2020; Berrone and Gomez-Mejia, 2009), we employ board independence. Board independence is defined as the proportion of independent directors relative to the total board size. Further, following de Villiers et al. (2011), Luo et al. (2012), Haque (2017), and Haque and Ntim (2020), we control several firm-specific characteristics, such as Firm Size (the natural logarithm of total assets), Leverage (the ratio of total debt to total assets), and Profitability (the ratio of net profit divided by total assets). We also control for R&D intensity, following Alam et al. (2022) and Harford et al. (2008). We define R&D Intensity as the ratio of R&D expenditure scaled by net sales.

## 4. Empirical Results

### 4.1. Descriptive Statistics and Baseline Analysis

Table 1 reports the summary statistics. It includes the number of observations, mean values, standard deviation, and the minimum and maximum values of the variables used in the baseline estimates. On average, the sample firms emit 11.546 million tons of CO<sub>2</sub>, with a maximum of 18.270 million tons. The CRG index falls between 0 and 5, with a mean value of 2.765 and a

standard deviation of 2.135. The average GTI value is 10.745, with a standard deviation of 6.882. The proportion of independent directors on the board is nearly 59%, which is comparable to the finding in Liao et al. (2015). In addition, consistent with Haque and Ntim (2018) and Tauringana and Chithambo (2015), the boards of our sample firms are served by an average of nine members. The mean of R&D Intensity is 0.515. The average firm size is 14.32. On average, the sample firms have 23.45% leverage, indicating that they do not rely heavily on debt financing. The average profitability of our sample firms is 7.125%. These statistics are also in line with those of similar studies in the extant literature. We also identify the variation inflation factors (VIFs)<sup>12</sup> for all the independent variables. Our results (unreported) show that the maximum VIF is 2.32, and the average is 1.55. Hence, the VIF results suggest that multicollinearity is not a concern for our study.

Table 2 presents the baseline results for CRG, GTI, and CMP. According to the reported results in columns 1 and 3, as expected, CRG exhibits a strong negative relationship with the dependent variable. This suggests that the greater the extent of the firm-level climate-focused governance activism, the lower the carbon emissions. In other words, CRG is associated with CMP, indicating that CRG reduces carbon emissions and boosts CMP. Our findings are in line with the predictions of both the resource-based view and agency theory. In terms of agency theory, the monitoring role, supported by reporting, compliance, incentives, and assurance, motivates firms to emphasize resilient climate activism for better environmental results. This finding corresponds to that of Moussa et al. (2019), who, using agency theory, report that effective monitoring by executive management can help secure actual carbon performance. In addition, climate risk governance, when aligned appropriately with the available resources and capabilities, can drive actual carbon performance. Our result is in line with that of Bui et al. (2020), who find that climate governance mechanisms drive carbon-related disclosure. Thus, our empirical result supports the first hypothesis (H<sub>1</sub>).

Next, in columns 2 and 3, we find that the coefficients of GTI are negative and highly significant, which suggests that transformation initiatives are responsible for reducing carbon emissions. Put differently, a higher level of GTI is related to minimizing carbon emissions and thereby maximizing CMP. Our results provide support for the resource-based view and neo-institutional theory, as the adequacy of resources and institutional isomorphism with the

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<sup>12</sup>Any value of VIF above 10 indicates the presence of multicollinearity (Chatterjee and Hadi, 2006; Lardaro, 1993).

efficiency motive reflect substantive responses and genuine attempts with the aim of improving actual carbon performance. This evidence aligns with that of Haque and Ntim (2022), who show that firms engage in substantive climate adaptation and mitigation initiatives in light of efficiency-based motives underlying the neo-institutional theory, which results in a reduction of actual carbon emissions and increased economic productivity. Thus, we argue that GTI is a strong driver of CMP, and this empirical evidence confirms the second hypothesis (H<sub>2</sub>).

In addition, column 4 in Table 2 presents the estimated results of the interaction term combining our test variables (CRG\*GTI). As reported, the interaction coefficient is negative and statistically significant. This shows that CRG strongly moderates the association between GTI and CMP. In other words, the blend of climate-focused governance mechanisms and GTI, identified as the quality of the institutional transformation, plays a significant role in ensuring sustained CMP. We therefore argue that the greater the extent or quality of firm-level transformation towards a green and carbon-neutral status, the lower the CO<sub>2</sub> emissions and, ultimately, the better the CMP. Overall, this empirical result supports our third hypothesis (H<sub>3</sub>).

Our empirical evidence reveals that the explanatory power of the main interest variables remains unchanged across all the models. Our baseline results contribute new knowledge to the ongoing debate on how climate governance framework and transformative climate-change initiatives can help decarbonization. Our findings with regard to the board-level control variables reveal that board independence is negatively associated with CMP, though the results are not statistically significant across all of our model specifications. In contrast, a larger board size is correlated with a lower CMP. Among the firm-level variables, R&D intensity appears to improve CMP, but the results are statistically insignificant. Further, our results show that the estimated coefficients of leverage are robust across different models, implying that leverage might be responsible for reducing carbon emissions and, hence, boosts CMP. Finally, profitability and firm size are positively correlated with carbon emissions, indicating that larger firms tend to release more carbon than smaller firms. Similarly, profitability relies largely on carbon emissions.

## 4.2. Endogeneity Concerns

Our empirical outcomes might indicate correlation instead of the predicted causality, due to the endogeneity bias. We assume that one of our key explanatory variables (climate risk governance) may be subject to a self-selection problem. Consequently, the findings might not reflect a systematic relationship with the dependent variable (carbon mitigation performance). To overcome this identification challenge, we employ two specific econometric techniques to check the causal association between CRG and CMP: namely, instrumental variable (IV) analysis and the difference in differences (DiD) model.

### 4.2.1. Instrumental Variable (IV) Analysis

First, we conduct IV analysis using 2SLS estimations to extract the exogenous component from CRG and GTI. We then employ the predicted values of CRG and GTI to regress CMP. We know that IV analysis calls for an instrument correlated with the endogenous regressor (i.e., CRG and GTI) but does not exert any direct impact on the explained variable (CMP), except through that endogenous regressor. To this end, we utilize the industry averages of the main independent variables as instruments to run the IV regressions. Following earlier studies (Martinez-Garcia et al., 2022; Ye et al., 2019), we use the industry average values of the CRG and GTI variables as instruments. The CRG and GTI of a firm may be strongly associated with those of industry peers because of the alignment between the firms' respective businesses and strategic perspectives. However, there is little reason to take for granted that such an industry average directly affects a firm's CMP. Taken together, we rely on these instruments because they are unlikely to be correlated with the error term and may not have a straightforward association with the dependent variable.

Through the first-stage regressions in columns 1 and 3 of Table 3, we examine the relevance of our instrument. Consistent with the requirements of a suitable instrument, CRG and GTI are positively associated with the IVs in columns 1 and 3, respectively, and the coefficient of the CRG-industry average and GTI-industry average are statistically significant at the 1% level. In addition, the F-statistics are high, and the CD F test for a weak instrument is 0.000, which rejects the null hypothesis since the instruments are weak (Cragg and Donald, 1993; Stock and Yogo, 2005). All other right-hand side variables remain the same as the baseline models. Columns 2 and 4 in Table 3 indicate the results of the second-stage regressions where

predicted CRG and GTI values (fitted values of CRG and GTI) from the first-stage estimations are applied to explain CMP. The empirical results are similar to the results of our baseline estimates, implying a negative and significant association between CRG, GTI, and carbon emissions. The estimated coefficients on the predicted CRG and GTI are significant at the 1% level in columns 2 and 4, respectively. Hence, our empirical results are robust to the use of the 2SLS approach and not driven by endogeneity bias.

#### 4.2.2. Difference-in-Differences (DiD) Analysis – a Quasi-Natural Experiment

Second, a difference-in-differences (DiD) model appraises the effectiveness of climate-related or economic policies and thus alleviates potential endogeneity concerns (Bertrand et al., 2004). Likewise, we use a DiD model to compare the variation between the experimental and control groups before and after the climate-related policy intervention. Here, the top 50% of the sample firms (indicating high carbon emissions on the eve of the historic climate agreement) are placed within the treatment group, while the control group accommodates the bottom 50% of firms (the control group acts as a counterfactual). Carbon footprints result in negative externalities that disrupt ecological balance, environmental safety, and sustainability.

However, to curb the consequences of carbon emissions, local and global bodies legislate (e.g., the Kyoto Protocol 1997, the Paris Agreement 2015) to persuade firms to minimize their negative externalities (Safiullah et al., 2021). For this reason, following the work of Capasso et al. (2020), this study treats the 2015 Paris Climate Agreement<sup>13</sup> as an exogenous component in a quasi-natural experiment applying the DiD estimator. The DiD analysis is built on the notion of the parallel trends between two preset groups (the treatment and control). Thus, any differences in the changes in outcomes before and after the exogenous treatment should be caused by the effect of that treatment, in place of any differences between the groups ahead of the treatment (Atif et al., 2021; Lemmon and Roberts, 2010). This study restricts itself to firms that do not transition in and out of the treatment and control groups, ensuring appropriate interpretation of the DiD estimators. Although this exogenous shock is equally applicable to all the sample firms, irrespective of industry differences, firms with very high CO<sub>2</sub> footprints may appear to react more severely to this shock than their low-emission counterparts. This is because high-emitting firms are typically subject to regulatory pressures or ongoing

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<sup>13</sup> Capasso et al. (2020) treat the 2015 Paris Agreement as an exogenous shock in a DiD model to regress credit risk on exposure to climate risk.

governmental oversight; thus, they remain more exposed to climate-related legislation and environmental policies. In addition, it is argued that regulatory bodies should refuse permits and passes to any firms that fail to comply with specific environmental policies (Frooman, 1999). As a form of regulative isomorphism, such regulatory restrictions necessitate high-emitting businesses to commit their internal processes and resources to compliance, climate protection, and the settlement of litigation (Bauer and Hann, 2010; Okereke and Russel, 2010). Thus, firms with larger CO<sub>2</sub> footprints are prompted to reinforce their transformative initiatives and climate activism in response to this climate consensus and stricter policies. In addition, due to the wide-ranging impact of this agreement, high-polluting firms are more likely to make changes in their strategic choices to facilitate greater institutional transformation, which then reinforces their CMP. Further, this analysis helps us to evaluate the effectiveness of this historic climate consensus in reality. We have equal pre-shock and post-shock periods for the DiD models, as we cover the period between 2011 and 2020. The DiD models constructed to address the endogeneity concern are described below.

$$CMP_{it} = \alpha + \beta_1 CRG_i + \beta_2 POSTEVENT + \beta_3 CRG*POSTEVENT + \delta X_{it} + \varepsilon_{it} \quad (a)$$

$$CMP_{it} = \alpha + \beta_1 GTI_i + \beta_2 POSTEVENT + \beta_3 GTI*POSTEVENT + \delta X_{it} + \varepsilon_{it} \quad (b)$$

$$CMP_{it} = \alpha + \beta_1 CRG*GTI_i + \beta_2 POSTEVENT + \beta_3 CRG*GTI*POSTEVENT + \delta X_{it} + \varepsilon_{it} \quad (c)$$

Table 4 presents the results of the DiD models. Here, **POSTEVENT** is a dummy variable that takes 1 for values after 2015 (i.e., from 2016 onward) and 0 otherwise. Our key coefficient of interest is  $\beta_3$  across all three models, representing the interaction variable between CRG and POSTEVENT in model 1, GTI and POSTEVENT in model 2, and CRG and GTI and POSTEVENT in model 3. We use the same set of control variables as the baseline models. According to the reported results, the coefficient on CRG\*POSTEVENT is negative and significant at the 5% level. Similarly, the coefficient on GTI\*POSTEVENT is also negative and significant at the 1% level. The empirical outcomes indicate that, after the Paris Agreement 2015, highly carbon-intensive firms in the treatment group tend to focus more on CRG and GTI to optimize their CMP, while the low carbon-intensive firms belong to the control group. More precisely, the exogenous shock highly encourages carbon-emitting firms to be more realistically responsive to climate change and sustainability issues, as they are subject to substantial institutional pressures and rigorous governmental surveillance. In

addition, as shown in model 3, the interaction variable CRG\*GTI\*POSTEVENT (which denotes a negative association with carbon emissions and is significant at the 5% level) accounts for a better institutional transformation that helps to reduce carbon emissions by highly carbon-sensitive firms following the Paris Agreement 2015. In other words, this result indicates that the compliant firms prioritize CRG and GTI to strengthen their overall institutional transformation, eventually supporting their CMP by minimizing their actual carbon emissions.

### 4.3. Robustness Checks

#### 4.3.1. Robustness test with Industry-fixed effects and an alternative metric of CMP

First, to check whether the baseline estimates are robust, we rerun them with industry and year effects. Table 5 presents the estimated regression results in four columns where CRG, GTI, a joint effect of both, and the interaction between CRG and GTI have been employed as the main independent variables to explain carbon mitigation performance. We use the same set of control variables as in the baseline tests. The empirical results suggest that our test variables are negatively associated with actual carbon emissions when industry and year effects are included across the four columns, thereby improving carbon mitigation performance. The results are statistically significant at the 1% level.

Second, the study treats—as an alternative measure of carbon emissions—the sum of scope 1 and scope 2 CO<sub>2</sub> emissions, scaled by total assets. Hence, following Kim et al. (2015), we replace the log of the sum of Scope 1 and Scope 2 carbon emissions (CMP) with the ratio of total GHG emissions to total assets (GHGA) to re-estimate the baseline tests. Accordingly, Table 6 presents the estimated coefficients from a fixed-effects regression of CRG and GTI on total GHG emissions to total assets, while controlling for board independence, board size, R&D intensity, leverage, firm size, and profitability. In particular, model 4 reports that the interaction between CRG and GTI is negatively and significantly associated with GHGA. Therefore, consistent with the baseline results, the outcomes of the robustness test with the alternative dependent variable suggest that compliant firms tend to improve the quality of their institutional transformation, ultimately improving CMP by reducing their CO<sub>2</sub> emissions. Even with the alternative measure, this evidence confirms that the quality of institutional transformation drives sustained carbon performance.

This study also conducts additional robustness checks using Scope 1 (direct emissions) and Scope 2 (indirect emissions) as alternative measures of the main outcome variable. Appendix Tables A5 and A6 present the regression results for Scope 1 and Scope 2 emissions, respectively. The findings from these robustness tests remain consistent with the baseline estimates, reinforcing the validity of our results.

#### 4.3.2. CRG, GTI, and CMP: GMM Regressions

In addition, we run the dynamic two-step system GMM estimates, following the proposition of Arellano and Bond (1991). Similar to Martínez-Ferrero and Frías-Aceituno (2015) and Haque and Ntim (2018), assuming lagged dependent variable as endogenous, we apply GMM regressions to test the association between CRG, GTI, and CMP.<sup>14</sup> Accordingly, as reported in all four columns of Table 7, the carbon emissions of firm *i* in year *t* are a function of the first lag of CMP (L.CMP), accompanied by our main variables of interest. All other right-hand side variables remain the same as the baseline regressions. As mentioned earlier, we use total carbon emissions as a proxy for CMP. The higher the value of the carbon emissions, the poorer the firm's performance, and vice versa. To determine the instrument's validity,<sup>15</sup> we run the Sargan test to address the overidentifying restrictions.

We also report the AR(1) and AR(2) for the first- and second-order Arellano–Bond tests for the serial autocorrelation. According to the post-estimation diagnostic tests, the null hypotheses cannot be rejected for overidentifying restrictions and no second-order serial autocorrelation.

### 4.4. Further Analysis

#### 4.4.1. Impact of Board Gender Diversity

A significant number of prior studies (e.g., Ben-Amar et al., 2017; Liao et al., 2015) investigate whether gender diversity, a dominant governance attribute, on corporate boards is associated with the extent and quality of voluntary carbon disclosure or actual carbon performance. Further, Liu (2018) and Kennedy and Dzialo (2015) report that female managers or directors are more inclined to engage in environmental protection and climate change actions. Likewise,

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<sup>14</sup> We also look into the CRG components separately as independent variables to test their impact on CMP. Since we aim to offer the overall CRG index as a driver of CMP in this study, we do not report the results. However, we are happy to share those upon request.

<sup>15</sup> The main conditions for a valid instrument are relevance ( $\text{Corr}[Z, X] \neq 0$ ) and exogeneity ( $\text{Corr}[Z, u] = 0$ ). This diagnostic test will validate whether the instrument is exogenous. Hence,  $H_0 = \text{instrument is exogenous}$ . If  $H_0$  cannot be rejected because of a higher P-value, this will prove the instrument's validity.

Atif et al. (2021) find evidence that female directors pay greater attention to long-term social and environmental concerns, including global warming and renewable energy consumption. Altunbas et al. (2022) also document the role of female managers in reducing carbon emissions. Therefore, we perform additional tests<sup>16</sup> controlling for gender diversity to check whether our empirical results are influenced by this variable. We measure gender diversity as the proportion of female directors on the board. All other control variables remain the same as the baseline regressions. Table 8 shows the results across four columns. Our results suggest that CRG, GTI, and the interaction term (CRG\*GTI) appear to lower carbon emissions—after controlling for board gender diversity—and are compatible with the initial baseline estimations that Table 2 reports in 4.1. As per the reported findings, gender diversity is negatively correlated with carbon emissions (the estimated coefficients are significant across four models), indicating that female participation on the board enhances CMP. Furthermore, the magnitude of the estimated coefficients for the main interest variables is consistent with our baseline results, implying that our findings hold after including gender diversity as a control variable.

#### 4.4.2. Heckman Selection Model

Although we address the endogeneity concerns in two ways, an issue may arise with regard to sample selection, as our sample selection process is not random. The final sample includes firms that do better in CRG and GTI than an average carbon-emission firm with some resource constraints. Hence, we employ the Heckman selection model to remedy any issues related to sample selection. For the Heckman models, we choose industry average figures of our key variables of interest as the prohibition restriction to eliminate self selection bias. We control for the sample selection issue via the inverse mills ratio and find that our results are similar to the baseline estimates. The Heckman models reported in columns 1, 2, and 3 of Table 9 include the same explanatory variables as our baseline regressions. The empirical results align with our baseline models, suggesting a negative association between CRG and actual carbon emissions

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<sup>16</sup> We perform sub-sample analysis after splitting the entire sample into two groups. The first sub-group (high-carbon risk) incorporates firms from the most heavily polluting industries. The second sub-group (low-carbon risk) includes all the other firms that belong to the remaining industries. The high-carbon-risk industries are as follows: 1) energy (oil, gas, and utilities), 2) transport, 3) consumer retail, 4) construction and basic materials, and 5) industrial goods and consumer discretionary. The Task Force on Climate-Related Financial Disclosure (Financial Stability Board, 2016) labels these industries predominantly vulnerable to climate risks (Palea and Drogo, 2020). Thus, the five industries mentioned above are classified as a high-carbon risk group because of their higher scope 1 carbon emissions. We then rerun the baseline models and find no significant qualitative differences between the estimated coefficients (not reported) for the high- and low-carbon risk groups. Overall, our empirical results hold after conducting the sub-sample study.

which is statistically significant. Likewise, GTI is also negatively associated with carbon emissions. Therefore, we argue that our empirical results are less likely to be affected by sample selection bias.

## 5. Conclusion and Implications

In response to the country's stringent climate-change policy, UK firms are more committed than ever before to mitigating their carbon footprints and meeting 2050 net-zero targets. We investigate how carbon-driven firms are adapting to the UK's climate-change commitments and moving toward decarbonization. Our study provides novel evidence on the impact of CRG and GTI on CMP, based on data from 276 compliant FTSE all-share index firms that are accountable for scope one and scope two emissions for the period of 2011–2020. We enrich the extant climate-change and carbon-related literature by proposing a novel pathway by which climate-focused governance and green transformation maximize CMP by minimizing actual carbon emissions. Moreover, we empirically show how the quality of institutional transformation improves sustained CMP. Hence, we argue that the stronger the integration between CRG and GTI, the higher the quality of the firm-level transformation and the better the carbon performance. We address endogeneity concerns and check the robustness of our results using different identification strategies and alternative measures to confirm our baseline estimates. Our findings withstand all tests and are robust across estimation techniques. Thus, we find that firm-level CRG, GTI, and a blend of CRG and GTI (CRG\*GTI) drive CMP. Overall, the findings of our study deliver a clear message to carbon-intensive firms regarding the significance of GTI and the need for structural shifts toward a safer and more sustainable future. More importantly, all carbon-sensitive firms should concentrate on ensuring the quality of their institutional transformation by integrating CRG and GTI, helping to attain the desired net-zero status.

The empirical evidence of this study provides politicians, social workers, environmentalists, civil society, and other international bodies with valuable insights to guide their action plans for securing carbon neutrality and thus meeting the aims of the Paris Agreement 2015, COP26, and COP27. Moreover, it provides critical insights for policymakers, corporate board members, and regulators regarding governance structure reformation and action plans for green institutional transformation on an international scale, particularly for firms from highly industrialized and polluting countries. It is surely the responsibility of every single division or wing of the firm to cooperate and actively engage in reducing carbon emissions (Mahmoudian et al., 2023). Thus, the implementation of GTI could inform and train employees at different levels of a firm on the execution of structural transformation and their specific roles. Finally, this study contributes to the global discussion on sustainable business practices, long-term environmental safety, and decarbonization. Though this study adds to the current body of knowledge in several ways and offers significant policy implications, it has some limitations, as outlined below, which can be addressed in future research. The non-compliance problem prevents this study from including many non-financial firms with respect to the green transformation initiatives (GTI) variable. In addition, managing firm-level, hand-collected data for a large number of firms to develop the GTI index is both time-consuming and challenging. This impacts the final sample size of this study. Thus, we could not manage to collect data in a global context that includes other highly industrialized and polluting countries, such as the G7 nations and China. Future research can extend this research by focusing on European countries and the USA to validate whether the key findings this study presents are consistent with a larger sample from a multi-country perspective, as well as gain more insights.

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Table 1: Summary Statistics

This table presents the statistics of our final sample, which includes 276 non-financial firms spread over ten industries between 2011 and 2020.

Name of the variable	Observations	Mean	Standard Deviation	Min	Max
Carbon Mitigation Performance (CMP)	2,050	11.546	2.548	3.025	18.270
Climate Risk Governance (CRG)	2,760	2.765	2.135	0.000	5.00
Green Transformation Initiatives (GTI)	2,760	10.745	6.882	2.000	28.00
Board Independence	2,672	58.889	14.210	0.000	100.00
Board Size	2,672	8.902	2.323	1.000	22.00
R&D Intensity	2,760	.515	1.015	0.000	3.070
Leverage	2,672	23.456	15.991	0.38	50.94
Firm Size	2,672	14.316	1.696	8.741	19.746
Profitability	2,622	7.125	5.449	-1.34	16.67

Table 2 : Baseline Estimates- CRG, GTI and CMP

Baseline Models: Variables	(1) CMP	(2) CMP	(3) CMP	(4) CMP
Climate Risk Gov. (CRG)	-0.170*** (0.031)		-0.159*** (0.031)	-0.112*** (0.033)
Green Transformation Initiatives (GTI)		-0.172*** (0.020)	-0.181*** (0.020)	-0.177*** (0.022)
CRG*GTI – Quality of Transformation				-0.037*** (0.010)
Board Independence	-0.001 (0.001)	-0.000 (0.001)	0.000 (0.001)	-0.000 (0.001)
Board Size	0.025*** (0.008)	0.021** (0.008)	0.024*** (0.008)	0.017** (0.008)
R&D Intensity	-0.025 (0.044)	-0.041 (0.043)	-0.049 (0.043)	-0.027 (0.044)
Leverage	-0.004*** (0.001)	-0.004*** (0.001)	-0.004*** (0.001)	-0.003*** (0.001)
Firm Size	0.392*** (0.031)	0.464*** (0.032)	0.510*** (0.033)	0.529*** (0.034)
Profitability	0.003*** (0.001)	0.003** (0.001)	0.002** (0.001)	0.003*** (0.001)
Constant	5.963*** (0.446)	5.076*** (0.439)	4.601*** (0.464)	4.458*** (0.480)
Observations	2050	2050	2050	2050
R-squared	0.108	0.129	0.149	0.159
Firm and Year Fixed Effects	Yes	Yes	Yes	Yes

This Table reports the results of the baseline regression estimates of climate risk governance (CRG) and green transformation initiatives (GTI) on carbon mitigation performance (CMP) while controlling for board independence, board size, R&D intensity, leverage, firm size, and profitability. This table also presents the results of the baseline regressions including an interaction variable (CRG\*GTI) in column 4. We use carbon emissions (the natural logarithm of scope 1 and scope 2 emissions) as the proxy for carbon mitigation performance (CMP). All variables are defined and measured in Appendix Tables A2, A3, and A4. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

Table 3: IV analysis (Two-stage Least Squares Estimates)

	(1)	(2)	(3)	(4)
2SLS Regressions: Variables	First stage CRG	Second stage CMP	First stage GTI	Second stage CMP
CRG_ Industry Average	0.917*** (0.0518)			
CRG- Fitted		-0.531*** (0.0751)		
GTI_ Industry Average			0.478*** (0.0164)	
GTI- Fitted				-0.349*** (0.0327)
CRG			-0.0434 (0.0306)	-0.131*** (0.0292)
GTI	0.00916 (0.0148)	-0.175*** (0.0196)		
Board Independence	0.000149 (0.000747)	0.000834 (0.000993)	0.00106 (0.00101)	0.00123 (0.000973)
Board Size	0.0178*** (0.00582)	0.0350*** (0.00795)	-0.0119 (0.00789)	0.0212*** (0.00757)
R&D Intensity	0.00894 (0.00753)	0.00488 (0.0100)	-0.00792 (0.0102)	-0.00117 (0.00976)
Leverage	0.00003 (0.000766)	-0.00331*** (0.00102)	-0.00175* (0.00103)	-0.0039*** (0.000987)
Firm Size	0.0771*** (0.0261)	0.452*** (0.0355)	0.237*** (0.0366)	0.545*** (0.0394)
Profitability	-0.00181** (0.000820)	0.000690 (0.00111)	- (0.00111)	0.00112 (0.00107)
Constant	-0.874** (0.386)	3.917*** (0.509)	-1.851*** (0.527)	2.745*** (0.526)
Firm and Year Effects	Yes	Yes	Yes	Yes
Observations		2050		2050
	<u>Model Fits</u>			
F statistic	316.57 [0.000]		333.86 [0.000]	
Weak identification test: (Cragg-Donald Wald F statistic):	313.18		855.75	
Stock-Yogo weak ID test critical values: 10% maximal IV size	16.38		16.38	

This Table reports the results of the 2SLS estimations. Column 1 reports the 1st stage regression, in which Climate risk governance (CRG) is the dependent variable. CRG\_ Industry Average, the industry average of the climate risk governance (CRG), is the instrumental variable. Column 2 presents the 2nd stage regression, wherein the fitted CRG variable is employed to explain carbon mitigation performance (CMP). Column 3 provides the first-stage regression, where GTI is the dependent variable. GTI\_ Industry Average, the industry average of GTI, is the instrumental variable. Column 4 exhibits the second-stage regression, where the fitted GTI variable is used to regress carbon mitigation performance (CMP). Our control variables remain the same as the baseline models. All variables are defined and measured in Appendix Tables A2, A3, and A4. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

Table 4: Difference-in-Differences estimates – to address endogeneity concerns

DID Models	(1)	(2)	(3)
Variables	CMP	CMP	CMP
CRG	-0.140*** (0.038)		
POSTEVENT	-0.139*** (0.046)	0.389*** (0.112)	-0.132*** (0.041)
CRG*POSTEVENT	-0.068** (0.034)		
GTI		-0.075*** (0.026)	
GTI*POSTEVENT		-0.203*** (0.041)	
CRG*GTI			-0.027** (0.011)
CRG*GTI * POSTEVENT			-0.026** (0.011)
Board Independence	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)
Board Size	0.017** (0.008)	0.015* (0.008)	0.009 (0.008)
R&D Intensity	-0.057 (0.046)	-0.050 (0.046)	-0.045 (0.048)
Leverage	-0.047*** (0.014)	-0.043*** (0.014)	-0.028* (0.015)
Firm Size	0.547*** (0.035)	0.501*** (0.034)	0.546*** (0.036)
Profitability	0.002 (0.001)	0.002 (0.001)	0.003** (0.001)
Constant	3.866*** (0.508)	4.506*** (0.485)	3.881*** (0.520)
Observations	1,885	1,877	1,746
R-squared	0.153	0.143	0.158

This Table shows the results of the difference-in-differences models, where carbon mitigation performance (CMP) is the dependent variable. The top 50% of the sample firms based on high carbon emissions before the climate agreement is placed in the treatment group. POSTEVENT is a dummy variable that takes one for values after 2015 (i.e., from 2016 onward) and zero otherwise. Our control variables remain the same as the baseline regressions. All variables are defined and measured in Appendix Tables A2, A3, and A4. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

Table 5: Robustness test with industry-fixed effects

Variables	(1) CMP	(2) CMP	(3) CMP	(4) CMP
Climate Risk Gov. (CRG)	-0.138*** (0.032)		-0.130*** (0.031)	-0.088** (0.034)
Green Transformation Initiatives (GTI)		-0.193*** (0.020)	-0.204*** (0.020)	-0.203*** (0.023)
CRG*GTI				-0.030*** (0.010)
Board Independence	-0.001 (0.001)	-0.000 (0.001)	0.000 (0.001)	0.000 (0.001)
Board Size	0.030*** (0.008)	0.025*** (0.008)	0.028*** (0.008)	0.020** (0.008)
R&D Intensity	-0.052 (0.042)	-0.070* (0.041)	-0.074* (0.041)	-0.056 (0.042)
Leverage	-0.005*** (0.001)	-0.004*** (0.001)	-0.005*** (0.001)	-0.003*** (0.001)
Firm Size	0.504*** (0.030)	0.565*** (0.030)	0.617*** (0.031)	0.627*** (0.032)
Profitability	0.003*** (0.001)	0.003** (0.001)	0.002** (0.001)	0.003** (0.001)
Constant	3.637*** (0.481)	3.081*** (0.477)	2.469*** (0.488)	2.389*** (0.512)
Observations	2050	2050	2050	1991
R Squared	0.431	0.461	0.450	0.430
Industry and Year Fixed Effects	Yes	Yes	Yes	Yes

This Table reports the results of regression estimates of climate risk governance (CRG) and green transformation initiatives (GTI) on carbon mitigation performance (CMP) while controlling for industry and year effects. This table also presents the results of the regressions including an interaction variable (CRG\*GTI) in column 4. We use carbon emissions (the natural logarithm of scope 1 and scope 2 emissions) as the proxy for carbon mitigation performance (CMP). All variables are defined and measured in Appendix Tables A2, A3, and A4. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

Table 6 : Test of robustness with the alternative measure of CMP

	(1)	(2)	(3)	(4)
Variables	GHGA	GHGA	GHGA	GHGA
CRG	-0.013*** (0.002)		-0.012*** (0.002)	-0.009*** (0.002)
GTI		-0.012*** (0.001)	-0.013*** (0.001)	-0.013*** (0.002)
CRG*GTI				-0.002*** (0.001)
Board Independence	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
Board Size	0.002*** (0.001)	0.002*** (0.001)	0.002*** (0.001)	0.001** (0.001)
R&D Intensity	-0.002 (0.003)	-0.003 (0.003)	-0.003 (0.003)	-0.002 (0.003)
Leverage	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
Firm Size	-0.023*** (0.002)	-0.017*** (0.002)	-0.015*** (0.002)	-0.013*** (0.002)
Profitability	0.000*** (0.000)	0.000*** (0.000)	0.000** (0.000)	0.000*** (0.000)
Constant	1.140*** (0.031)	1.060*** (0.030)	1.041*** (0.032)	1.028*** (0.033)
Observations	1,991	1,988	1,991	1,991
R-squared	0.141	0.181	0.192	0.189
Firm and Year Fixed Effects	Yes	Yes	Yes	Yes

This Table exhibits the fixed effects regression results using GHGA as an alternative measure of carbon mitigation performance (CMP). GHGA, the total carbon emissions scaled by total assets, is introduced as the dependent variable in all four model specifications. The same set of control variables is used as the baseline models. All variables are defined and measured in Appendix Tables A2, A3, and A4. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

Table 7 : Two-stage System GMM estimations

Variables	(1) CMP	(2) CMP	(3) CMP	(4) CMP
L.LNCE	1.194*** (0.043)	1.154*** (0.039)	1.152*** (0.037)	1.154*** (0.035)
CRG	-0.165*** (0.045)		-0.126*** (0.038)	-0.070* (0.038)
GTI		-0.090*** (0.025)	-0.073*** (0.026)	-0.022 (0.032)
CRG*GTI				-0.035** (0.016)
Board Independence	-0.002 (0.001)	-0.002** (0.001)	-0.002* (0.001)	-0.002 (0.001)
Board Size	0.001 (0.011)	-0.002 (0.009)	0.000 (0.009)	0.001 (0.009)
R&D Intensity	0.040** (0.020)	0.028* (0.016)	0.032* (0.017)	0.032** (0.016)
Leverage	-0.022 (0.020)	-0.014 (0.017)	-0.015 (0.017)	-0.014 (0.017)
Firm Size	-0.156*** (0.040)	-0.128*** (0.038)	-0.108*** (0.034)	-0.104*** (0.031)
Profitability	0.004* (0.002)	0.004* (0.002)	0.004 (0.002)	0.004 (0.002)
Constant	0.328 (0.266)	0.447** (0.212)	0.229 (0.214)	0.026 (0.217)
Observations	1,643	1,635	1,619	1,582
AR(1)	0.002	0.003	0.003	0.003
AR(2)	0.266	0.256	0.209	0.184
Hansen Test	0.350	0.251	0.389	0.466
Sargan Test	0.492	0.318	0.496	0.541

This Table includes the dynamic two-stage system GMM panel data estimates of climate risk governance (CRG) and green transformation initiatives (GTI) on carbon mitigation performance (CMP) as part of the robustness check. Here, the lagged dependent variable is considered endogenous in all the model specifications. Control variables remain the same as the baseline models. All variables are defined and measured in Appendix Tables A2, A3, and A4. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

Table 8 : Additional test – Impact of Board Gender Diversity

Variables	(1) CMP	(2) CMP	(3) CMP	(4) CMP
CRG	-0.144*** (0.033)		-0.135*** (0.032)	-0.109*** (0.035)
GTI		-0.172*** (0.022)	-0.187*** (0.022)	-0.188*** (0.024)
CRG*GTI				-0.022** (0.011)
Gender Diversity	-0.118*** (0.028)	-0.075*** (0.028)	-0.061** (0.028)	-0.050* (0.029)
Board Independence	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)
Board Size	0.020** (0.008)	0.012 (0.008)	0.016* (0.008)	0.016* (0.008)
R&D Intensity	-0.030 (0.048)	-0.046 (0.048)	-0.060 (0.047)	-0.044 (0.048)
Leverage	-0.025* (0.015)	-0.022 (0.015)	-0.025* (0.014)	-0.016 (0.015)
Firm Size	0.355*** (0.034)	0.397*** (0.033)	0.437*** (0.035)	0.465*** (0.036)
Profitability	0.003*** (0.001)	0.003** (0.001)	0.003** (0.001)	0.003*** (0.001)
Constant	6.947*** (0.478)	6.467*** (0.456)	6.030*** (0.476)	5.652*** (0.498)
Observations	2050	2050	2050	2050
R-squared	0.084	0.112	0.127	0.140
Firm and Year Fixed Effects	Yes	Yes	Yes	Yes

This Table reports the empirical results after controlling for board gender diversity. Board gender diversity is defined as the proportion of female directors on the board. The dependent variable in all four model specifications is carbon mitigation performance (CMP). All other right-hand side variables remain the same as the baseline models. All variables are defined and measured in Appendix Tables A2, A3, and A4. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

Table 9: Heckman sample selection models

Heckman models for sample selection bias			
Variables	(1) CMP	(2) CMP	(3) CMP
CRG	-0.162*** (0.029)		-0.183*** (0.029)
GTI		-0.181*** (0.019)	-0.051** (0.025)
CRG*GTI			-0.008* (0.005)
Board Independence	-0.001 (0.001)	-0.000 (0.001)	0.001 (0.001)
Board Size	0.025*** (0.008)	0.020*** (0.007)	0.021*** (0.007)
R&D Intensity	-0.024 (0.041)	-0.042 (0.040)	-0.051 (0.038)
Leverage	-0.004*** (0.001)	-0.004*** (0.001)	-0.004*** (0.001)
Firm Size	0.371*** (0.030)	0.460*** (0.029)	0.574*** (0.032)
Profitability	0.003*** (0.001)	0.003*** (0.001)	0.002** (0.001)
Inverse Mills ratio	-0.170** (0.072)	-0.103* (0.054)	0.386*** (0.060)
Constant	4.258*** (0.493)	3.170*** (0.402)	1.813*** (0.501)
Observations	1,991	1,991	1945
Wald chi2	0.000***	0.000***	0.000***

This Table demonstrates the regression results of the Heckman selection models. Industry average values of our test variables are used as the exclusion restrictions to eliminate self-selection bias. The dependent variable in all three model specifications is carbon mitigation performance (CMP). All other right-hand side variables remain the same as the baseline models. All variables are defined and measured in Appendix Tables A2, A3, and A4. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

## Appendix Table A1

### Panel A

Sample distribution based on industry

Industry	Sample
Automobiles, aerospace, defense	17
Construction and Basic Materials	40
Food and Beverage	28
Gas, Water and Utilities	18
Healthcare and Pharmaceuticals	30
IT and Electronics	29
Industrials and Consumer Discretionary	42
Oil, Gas and Energy	20
Retail	21
Services	31
Total	276

### Panel B

Sample selection process

Initial sample:	600
(Less) Firms with Missing data:	156
(Less) Financial firms:	168
Final sample:	276

Appendix Table A2: Components of Climate Risk Governance (CRG)

Climate Risk Governance (CRG)	Reference	Source of Data
1. Board's responsiveness / awareness of climate change risk and opportunities: A dummy variable will equal 1 if the firm is aware of the commercial risk and opportunities arising from climate change, and 0 otherwise.	Bui et al. (2020)	Refinitiv Eikon Datastream
2. Executive compensation for climate change activism: A dummy variable will equal 1 if the company provides executive compensation for ESG performance or climate change actions, and 0 otherwise	Haque and Ntim (2020)	Refinitiv Eikon Datastream
3. Board-level Environmental or ESG Committee: A dummy variable will equal 1 if the firm has an environmental or ESG related committee, and 0 otherwise	Orazalin et al. (2023) Liao et al. (2015) Peters and Romi (2013)	Refinitiv Eikon Datastream
4. Sustainability or Environmental reporting: A dummy variable will equal 1 if the firm publishes sustainability or environmental impact reports, and 0 otherwise.	Al-Shaer (2020)	Refinitiv Eikon Datastream
5. External assurance of disclosures: A dummy variable will equal 1 if the firm's published reports or disclosures are externally assured, and 0 otherwise	Simnett et al. (2009) Moroney et al. (2012)	Refinitiv Eikon Datastream

The climate risk governance index embodies firm-specific governance mechanisms to address climate change and sustainability issues. This index comprises the following five dummy components; hence, the possible score of each firm will fall between 0 and 5.

### Appendix Table A3: Green Transformation Initiatives (GTI)

A firm's green transformation Initiatives (GTI) is a composite score that adds up the below 16 Initiatives. Based on the implemented level of transformation with respect to each initiative, numerical values are awarded to all those initiatives in the following manner:

Not implemented at all = 0

Moderate level of transformation / General indication of any transformation initiative using non-quantifiable evidence / without number values = 1

Broad level of transformation / detailed indication of any transformation activity with quantitative focus/ number values = 2

Green Transformation Initiatives (GTI):	Reference	Source of Data
1. Does the company engage in any emission trading activity?	Haque (2017), Haque and Ntim (2020)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
2. Does the company employ renewable energy such as wind, wave, solar powers?	Haque (2017), Haque and Ntim (2020)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
3. Does the company consistently report on initiatives to reduce, reuse, or recycle water?	Haque (2017), Haque and Ntim (2020)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
4. Does the company take actions to reduce, reuse, replace or phase out toxic chemicals or substances?	Haque (2017), Haque and Ntim (2020)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports

5. Does the company follow environmental criteria (e.g., ISO 14000) or relevant sustainability attributes in the selection process of its suppliers or sourcing partners?	Bleda and Shackley (2008), Freedman and Jaggi (2005), Luo et al. (2012)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
6. Does the company show any systematic initiatives to reduce, reuse, recycle, replace, phase out or compensate carbon equivalents in the production processes?	Haque (2017), Haque and Ntim (2020)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
7. Does the company have required methods in place to improve its energy efficiency?	Haque (2017), Haque and Ntim (2020)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
8. Does the company provide incentives for the green vendors/ suppliers or have strategies for retaining them?	Bleda and Shackley (2008), Freedman and Jaggi (2005), Luo et al. (2012)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
9. Does the company report or indicate any climate change mitigation initiatives?	Weinhofer and Busch (2013)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
10. Does the company gauge financial risks that may stem from climate change?	Weinhofer and Busch (2013)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports

11. Does the company have required actions in place to join and support Race to Zero campaign?	UNFCCC (2020)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
12. Does the company consistently adopt measures for pollution control?	Kassinis and Vafeas (2006) Kakabadse (2007), Iatridis (2013), Wang et al. (2021)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
13. Does the company have policies to choose eco-friendly instruments and infrastructure?	United Nations Environment Program (UNEP) ( <a href="https://www.unep.org/">https://www.unep.org/</a> )	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
14. Does the company have processes in place to develop and market low-carbon products?	Kolk and Pinkse (2005) Töbelmann and Wendler (2020)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
15. Does the company consider training and motivating its employees for sustainable and eco-friendly code of conduct?	(Singh et al., 2019)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports
16. Does the company consider spending for climate-focused or environmental R&D consistently?	Hollindale et al. (2019)	Hand collected data from ESG/ Sustainability/ Corporate Environmental Reports

Appendix Table A4 : Definitions of Other Variables

Carbon Mitigation Performance (CMP)	The natural logarithm of total carbon emissions (in tons), including both Scope 1 (direct) and Scope 2 (indirect) emissions, where higher CMP values exhibit a greater level of carbon emissions and weaker actual carbon performance.
Board Independence	The proportion of independent directors relative to the total board size
Board Size	The number of directors serving on the board
R&D Intensity	The ratio of R&D expenditure scaled by net sales
Leverage	The ratio of total debt to total assets
Firm Size	The natural logarithm of total assets of the firm
Profitability	The ratio of net profit divided by total assets

Appendix Table A5: Additional robustness test (I)

Variables	(1) Scope One Emission	(2) Scope One Emission	(3) Scope One Emission	(4) Scope One Emission
CRG	-0.269*** (0.066)		-0.262*** (0.067)	-0.108** (0.074)
GTI		-0.127*** (0.043)	-0.118*** (0.044)	-0.147*** (0.049)
CRG*GTI				-0.042* (0.022)
Board Independence	-0.001 (0.002)	0.000 (0.002)	0.001 (0.002)	-0.000 (0.002)
Board Size	0.043** (0.017)	0.036** (0.017)	0.042** (0.017)	0.024 (0.018)
R&D Intensity	-0.073 (0.091)	-0.080 (0.094)	-0.096 (0.094)	-0.059 (0.096)
Leverage	-0.006*** (0.002)	-0.005** (0.002)	-0.006*** (0.002)	-0.003 (0.002)
Firm Size	0.377*** (0.065)	0.342*** (0.068)	0.477*** (0.072)	0.466*** (0.076)
Profitability	0.002 (0.002)	0.002 (0.002)	0.001 (0.002)	0.002 (0.003)
Constant	6.112*** (0.933)	6.567*** (0.954)	4.971*** (1.011)	5.344*** (1.060)
Observations	1,985	1,985	1,945	1,819
R-squared	0.034	0.10	0.110	0.109
Firm & Year Fixed Effects	Yes	Yes	Yes	Yes

This Table exhibits the regression results using Scope One emission (direct carbon emissions) as an alternative measure of carbon mitigation performance (CMP), as part of the additional robustness test. The same set of control variables is used as in the baseline models. Appendix Tables A2, A3, and A4 define and measure all variables. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

Appendix Table A6: Additional robustness test (II)

Variables	(1) Scope Two Emission	(2) Scope Two Emission	(3) Scope Two Emission	(4) Scope Two Emission
CRG	-0.144*** (0.049)		-0.129*** (0.049)	-0.144** (0.058)
GTI		-0.193*** (0.035)	-0.153*** (0.038)	-0.169*** (0.044)
CRG*GTI				-0.003 (0.019)
Board Independence	0.000 (0.002)	0.000 (0.002)	0.001 (0.002)	0.002 (0.002)
Board Size	0.016 (0.013)	0.021 (0.013)	0.021 (0.013)	0.012 (0.014)
R&D Intensity	0.147** (0.072)	0.131** (0.066)	0.151** (0.070)	0.166** (0.075)
Leverage	-0.002 (0.002)	-0.001 (0.002)	-0.000 (0.002)	-0.001 (0.002)
Firm Size	-0.185*** (0.053)	-0.014 (0.052)	-0.138** (0.061)	-0.154** (0.068)
Profitability	0.002 (0.002)	0.001 (0.002)	0.002 (0.002)	0.001 (0.002)
Constant	13.065*** (0.752)	10.829*** (0.710)	12.625*** (0.853)	12.972*** (0.953)
Observations	1,985	1,985	1,910	1,805
R-squared	0.031	0.040	0.051	0.052
Firm & Year Fixed Effects	Yes	Yes	Yes	Yes

This Table presents the regression results using Scope Two emission (indirect carbon emissions) as an alternative measure of carbon mitigation performance (CMP), as part of the additional robustness check. The same set of control variables is used similar to the baseline models. Appendix Tables A2, A3, and A4 define and measure all variables. Standard errors are reported in parentheses. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10 % level respectively.

## Chapter 4

# Empirical Essay Two

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## **Does climate risk governance affect environmental innovation?**

### **Abstract**

The existing body of literature with regard to climate-oriented governance focuses on carbon disclosure and climate change commitments, with a notable omission of an essential aspect of sustainable business practices and decarbonization, i.e., environmental innovation. In this study, we examine the effect of climate risk governance on firm-level environmental innovation. Based on a panel of 4,378 firm-year observations from the non-financial S&P 500 components over the period of 2011 to 2021, we provide novel empirical evidence that corporate climate risk governance is positively associated with environmental innovation. Firms with strong climate risk governance appear to engage more in environment-friendly innovative approaches to reduce environmental costs and the burden on customers. In simpler terms, we argue that executing climate-focused governance mechanisms enables firms to leverage market prospects by improving existing environmental technologies and creating environmentally sustainable products or services. Further analysis identifies a channel, namely environmental investment, through which climate risk governance facilitates environmental innovation. Our results remain consistent after we employ an instrumental variable approach and propensity score matching estimates to address potential endogeneity bias. The empirical results also pass a battery of robustness tests with alternative variables and different estimation techniques. Overall, this study contributes to the global discourse on environment-friendly innovations that promote more sustainable business solutions and are intended to mitigate the impact of climate change.

Keywords: Climate risk governance, Environmental innovation, Sustainability, Resource-based view

## 1. Introduction

Carbon-emitting firms encounter enormous pressure from policymakers and regulators to curb their carbon emissions, widen their environmental engagements, and adhere to disclosure requirements (Safiullah et al., 2021; Backman et al., 2017; Okereke and Russel, 2010). The escalation of carbon risk potentially dissuades firms from utilizing technologies with high carbon emissions, while motivating them to deliberately transition towards more carbon-reducing and environment-efficient alternatives (Nguyen and Phan, 2020). The transition to environmentally responsible innovations and green technology is unquestionably a prerequisite for managing climate change risk (Acemoglu et al., 2012). Such environmentally beneficial technology aims to reduce environmental stress (Costantini et al., 2017) and helps firms gain environmental competitiveness for long-term sustainability. Additionally, there is a growing call from investors, shareholders, and other business partners for firms accountable for carbon emissions and environmental pollution to provide evidence of accountability and reliability to stakeholders by bettering corporate climate commitments with appropriate substantive initiatives (Afrifa et al., 2020; Hollindale et al., 2019). It is well established that sustainable business initiatives in pursuit of addressing climate change predominantly include investing in renewables, preventing pollution, recycling and reusing materials, controlling carbon emissions, and using more energy-efficient production processes (Alam et al., 2019; Atif et al., 2022; Haque and Ntim, 2022; Orazalin et al., 2023). Furthermore, long-term business sustainability necessitates environmentally suitable innovation and technological advancements of sufficient scope and capacity (Shi et al., 2021). According to Asongu and Odhiambo (2021), environmental innovation is recognized as a means of attaining firm-level sustainability objectives by enhancing energy efficiency, mitigating the adverse impacts of resource utilization, and diminishing environmental hazards and pollution. A consensus among environmentalists, regulators, experts, and academics exists regarding the critical nature of a green economy with net zero status. Nevertheless, attaining such an economy is impossible without eco-driven approaches and innovation (Swainson and Mahanty, 2018). More importantly, environmental innovation technologies create vast opportunities and have the potential to increase the efficacy of manufacturing processes. In this connection, Choudhary et al. (2019) find evidence that uniting lean and green paradigms through the Green Integrated Value Stream Mapping technique leads to a synergistic impact on employee productivity, operational effectiveness, and overall environmental sustainability. However, the available literature primarily sheds light on conventional innovation that triggers profit-oriented firm

performance; for instance, Bocquet et al. (2017). Environmental innovation, on the other hand, is distinguished from innovation in general by its primary objective, which is to improve environmental conditions and ensure long-term sustainability rather than focusing solely on financial gain. The purpose of this study is, thus, to look into a resilient determinant of environmental innovation at the firm level.

According to Gerged et al. (2021), climate-focused board processes that reflect increased concern about climate change and related activism have come to the forefront of executive management decision-making in an era of socio-environmental pressures. Bui et al. (2020) argue that shifting the emphasis of corporate governance towards a more robust climate governance approach is critical, and this means moving beyond the conventional corporate governance mechanisms that may not adequately explain climate protection undertakings and obligations. Therefore, in the context of climate change and its far-reaching global impact, the firm-level climate risk governance measures aim to determine how well climate activism and related compliance have been incorporated into the corporate boardrooms. In addition, corporate boards with a strong focus on climate change risk and sustainability can restrain potential greenwashing attempts (Bui et al., 2020). A climate-focused governance structure might help mitigate the potential harmful impact of climate change (Galbreath, 2010) as well as position firms to harness opportunities arising from an environmentally responsive business model (Drobotz et al., 2023). Conventional governance mechanisms, in contrast, do not sufficiently reflect firm-level climate-focused pledges and actions. Thus far, the limited body of literature that exists on climate governance is focused on carbon disclosure (Bui et al., 2020), carbon emissions (Albitar et al., 2022), and firm-level commitments regarding climate change risk or sustainability (Albitar et al., 2023). However, climate risk governance is likely to affect one of the critical components of sustainable business practices and environmental safety for the long term, namely environmental innovation, which has been noticeably absent from this discourse. Therefore, the question that comes into play is whether climate risk governance influences firm-level environment-friendly innovation.

In this study, we investigate the association between climate risk governance and environmental innovation based on a sample of 4,378 firm-year observations obtained from 398 non-financial firms that are constituents of the S&P 500 index during the period between 2011 and 2021. Our results reveal a significant positive relationship between climate risk governance and environmental innovation consistent with resource-based view and agency theoretical predictions. As is the case, firms with effective climate risk governance tend to be more environmentally aware, and their climate activism within the boardroom increases the potential for environmental innovation. This association is more pronounced for large firms with a strong emphasis on climate risk governance. The use of IV analysis and propensity score matching (PSM) confirms that our results are robust to the endogeneity concerns. As per the findings of our channel analysis, climate risk governance practices result in high environmental expenditures, which in turn supports firm-level environmental innovation. To prevent sample selection bias, we apply two-stage Heckman selection models in this study. We also perform additional tests using various estimation techniques, such as the FE model and GMM regressions. Furthermore, alternative variables were used for the dependent variable. Across all the analyses, our empirical results remain consistent.

Our study makes a valuable contribution to the growing body of literature in several ways. First, to the best of our knowledge, this study represents a novel empirical investigation into the association between environmental innovation and climate risk governance. Previous climate governance studies have concentrated on carbon-related disclosures (Bui et al., 2020) and commitments to climate protection (Albitar et al., 2023). However, a vital and more dynamic dimension of any efforts to reduce carbon footprints and ensure environmental safety, namely eco-friendly innovation capacity, has been left unexplored. Therefore, our results are a crucial contribution to the emerging body of literature on climate governance. Second, we look into the mechanism by which climate risk governance affects environmental innovation. We reveal that climate risk governance facilitates environmentally favorable innovations by committing more environmental expenditures to it. Earlier studies have shown that firms with ample cash and related resources tend to invest more in renewable energy consumption and green innovation (Alam et al., 2022; Li et al., 2020; Lyandres and Palazzo, 2016). Therefore, this study extends the existing body of literature. According to the results of our channel analysis, we provide novel empirical evidence that the pursuit of climate risk governance induces firm-level environmental expenditures, which provides support for environmental innovation. Moreover, we analyze subsamples of large and small firms to obtain deeper

insights. It has been argued that large firms tend to have limited financial challenges and a better mix of resources, allowing them to recognize and cope with environmental worries more effectively (Al-Tuwaijri et al., 2004; Clarkson et al., 2008; de Villiers et al., 2011), giving rise to their environmental innovation. Larger firms also face greater societal pressure and are subject to a strict regulatory compulsion to get involved in environmentally friendly projects or green initiatives than their smaller counterparts (Al-Tuwaijri et al., 2004). Accordingly, we offer new evidence that the impact of CRG on eco-innovation is more notable for large firms than for their smaller counterparts. Third, we are among the first to apply Refinitiv Eikon Datastream database scores to proxy firm-level environmental innovation. Unlike those used in earlier studies (i.e., Mongo et al., 2021; Afrifa et al., 2020; Hashmi and Alam, 2019), the environmental innovation scores used in our study do not merely rely on the number of patents the firms hold or the firm-level R&D expenditures as proxies of environmental innovation. Instead, as is the case, our environmental innovation score considers the environmental technologies and specific sustainable processes that enable firms to lower their environmental costs and reduce the burdens for their customers. Therefore, our dependent variable, environmental innovation score, covers all eco-friendly innovative business aspects ranging from the patents the firm may possess to all other innovative methods, purchased technological support, and related expertise that do not require patenting. Overall, our empirical findings provide vital insights for firms and regulators seeking to incorporate climate governance mechanisms and embark on more [environment-friendly](#) innovations to minimize the effect of climate change.

The remainder of this study is structured as follows. Section two develops the theoretical framework and reviews related literature. Section three presents the data, empirical models, and summary statistics, while section four reports the empirical results. Finally, section five concludes the essay, presenting policy implications and the scope of future research.

## 2. Theory, Related Literature, and Development of Hypotheses

As far as a firm's ability to use internal resources and manage external relations and dependencies is concerned, the resource-based view and resource dependence theory are at play. Although both theories focus, in a sense, on resources, they differ in their approaches. In the current context, we focus on the resource-based view because, by emphasizing corporations' internal resources and capabilities, this theory stresses how best to use them to attain and withstand a competitive advantage. The resource-based view is concerned with a firm's internal resources, examining how the unique and valuable resources of the organization can provide a competitive advantage (Barney, 1991; Peteraf, 1993). The operating performance of a firm depends on its capacity to identify, cultivate, and protect its internal resources that are valuable, rare, and non-substitutable (Amit and Schoemaker, 1993). In the same vein, Barney (2001) claims that the resource-based view stimulates a direct association between firms' valuable, inappropriately mimicable resources, capacities, and competitive advantage that is sustainable for the long term. The resource-based insight supports the view that firm competitiveness and the ability to outstrip others rest on the available in-house resources that are heterogeneous in character and distinctive in value (Lee and Min, 2015). The existing climate change literature evolves around the resource-based view, under the assumption that climate activism may necessitate huge investments that firms with adequate resources are better able to bear (Qiu et al., 2016). However, as observed, many firms appear to prioritize symbolic activism over substantive environmental performance. For instance, a greenwashing (or impression management) tendency may induce managers to implement process-based carbon performance that does not enhance actual carbon performance (Boiral and Hras-Saizarboritoria, 2017; Haque and Ntim, 2020). As Bowen (2014) explains, environmental disclosure does not necessarily reflect actual environmental performance. Likewise, Dragomir (2012) provides evidence that several highly carbon-intensive firms have provided misleading carbon footprint data. Moreover, incongruity in the methodologies has been uncovered in those firms' environmental impact reports. As a result, it is crucial to take into account not only the assumption of possessing and exercising control over assets and resources, as per the resource-based view but also the intent of top-level management and the ability of firms to efficiently and timely modernize and reconfigure critical resources to adapt to a rapidly changing environment. This ability is commonly known as a dynamic capability (Huang and Li, 2017; Zahra et al., 2022). Simply put, the strategy of moving beyond the traditional resource-based model entails the ability to transform a firm's owned and controlled resources into its primary

strength as well as a competitive edge. Given the circumstances, it is reasonable to expect that not all firms possessing ample resources are capable of leveraging them to gain a competitive edge. Thus, we argue that it is corporate climate risk governance (CRG), as an organizational factor, that helps make the usage of firm-specific resources and know-how more effective and actionable to realize dynamic capabilities, such as environmental innovation. The executive management team is responsible for leading and implementing the corporate governance mechanisms. A climate-focused governance structure inside corporate boardrooms plays a vital role in setting preferences for capacity building in the process of addressing climate change issues (Zahra et al., 2022). Overall, from the perspective of resource availability, such governance mechanisms are expected to facilitate the development and strategic management of environmentally sustainable innovation. On the contrary, firms lacking a well-established climate governance framework would struggle to effectively address climate change issues, likely resorting only to symbolic responses.

Agency theory, as proposed by Jensen and Meckling (1976), explores the conflict of interest that arises between principals (shareholders) and their delegated agents (managers). The theory is based on the premise that monitoring mechanisms, increased compliance, and incentive structures are necessary to mitigate the prevailing conflict. A reasonable alignment between shareholders' interests and management priorities can effectively mitigate agency issues (Liao et al., 2015) and thereby support firm-level outcome-based sustainable performance, i.e., an upsurge in environment-friendly innovation, as well as maximizing firm performance. Corporate governance mechanisms in response to climate change, motivated by agency theory, entail the existence of a board-level environment/ESG committee (Peters and Romi, 2013) and reporting responsibilities regarding climate change actions to prevent information asymmetry and ensure greater transparency (Grimmelikhuisen et al., 2013; Jensen and Berg, 2012). In addition, an effectively functional monitoring role, which originates from the agency perspective, can reinforce corporate boards' responsiveness to climate-related risks and opportunities. As predicted by this theory, external mechanisms of control, including government-recommended reporting obligations and other regulatory mandates, function effectively (Tauringana and Chithambo, 2015). Finally, agency theory posits that incentive-based mechanisms are likely to motivate managers to pursue substantial climate change activism, which aligns effectively with the interests of managers and shareholders (Cordeiro and Sarkis, 2008; Haque, 2017). Hence, based on the predictive power of agency theory, we conjecture that the proficient supervision of management, through the presence of a board-

level sustainability committee and increased compliance, can persuade the board with an explicit focus on the climate-focused governance structure, which in turn provides support for firm-level eco-friendly innovation and technological advancement.

In sum, seen from a resource-based view, firms that implement climate risk governance are expected to optimize their current resources and capabilities to achieve a genuine impact on environmental innovation beyond that of their competitors. In addition, agency theory argues that superior monitoring roles, sound compliance, and incentive mechanisms promote climate-focused commitments in corporate boardrooms. Based on the above discussion, it is apparent that RBV and agency theory lay the theoretical foundation for our research. Therefore, we follow, among others, de Villiers et al. (2011), Mallin and Michelon (2011), and Haque (2017) in utilizing the resource-based view and agency-based theoretical arguments to explain the intricate relationship between climate risk governance and environmental innovation.

The primary challenge faced by carbon-intensive firms is an excessive level of carbon emissions. As an alternative, environmental innovation, which refers to a firm's ability to develop new eco-friendly technologies and processes to reduce costs and create new market opportunities by improving existing processes, is acknowledged as the solution to reinforcing environmental protection and stability. The related literature shows that environmental innovation aimed at sustainability is arguably the most plausible remedy to the ever-growing climate change concerns by limiting environmental liabilities, saving energy, and reducing and recycling waste and other substances (Cainelli et al., 2020; Krieger and Zipperer, 2022; Rennings, 2000). Mensah et al. (2018) argue that environmentally sustainable innovation can play a crucial role in carbon mitigation performance in the majority of OECD nations. In the same vein, Ali et al. (2016) report that investments in sophisticated and eco-friendly technologies substantially reduce carbon footprints and enhance environmental quality. Furthermore, according to Lee and Min (2015), a firm's competitive advantage can be enhanced by its capacity to envisage and develop sustainable products and technologies. However, in many cases, firms may lack the motivation to engage in environmental innovation owing to its dual external effects, the associated uncertainty, and market inefficiencies, as seen from the standpoint of both environmental policy and economics (Horbach et al., 2012; Rennings, 2000; Weitzman, 2007). Therefore, it would be valuable to consider a resilient driver that is rooted in climate change affairs and could motivate firms to better implement environmentally sustainable innovation.

There is a sparse body of research that deals with the association between conventional corporate governance mechanisms and environmental innovation. Surprisingly, of the various governance attributes, only a few mechanisms have been explored. Those that have received attention include board gender diversity (Nadeem et al., 2020), governance shocks and institutional ownership (Amore and Bennedsen, 2016), and the overall corporate governance rating (Makpotche et al., 2024). Based on the above evidence, it is clear that conventional corporate governance measures may not consistently promote innovation within firms, and they may only be effective up to a certain point, beyond which there will be room for friction that requires further exploration. In this context, we argue that climate-focused governance with an action-based approach might offer a plausible explanation for going beyond this threshold to reach a more advanced and extensive level of innovation. Thus, we aim to present climate risk governance as a potential driver of environmental innovation.

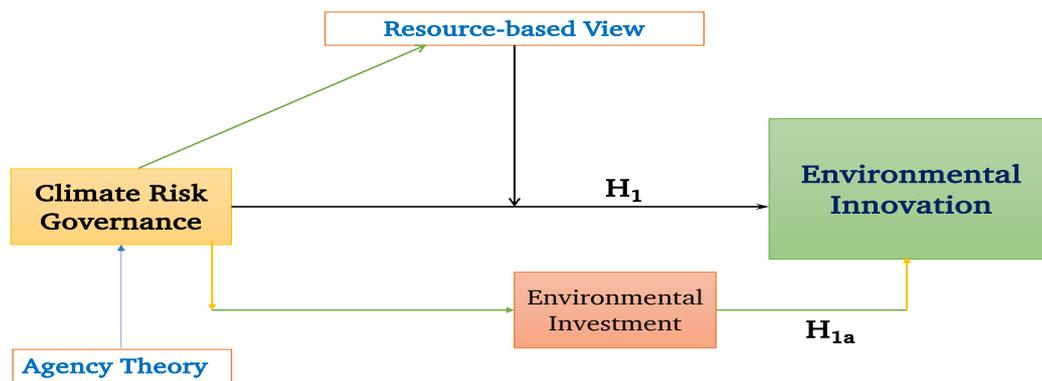
The academic debate with regard to corporate climate responsibility has increasingly pointed out the role of climate governance in addressing climate change risk, devising carbon control strategies, and accelerating sustainable business actions. The scope to which a firm is dedicated to governing climate change risk can be assessed by examining whether it is watchful and has adequately integrated climate-focused aspects into its board-level decision-making processes. Ntim and Soobaroyen (2013) suggest that robust governance mechanisms concerning climate change can serve as a deterrent for carbon-intensive firms, preventing them from evading compliance responsibility and environmental accountability. For example, climate activism may involve establishing a board-level sub-committee that seeks to remain particularly responsible for addressing climate change issues and providing incentives to executive management to encourage contributions towards climate change and eco-friendly business actions (Ioannou et al., 2016; Prado-Lorenzo and Garcia-Sanchez, 2010). It has been argued that governance measures building upon climate change issues are a better fit than conventional governance mechanisms, such as gender diversity, board size, and board independence, as these parameters do not translate climate activism or adequately address sustainability issues (Arena et al., 2018; Bui and de Villiers, 2017; Bui et al., 2020). As a result, earlier studies have reported mixed empirical results after investigating traditional governance characteristics as the determinants of substantive carbon performance (Haque, 2017; Moussa et al., 2019; Luo, 2019). Further, it is asserted that particular boardroom attributes may have varying effects on a variety of environmental and sustainability performance outcomes (Jain and Zaman, 2020). Therefore, a significant emphasis on climate-focused governance is anticipated to represent a

reasonable understanding of climate change risk and sustainability issues encouraging firms to institute substantive involvement required for environmentally sustainable innovativeness.

Accordingly, we expect that climate risk governance mechanisms to enable firms to comply with regulatory requirements, such as carbon and climate-related disclosure to minimize the legitimacy gap due to the increase in stakeholders' concerns over climate change (Talbot and Boiral, 2018) and with climate change policies to escape monetary penalties (Matsumura et al., 2014). This, in turn, is expected to affect firm-level scope and capacity for eco-driven innovative approaches. Based on the above discussion, we formulate our first hypothesis as follows:

Hypothesis 1: Ceteris paribus, climate risk governance is associated with higher firm-level environmental innovation.

Figure 4: The conceptual model of essay two



Source: Author's Proposition

It is argued that adequate investment always plays a crucial role in boosting environmental engagement and sustainability performance (Betts et al., 2018; Li and Ramanathan, 2020; Pekovic et al., 2018). Similarly, environmental investment can help firms to implement environment-friendly strategies (Alam et al., 2022). Gonzalez-Benito and Gonzalez-Benito (2005), together with Klassen and Whybark (1999) contend that investment in environmental initiatives enhances firms' operational efficiency. This is because firm-level investment in sustainable business practices may increase energy efficiency and reduce carbon emissions (Tolliver et al., 2020; Journeault et al., 2016), which ultimately helps to accelerate

environmental engagements. Firms, thus, spend money to overcome the cost and knowledge hurdles of innovation (Andries and Hünermund, 2020). Environmental spending primarily entails allocating funds to support the development of sustainable business actions. The primary goal is to reduce harmful environmental effects and contribute to environmental well-being. The extant literature, in this regard, informs us that spending on environmental initiatives is likely to accelerate technological progress directly by improving product design as well as indirectly through sustainable transition and innovation (Clarke et al., 2006; Fischer and Newell, 2008). Therefore, based on the above line of reasoning, it is plausible to consider that the higher the environmental expenditure, the greater the potential for environmentally friendly innovative capacity.

Since the climate risk governance framework is expected to explain firm-level environmental innovation significantly, a pertinent follow-up question that might arise is through which channel higher climate risk governance drives environmental innovation. With respect to this, we argue that climate risk governance (CRG) fosters systematic and credible investment in environmental initiatives, which ultimately serves as a mechanism through which CRG affects firm-level environmental innovation. A resilient and robust climate risk governance framework appears to influence corporate sustainability strategies and related investments through several well-defined mechanisms, including the assessment of climate risks and opportunities, environmental committees, sustainability reporting, external assurance, and sustainability-linked incentives. By integrating climate risks into corporate strategy, firms recognize environmental challenges as financial risks, prompting proactive investment in sustainable initiatives. Environmental committees play a crucial role in ensuring accountability, formulating strategies, and recommending the allocation of funds toward sustainability-focused spending. Meanwhile, sustainability reporting and external assurance enhance transparency and investor confidence, further reinforcing environmentally responsible investment decisions. In addition, sustainability-linked incentives align corporate sustainability objectives with financial commitments, encouraging firms to develop and implement plausible environmental strategies. Overall, the climate risk governance framework tends to persuade firms to commit more funds to environmental spending, eventually facilitating environmentally friendly innovations. Therefore, we propose the following hypothesis:

Hypothesis 1a: *Ceteris paribus*, climate risk governance supports firm-level environmental innovation through increased environmental investments.

### 3. Data, Variables and Empirical Models

We focus on the S&P 500 index, including the largest publicly traded firms listed on the NYSE or NASDAQ. Firms with significant capitalization are subject to considerable regulatory obligations and societal expectations to assume a leading role in climate activism and get responsibly involved in environment-friendly innovations and technological advancements. Accordingly, our investigation incorporates 4378 firm-year observations from 398 non-financial S&P constituents between 2011 and 2021 after we drop banks and other financial institutions<sup>17</sup> from the initial sample. It is also pertinent to mention that we focus on firms that are liable for direct CO<sub>2</sub> emissions as part of their regular business functions and are regarded as carbon-intensive<sup>18</sup>. These carbon-intensive companies are responsible for CO<sub>2</sub> emissions classified as Scope One<sup>19</sup> (direct emissions). In addition, we consider non-financial firms that are prone to Scope Two<sup>20</sup> (indirect) emissions. There are two justifications for selecting the study period from 2011 to 2021. First, the selection of 2011 as the starting point for our sample period effectively sidesteps any complications stemming from the global financial crisis and its aftermath. Second, since the post-crisis period, the top-level management of non-financial firms has demonstrated increased awareness of climate change issues and the importance of eco-friendly approaches, responding to national climate change policies and related global accords.

#### 3.1 Dependent Variable: Environmental innovation

The extant literature (i.e., Kesidou and Demirel, 2012; Lin and Zhu, 2019) informs us that environmental innovation can enhance energy efficiency and reduce the energy consumption and carbon footprints of manufacturing and distribution. As a result, there has been a growing emphasis on eco-friendly products and services and more ecologically sustainable production processes (Hole and Hole, 2019). According to Zhang and Walton (2017), environmental innovation has been acknowledged as a practical approach to addressing climate change issues.

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<sup>17</sup> Banks and other financial institutions are not included in our final sample because they are not liable for direct carbon emissions. Furthermore, due to the regulatory framework imposed on banks and other financial institutions, they adhere to governance mechanisms different from those of non-financial firms (Luo and Tang, 2020; Orazalin, 2020).

<sup>18</sup> <https://www.greenelement.co.uk/blog/carbon-footprint-scope-1-2-3/> (Accessed on January 30, 2024)

<sup>19</sup> Scope one: This encompasses all types of direct emissions from owned or controlled sources.

<sup>20</sup> Scope two: The reporting firm categorizes indirect emissions, which include the production of purchased electricity, cooling, steam, and heating. Scope two, for example, includes electricity from energy suppliers to power up computers.

Environmental innovation<sup>21</sup> can consistently deliver practicable solutions for ecosystem issues. This approach enables firms to modify their production methods and efficiently manage their resource consumption and pollution levels (Pan et al., 2020). Hence, firms must develop more eco-driven approaches to remain environmentally sustainable in their business actions. However, it has been argued that assessing environmental innovation can be challenging. Several studies employ R&D expenses as a proxy for innovation; but firms are not subject to any regulatory requirement to disclose their expenditure on environment-focused R&D and only a handful of firms are found to have reported on environmental R&D. Thus, consistent with Albitar et al. (2022), Nadeem et al. (2020) and Zaman et al. (2021), we use the environmental innovation score from the Refinitiv Eikon DataStream database. The environmental innovation score accumulated from Refinitiv Eikon DataStream refers to a firm's capability to develop new environmental technologies and processes to lower its environmental costs and the burdens for its customers. This allows the firms to create new market opportunities by improving existing environmental technologies and processes or by developing eco-friendly products or services. It also shows how efficiently firms are advancing their research and development into eco-friendly products and services. The score for environmental innovation ranges from 0 to 100.

### 3.2 Independent Variable: Climate Risk Governance

First, a board's awareness of climate change risks, opportunities, and regulatory directives is the cornerstone of the climate governance configuration. Climate change issues are anticipated to generate business threats and create potential opportunities. Therefore, it is the responsibility and commitment of the board to remain informed of the climate change risk factors, opportunities, and potential courses of action. For instance, when a board is accountable for the risks and opportunities stemming from climate change, the executive management might develop new environmentally sustainable products, services, or business solutions to accommodate the variations and control the resulting impact. Therefore, if the firm is aware of

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<sup>21</sup> Upon examining environmental R&D expenditures and the number of environment-related patents as a proxy of environmental innovation, we face significant challenges related to data availability. A critical issue lies in the absence of regulatory mandates requiring US firms to report these variables, leading to inconsistent and incomplete datasets. Further, we observe numerous instances of missing data, even among prominent carbon-sensitive non-financial firms expected to prioritize environmental innovation.

the commercial risks and opportunities arising from climate change, we assign 1 and 0 otherwise.

Second, the available literature indicates that executive compensation is associated with firms' environmental performance. For example, Campbell et al. (2007) argue that a well-planned sustainable compensation policy can encourage executives to increase their involvement in environmental initiatives, eventually resulting in substantive environmental performance. We intend to observe whether sustainability-linked incentives for executive managers spur firm-level eco-friendly innovation. Hence, a firm will be awarded one if it confers executive incentives or compensation for substantial climate change actions or contributions, and zero otherwise.

Third, relevant studies (i.e., Liao et al., 2015; Peters and Romi, 2013) have found that corporate environmental committees as a component of the board are positively related to the likelihood of sustainability or CO<sub>2</sub> disclosure. It is also argued that although independent directors may not possess the authority or scope to mandate that powerful executives commit significant long-term resources (financial and otherwise) to carbon mitigation, a board-level sustainability or environmental committee will consistently promote the incorporation of environmental strategies and practices within the organization (Albitar et al., 2023). Ioannou et al. (2016) also claim that any specialized committee can better manage and advise on climate-related issues. In the same vein, we argue that an environmental committee can be an effective governance measure to promote innovation and improve the quality and strength of overall climate risk governance. Hence, we consider the board-level environmental or ESG-related committee to be a component of the climate risk governance index.

Fourth, over the past two decades, sustainability reporting has received enormously increasing attention, which is more noticeable in highly polluting countries worldwide. Firms now publish environmental impact reports or sustainability reports to demonstrate their commitment to transparency (Dhaliwal et al., 2011). These reports also offer detailed insights into how the firm allocates its resources and leverages its capabilities to address climate-related challenges. Socially responsible firms are expected to prepare and publish such reports, and due to regulatory and stakeholder pressure, this is crucial for firms accountable for both scope 1 and scope 2 emissions. Sustainability reporting is intended to communicate a substantive and fair stance on firms' long-term sustainability performance and to reflect on the climate protection

initiatives likely to trigger environmental innovation. Therefore, we consider sustainability reporting as one of the components of climate risk governance.

Finally, we focus on the external assurance of the sustainability, ESG, or environmental reports to be a component as external validation authenticates the climate activism and reduces the potential for greenwashing in disclosure and compliance. In this respect, we follow Simnett et al. (2009) and Moroney et al. (2012) by incorporating external assurance into the index. Firms that get their reports or disclosures externally assured or audited receive one and zero otherwise. Overall, the climate risk governance index includes firm-specific governance mechanisms to deal with climate change and sustainability, with a higher climate governance score indicating superior climate activism by the firm. As our index comprises five indicator variables, the possible score of each firm falls between 0 and 5. Appendix A1 lists all five CRG components.

### 3.3 Control Variables

Having considered the related literature, we select the below control variables as potential drivers of environmental innovation. We use Board Size (the size of the board), which is measured as the number of directors serving on the board (Kang et al., 2007; Lim et al., 2007). Consistent with previous studies (i.e., Haque and Ntim, 2020; Bui et al., 2020; Berrone and Gomez-Mejia, 2009), we also control for Board Independence. Board independence is defined as the number of independent directors as a percentage of the board size. Further, following de Villiers et al. (2011), Luo et al. (2012), Haque (2017), and Haque and Ntim (2020), we control for several firm-specific characteristics, such as Firm Size (the natural logarithm of total assets), Leverage (the ratio of total debt to total assets), and Profitability (proxied by net profit scaled by total assets). Following earlier works (Albitar et al., 2023; Nadeem et al., 2020), we include Capital Intensity, categorized as a firm's capital expenditures scaled by total sales. Following Leyva-de la Hiz et al. (2019) and Konadu et al. (2022), we also add Liquidity (the ratio of current assets to current liabilities) to our models. Finally, we control for Market to Book, the ratio of market price to book value of the firm (Albitar et al., 2023; Safiullah et al., 2021).

### 3.4 Empirical Model

This study employs univariate and multivariate analyses to examine the effects of climate risk governance on firm-level eco-friendly innovation. The following empirical model includes climate risk governance<sup>22</sup> (CRG) as the main explanatory variable, together with firm-specific control variables:

$$\text{Environmental innovation}_{it} = \beta_0 + \beta_1 \text{CRG}_{it} + \beta_2 \text{Board Independence}_{it} + \beta_3 \text{Board Size}_{it} + \beta_4 \text{Firm Size}_{it} + \beta_5 \text{Capital Intensity}_{it} + \beta_6 \text{Leverage}_{it} + \beta_7 \text{Liquidity}_{it} + \beta_8 \text{MTB}_{it} + \beta_9 \text{Profitability}_{it} + \beta_{10} \text{Industry fixed effects}_{it} + \beta_{11} \text{Year fixed effects}_{it} + \varepsilon_{it} \quad (1)$$

We apply the ordinary least squares estimate as the baseline regression while controlling for industry and year effects. Both the industry and year-fixed effects allow us to control for any time and industry-specific differences (Shen et al., 2021; Siddique et al., 2021). We also employ different estimation techniques to check the robustness of our baseline results and address the endogeneity bias. Appendix A1 presents the definitions of the variables.

## 4. Empirical Results

### 4.1 Summary Statistics and Baseline Estimates

Table 10 presents the descriptive statistics of all the variables used in our empirical model. The mean value of the environmental innovation score is 31.96, with a standard deviation of 32.36, which is qualitatively consistent with the prior research (Albitar et al., 2022). The environmental innovation score ranges from 0 to 100, with a maximum value of 99.70. The average score on the climate risk governance index stands at 2.498, with a standard deviation of 1.719. The range of CRG values spans from 0 to 5, as our CRG index is comprised of five components. With regard to the governance variables, we find that an average of 77% of the directors are independent, which is comparable to the figure presented by Alam et al. (2022). In addition, in line with the findings in Haque and Ntim (2018) and Tauringana and Chithambo (2015), the boards of our sample firms are, on average, served by nine members. We also detect that the average firm size is 16.47, which is calculated as the natural logarithm of the total assets. Among other firm-specific control variables, the average values of capital intensity, leverage, and market-to-book ratio are 6.964%, 28.90%, and 3.773, respectively. The observed

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<sup>22</sup> Appendix A1 lists all five CRG components.

mean liquidity (current ratio) value of our sample firms is 1.665. Finally, the summary statistics of profitability indicate that the average return on assets of the sample firms is 8.107%.

Table 11 shows the matrix of correlations for the independent and control variables included in our analysis. The correlation coefficient between climate risk governance and environmental innovation is positive and significant at the 1% level. As expected, the climate risk governance index is positively associated with firm-level environment-friendly innovation, which is in line with our argument. We also perform the variance inflation factor (VIF) test to check for potential multicollinearity issues. The mean VIF score is 1.77, and the VIF values for our model variables range from 1.11 to 3.04. Any value of VIF above 10 indicates the presence of multicollinearity (Chatterjee and Hadi, 2006; Lardaro, 1993). Hence, our VIF results suggest that multicollinearity does not tend to be a concern for our study, and the econometric techniques we apply are likely to produce unbiased results.

Table 12 illustrates the baseline estimates for climate risk governance (CRG) and environmental innovation. Here, column 1 reports the estimated coefficient for climate risk governance without the presence of the control variables, while column 2 shows the regression estimates after including all the control variables. We account for year and industry effects based on the assumption that unobserved factors particular to years and industries may influence firms' environmentally sustainable innovative capacity to a considerable extent. Accordingly, column 3 presents the estimated results after controlling for industry and year effects. Finally, column 4 exhibits the results by incorporating one-year-lagged values of all the explanatory variables. According to the reported results, as anticipated, CRG reveals a strong positive relationship with the dependent variable, which is statistically significant at the 1% level. This finding suggests that the greater the extent of firm-level climate-focused governance activism, the more environment-friendly the innovative approaches would be. Our results are consistent with the arguments of the resource-based view and agency theory in that they suggest the monitoring role with required compliance persuades firms to emphasize a climate-oriented governance structure, while at the same time, climate-risk governance mechanisms ensuring the best use of available resources in support of the firm-level scope and capacity of environmental innovation. Our finding is in line with those of earlier studies showing that a higher level of climate governance activism is associated with stronger commitments to addressing climate change (Albitar et al., 2023) and carbon disclosure (Bui et al., 2020). Among the control variables, board size is significant and positively related to firm-

level environmental innovation. This finding indicates that firms with larger boards appear to be environmentally innovative. Further, we find that firm size and liquidity are positively related to environmental innovation across all the models. Overall, this empirical evidence confirms our first hypothesis.

## 4.2 Tests for Robustness

In order to determine the robustness of the baseline results, we analyze the effect of climate risk governance on environmental performance. Following prior literature (i.e., Lys et al., 2015; Albitar et al., 2023), we treat the environmental pillar score as an alternative to the dependent variable and re-estimate the baseline tests. The environment pillar score is an environmental performance measure sourced from the Refinitiv Eikon Datastream database. The database explains "The environmental pillar evaluates a firm's impact on living and nonliving natural systems, including the air, land, and water, as well as complete ecosystems". Column 1 of Table 13 reports the estimated coefficients. Similar to the baseline models, we use the same set of control variables. Our results reveal that the climate risk governance index is statistically significant at the 1% level and strongly affiliated with the environmental pillar. Therefore, consistent with the baseline results, the outcomes of the robustness test with the alternative dependent variable reveal that climate risk governance drives the environmental performance of a firm. In addition, we also examine whether climate risk governance affects firm-level product design with the objective of recycling or reusing them in order to limit environmental concerns. Accordingly, we apply eco-designed product data, which is an indicator variable equal to one if a firm provides information on products specifically designed to reuse, recycle, or reduce environmental impact. Column 2 of Table 13 presents the regression results from the effects of climate risk governance on eco-designed products. All the other control variables remain the same as in the baseline models. The results align with the baseline estimates, as the coefficient of climate risk governance is positive and statistically significant at the 1% level. Overall, our findings are robust to the use of alternative measures of firm-level environmental innovation.

Now, as part of using alternative estimation methods to ensure the robustness of the baseline results, we focus on a fixed effects panel data estimator, including firm and year effects. The application of the fixed effects analysis helps to minimize the potential threat of estimation bias and control the omitted variable bias (Wooldridge, 2020; Hsiao, 2007). In addition, Fixed effects models can capture the unobserved heterogeneity over time and between individual items (Hsiao, 2007). Column 1 of Table 14 presents the empirical results of the fixed effects regression model. The results are consistent with our baseline findings, as the coefficient for climate risk governance remains highly significant at the 1% level and is positively associated with environmental innovation.

We also run the dynamic two-step system GMM regression following the proposition of Arellano and Bond (1991). Similar to Martínez-Ferrero and Frías-Aceituno (2015) and Haque and Ntim (2018), we assume the lagged dependent variable is endogenous and use GMM estimates to test the association between climate risk governance and environmental innovation. Accordingly, as reported in column 2 of Table 14, the environmental innovation of firm  $i$  in the year  $t$  is a function of the first lag of environmental innovation ( $L$ .Environmental innovation) accompanied by the main variable of interest. All the other right-hand side variables remain the same as in the baseline regression. As mentioned earlier, we account for the total environmental innovation score sourced from Refinitiv Eikon Datastream as a proxy for environmental innovation. To determine the instrument's validity<sup>23</sup>, we run the Hansen test that addresses the overidentifying restrictions. Our findings align with the baseline analysis, which implies that climate risk governance is a significant driver of environmentally sustainable innovation.

### 4.3 Channel Analysis

Our baseline results reveal that climate risk governance is positively associated with firm-level environmental innovation scores. However, a natural follow-up question is about the channel by which climate risk governance supports environmental innovation. In order to answer this question, we envisage that climate risk measures encourage firms to commit larger amounts of environmental spending, which in turn increases firm-wide capacity and the potential for

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<sup>23</sup> The main conditions for a valid instrument are relevance ( $\text{Corr}[Z, X] \neq 0$ ) and exogeneity ( $\text{Corr}[Z, u] = 0$ ). This diagnostic test will validate whether the instrument is exogenous. Hence,  $H_0 =$  instrument is exogenous. And, if  $H_0$  cannot be rejected because of a higher P-value, it will prove the instrument's validity.

environmental innovation. Using the channel analysis technique, we assess a potential mechanism (environmental expenditure) through which climate risk governance (CRG) tends to facilitate environmental innovation. The prevailing consensus suggests that the development and adoption of eco-friendly technologies and approaches require a credible and systematic financial commitment. Accordingly, this study seeks to examine whether this firm-level spending on environmental initiatives serves as a potential channel through which climate risk governance influences environmental innovation. Following previous studies (Alam et al., 2022; Miller and del Carmen Triana, 2009; Safiullah et al., 2021), we perform the channel analysis in two steps. The channel analysis approach operates as a causal chain, considering the mediation effect. The fundamental concept of mediation posits that the mediator (M) transmits the effect of the independent variable (X) on the outcome variable (Y). In the first stage, we investigate the association between the climate risk governance index and environmental investments, and in the second stage, we analyze the effect of climate risk governance on environmental innovation after controlling for environmental expenditure.

Table 15 reports the empirical results of the channel analysis based on firm-level environmental expenditure. In column 1, the dependent variable is environmental investments, and we obtain evidence that climate risk governance exhibits a strong positive relationship with environmental investments as the estimated coefficient is significant at the 1% level. This result suggests that the more firm-level climate-focused governance activism there is, the higher the level of environmental spending. In other words, a robust climate risk governance framework is positively associated with a higher level of environmental expenditure. Column 2 in Table 15 shows the estimated results of the impact of climate risk governance on environmental innovation after controlling for environmental investments. The coefficient of environmental investments is positive and statistically significant at the 5% level. All the other right-hand side variables remain the same in columns 1 and 2 as in the baseline models. The channel analysis results indicate that firms more committed to climate risk governance tend to invest more in environmental initiatives, which serves as the mechanism linking climate risk governance and environmental innovation at the firm level. Hence, this empirical evidence provides support for Hypothesis 1a.

#### 4.4 Analysis of CRG Components and Sub-samples

It is argued that climate-focused governance components are better suited when integrated to form an index (Bui et al., 2020). Nevertheless, we look into the individual climate risk governance components as part of our further analysis. Accordingly, to obtain further insights, we include all the CRG components separately as the right-hand side variables to examine how impactful they are in explaining firm-level environmental innovation. Table 16 presents the estimated results, and as in the baseline model, we also use all the other control variables. We find that climate risk opportunities and risks, sustainability committees, sustainability reporting, and external assurance exhibit a positive association with environmental innovation. The results in columns 1 and 2 of Table 16 reveal that all four coefficients are statistically significant, suggesting that each of these climate governance components plays a vital role individually in strengthening environmental innovation. Our results align with those of Albitar et al. (2023) as they document a positive relationship between the presence of a board-level sustainability committee, sustainability reporting, and greater corporate commitments to handling climate change issues. However, unlike Albitar et al. (2023), we detect that sustainability-linked executive compensation is not statistically significant as a standalone driver of environmental innovation. This finding is comparable to that of Haque (2017), who reports that ESG-based compensation does not affect actual carbon performance.

Although the constituents of the S&P 500 are widely recognized for their substantial market capitalizations, there are significant variations in their sizes. For this reason, it is not irrational to anticipate that the size of a firm is likely to affect the complex association in force. Hence, to gain a deeper understanding of the link between our variables of interest, we break down our entire sample into large and small firms (as denoted by firm size) and conduct sample-split analysis. First, we examine the relationship between the overall climate risk governance score and environmental innovation. We report the results in columns 1 and 3 of Table 17. We find no qualitative difference between the estimated coefficients of CRG for small and large firms as the results are statistically significant at the 1% level, and the magnitudes of the coefficients are nearly identical. We then evaluate the impact of individual components of climate risk governance on environmental innovation in columns 2 and 4 of Table 17. However, the analyses of individual CRG components for the sub-samples indicate that, relative to their larger counterparts, smaller firms are less aware of climate change risk and opportunities. Our results also reveal that the presence of an environmental committee, sustainability reporting,

and external assurance of sustainability reporting appear to be significant drivers of environmental innovation, irrespective of the size of the firms.

Further, we do not detect any linkage between executive incentives for sustainability or environmental performance and environmental innovation for either large or small groups of firms, which is in line with the findings of Albitar et al. (2023). In sum, our results imply that when individual climate risk governance components are compared, the effect of corporate climate risk governance on environmental innovation is more pronounced for large firms. This may be because larger firms are expected to possess an appropriate mix of required resources and have fewer financial challenges.

#### 4.5 Identifications

Our empirical findings might represent correlation in place of causality due to the endogeneity bias. We assume that our test variable, climate risk governance, may experience an omitted variable and sample selection problems, and for this reason, it might not reflect a systematic relationship with the dependent variable (environmental innovation). Therefore, to overcome this identification challenge, we employ two specific econometric techniques, i.e., IV analysis and a propensity score matching (PSM) model, to check the causal association between climate risk governance and environmental innovation.

IV analysis calls for an instrument that is correlated with the endogenous regressor (i.e., climate risk governance) but which does not exert any direct impact on the explained variable (environmental innovation) except through that endogenous regressor (Atif et al., 2021). To achieve this, following Haque and Ntim (2018) and Xue et al. (2019), we use the United Nations Global Compact (UNGC) in this study as an exogenous instrument to run the IV analysis. The intuition behind the selection of the UNGC as an instrument is that firms that are signatories to the UNGC are more likely than others to address climate change issues and integrate climate-focused components into their governance framework. The UNGC is considered a comprehensive policy directive for 'firms to align strategies and operations with universal principles on human rights, labor, the environment, and anti-corruption'<sup>24</sup>. Thus, it is

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<sup>24</sup> <https://www.unglobalcompact.org/what-is-gc> (Accessed on July 25, 2023).

reasonable to believe that becoming a signatory of the UNGC, which is voluntary, will not directly affect firm-level environmental innovation.

We conduct the IV analysis using a two-stage least squares (2SLS) estimate. Through the first-stage regression in column 1 of Table 18, we examine the relevance of our instrument. In line with the requirements for a good instrument, we find that the exogenous variable UNGC (United Nations Global Compact) is positively linked to climate risk governance in column 1, and the coefficient of UNGC is statistically significant at the 1% level. The F-statistic value is high, and the CD F weak instrument test is 0.001, rejecting the null hypothesis that the instrument is weak (Cragg and Donald, 1993; Stock and Yogo, 2005). Then, the results of the second-stage regression are shown in column 2 of Table 9. We use the predicted CRG (fitted CRG values) from the first-stage estimation to regress environmental innovation. The estimated coefficient on the predicted CRG is significant at the 1% level in column 2. All the other right-hand side variables are the same in the IV models as in the baseline tests. Industry and year-fixed effects are also controlled. Therefore, our main empirical result remains robust and confirms a positive and significant relationship between climate risk governance and environmental innovation.

We also employ a propensity score matching estimator (Atif et al., 2021; Alam et al., 2019; Lennox et al., 2011) to address endogeneity concerns that may originate from the misspecification of empirical models. To start with, we calculate the above-average industry dummy variable, which is set to 1 if the climate risk governance value is above the industry average value and 0 otherwise. Then, in the first stage, we apply Probit regression to explain the above-average industry indicator variable. Like the baseline models, we use all the right-hand side explanatory variables in this pre-match first-stage estimation. The PSM estimates are reported in Panel A of Table 19. Column 1 of Table 19 presents the results of the pre-match estimates with the full sample. We estimate the propensity score utilizing the nearest neighbor matching with a 1% radius matching technique (Shipman et al., 2017). After the investigation, 683 firm-year observations for the industry above-average dummy have been matched. We finally run the post-match regression based on the paired firm-year observations through an OLS model. Column 2 of Table 19 shows the estimated results, revealing that climate risk governance strongly affects firm-level environmental innovation as the coefficient of CRG in the post-match diagnostic regression is significant at the 1% level. We find that both the likelihood ratio in the Probit model and the F-statistic in the post-match regression are

statistically significant with a p-value of 0.000, which ensures the model fit and validity of the association between the regressors and the outcome variable (Chib, 1998). The t-test results, presented in Panel B of Table 19, confirm that the treatment and control groups are well-balanced. The firm characteristics (covariates) show no significant differences between the groups after matching, as indicated by the higher p-values. This suggests that the firm-year observations in both groups are comparable with respect to observable attributes. Overall, the empirical evidence from our PSM analysis suggests that climate risk governance has a substantial impact on the capacity of firms to engage in environmental innovation; hence, we conclude that our baseline estimates are not influenced by endogeneity bias.

#### 4.6 Heckman Model and Tests for Reverse Causality

Although we address the endogeneity concerns through two different identification strategies, another issue could arise in the sample selection as our sample selection process is not random. For this reason, we run the two-step Heckman selection model to remedy potential issues linked to sample selection. In the first stage, as reported in column 1 of Table 20, we employ the Probit model that utilizes the climate risk governance index (CRG) as the dependent variable. All the other control variables remain the same as in the baseline tests. We calculate the inverse mills ratio (IMR) using the parameters estimated in the first stage. We then control for the sample selection issue via the inverse mills ratio by incorporating it as an independent variable in the second-stage estimates derived from an FE model in column 2 of Table 20. The empirical results are compatible with the baseline findings, suggesting a positive and significant relationship between climate risk governance and environmental innovation approaches. Hence, we argue that our empirical results are unlikely to be driven by sample selection bias.

We also investigate concerns associated with reverse causality. Faleye et al. (2014) argue that using a time lag of more than one year for the main explanatory variables can effectively mitigate any potential issues related to reverse causality. Moreover, it is argued that if the distantly lagged explanatory variables exhibit statistical significance, reverse causality becomes less apparent, as evidenced by earlier studies (Faleye, 2007; Cheng, 2008). Following this argument, we run additional tests to eliminate the issue of reverse causality. Table 21 reports the empirical results, where in column 1, we use two-period lagged values of the main variable of interest, climate risk governance. In column 2, we include the three-period lagged values of climate risk governance. In accordance with the baseline models, we employ the same set of control variables along with industry and year-fixed effects. Both models use one-period

lagged versions of these control variables. The dependent variable in all two models is environmental innovation. Our results remain consistent across the models, as two-year and three-year lagged climate risk governance variables are positive and statistically significant at the 1% level. Overall, this evidence suggests that the reverse causality issue is not likely to have an impact on our findings.

## 5. Conclusion

Over the past decade, the tensions surrounding climate change have drawn heightened attention from academicians, politicians, practitioners, and policymakers due to the vast increase in carbon release, especially the harmful effects of carbon emissions on the safety of the environment and the stability of biodiversity. In this connection, it has also been frequently argued that firm-level environmentally sustainable innovative processes along with responsible business policies can contribute substantially to carbon reduction and climate protection. Integrating eco-friendly innovation into a typical business model promotes a creative atmosphere, encouraging firms to develop environmentally efficient technologies to mitigate the environmental burdens on their clientele. This approach also facilitates the enhancement of traditional technologies and procedures, which eventually helps firms to develop and market their eco-friendly goods or services. However, the existing literature on climate governance provides no evidence of the role of climate risk governance in increasing environmental innovation capacity. Hence, to address this gap, we investigate the effects of corporate climate risk governance mechanisms on environmental innovation using 4378 firm-year observations collected from non-financial carbon-sensitive US firms between 2011 and 2021. To the best of our knowledge, this study is the first to examine the impact of climate risk governance on environmental innovation capacity. Drawing on the resource-based view and agency theory, our study reveals that a higher level of climate risk governance activism leads to greater environmental innovation. However, this association is more pronounced for large firms in contrast to their smaller counterparts. Our baseline findings remain robust after we introduce alternative variables and different estimation techniques. We also identify environmental investment as the channel by which climate risk governance supports eco-driven innovation. By looking into the individual components of climate risk governance, we show that awareness of climate risk and opportunities, a board-level sustainability committee, sustainability reporting, and external assurance of sustainability reporting are positively and significantly related to environmental innovation. However, ESG-based or sustainability-linked executive

compensation does not appear to have a positive association with environmental innovation for US firms. Further, we employ an instrumental variable approach, and the propensity score matching method to address potential endogeneity concerns. Our empirical results from the identification strategies confirm that endogeneity concerns are not likely to drive the baseline results.

Our study extends the available climate governance literature by offering novel empirical evidence that climate risk governance activism has a significantly positive effect on environmental innovation capacity. This study is also among the first to demonstrate a channel through which climate risk governance can improve a firm's scope and capacity for environmental innovation. The empirical findings of our study offer crucial insights for corporate board members and regulators regarding the potential reorganization of governance structures and a strong emphasis on climate-focused governance mechanisms. Overall, our study contributes to the ongoing global debate on climate governance and climate change.

This study has several limitations that could be addressed in future research. We lay the groundwork for prospective scholars interested in this area by providing the first empirical evidence of the relationship between climate risk governance and environmental innovation based on the data obtained from US firms. To obtain new insights, future research could extend our work by performing a multi-country comparison, particularly by looking at the United Kingdom, Canada, China, and other major European nations. Moreover, our study is based on publicly traded S&P 500 firms that are responsible for both scope one and scope two emissions. For this reason, our empirical findings are not likely to be generalizable to small-cap, mid-sized, and unlisted firms. Therefore, future research could offer unique insights by investigating whether the takeaways this study provides hold for small-cap, mid-sized, or unlisted firms. Finally, it would also be beneficial for future research to explore other relevant factors such as climate change accords, environmental legislation, and the cultural and ethnic diversity of both members of the sustainability or environmental committee and the CEO. These factors could potentially be influencing environmental innovation alongside climate-focused governance mechanisms.

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Table 10: Summary Statistics

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Environmental innovation	1.000									
(2) Climate Risk Governance	0.445*	1.000								
(3) Board Independence	0.299*	0.457*	1.000							
(4) Board Size	0.355*	0.518*	0.773*	1.000						
(5) Firm Size	0.330*	0.585*	0.310*	0.482*	1.000					
(6) Capital Intensity	0.004	0.232*	0.079*	0.110*	0.291*	1.000				
(7) Leverage	0.071*	0.192*	0.186*	0.230*	0.214*	0.181*	1.000			
(8) Liquidity	-0.040*	-0.189*	0.001	-0.088*	-0.329*	-0.211*	-0.236*	1.000		
(9) MTB	0.012	-0.002	0.154*	0.114*	-0.144*	-0.202*	0.058*	0.088*	1.000	
(10) Profitability	0.006	-0.054*	0.091*	0.020	-0.244*	-0.279*	-0.090*	0.329*	0.383*	1.000

This table reports the pairwise correlation coefficients between the variables employed in our study.

\* Indicates the statistical significance for the correlation estimates at the 1% level.

Table 11: Baseline Estimates

Baseline Estimates	(1)	(2)	(3)	(4)
	Environmental innovation	Environmental innovation	Environmental innovation	Environmental innovation
	without controls	without industry/year effects	with industry/year effects	One-year lagged variables
Climate Risk Governance	8.382*** (0.255)	6.423*** (0.333)	5.361*** (0.340)	3.929*** (0.352)
Board Independence		0.032 (0.029)	0.043 (0.029)	0.037 (0.030)
Board Size		1.201*** (0.215)	0.980*** (0.214)	0.677*** (0.220)
Firm Size		3.207*** (0.533)	5.252*** (0.527)	6.143*** (0.545)
Capital Intensity		-0.545*** (0.070)	-0.863*** (0.086)	-0.780*** (0.084)
Leverage		-0.042 (0.030)	-0.049* (0.030)	-0.026 (0.031)
Liquidity		1.695*** (0.584)	3.506*** (0.578)	3.689*** (0.597)
MTB		-0.199 (0.166)	-0.031 (0.163)	-0.094 (0.168)
Profitability		0.036 (0.096)	-0.047 (0.094)	-0.049 (0.098)
Constant	11.036*** (0.772)	-48.716*** (8.583)	-88.375*** (8.833)	-108.471*** (9.368)
Industry FE	-	-	Included	Included
Year FE	-	-	Included	Included
Adj R-squared	0.198	0.245	0.308	0.257
N	4,378	4,378	4,378	4,377

This Table presents the baseline regression estimates examining the effect of climate risk governance on environmental innovation. In all four columns, environmental innovation serves as the dependent variable. Column (1) reports the regression estimates without including any control variables. Column (2) presents the results without controlling for industry and year effects. Column (3) incorporates all control variables as well as industry and year-fixed effects. Finally, Column (4) reports the results using one-year lagged independent variables. The control variables included in the analysis are Board Independence, Board Size, Firm Size, Capital Intensity, Leverage, Liquidity, MTB (Market-to-Book Ratio), and Profitability. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 12: Robustness tests with alternative outcome variables

Robustness Tests with Alternative Measures	(1)	(2)
	Environment Pillar	Eco-designed Products
Climate Risk Governance (CRG)	10.310*** (0.212)	0.024*** (0.004)
Board Independence	0.014 (0.018)	-0.000 (0.000)
Board Size	0.729*** (0.133)	0.006** (0.003)
Firm Size	5.699*** (0.328)	0.033*** (0.007)
Capital Intensity	-0.199*** (0.054)	-0.009*** (0.001)
Leverage	-0.015 (0.018)	0.001 (0.000)
Liquidity	0.568 (0.360)	0.045*** (0.007)
MTB	0.299*** (0.102)	-0.000 (0.002)
Profitability	0.276*** (0.059)	0.001 (0.001)
Constant	-94.116*** (5.498)	-0.640*** (0.111)
Industry FE	Included	Included
Year FE	Included	Included
Adj R-squared	0.677	0.117
N	4,378	4,377

This Table presents the robustness tests for the impact of Climate Risk Governance (CRG). The regression coefficients of CRG are displayed in Columns (1) and (2). In Column (1), the Environmental Pillar is employed as an alternative measure for environmental innovation, while Column (2) utilizes Eco-designed Products as an alternative outcome variable. Both columns maintain the same set of control variables as specified in the baseline models. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. Statistical significance is denoted by \*\*\*, \*\*, and \* at the 1%, 5%, and 10% levels, respectively.

Table 13: Robustness tests with alternative estimation methods

	(1)	(2)
Robustness Check	FE Model	GMM Regression
	Environmental innovation	Environmental innovation
L.Environmental innovation		0.953*** (0.098)
Climate Risk Governance (CRG)	3.373*** (0.317)	4.955*** (1.813)
Board Independence	0.073*** (0.025)	-0.138 (0.179)
Board Size	0.381** (0.185)	2.093* (1.080)
Firm Size	0.301 (0.787)	-5.479 (7.149)
Capital Intensity	-0.246** (0.116)	-5.901* (3.502)
Leverage	0.013 (0.033)	1.030 (1.002)
Liquidity	-0.393 (0.629)	8.200 (25.911)
MTB	0.062 (0.143)	-2.942 (3.156)
Profitability	0.186** (0.077)	-5.905* (3.181)
Constant	48.381*** (14.252)	126.956 (175.485)
Firm and Year Effects	Included	Included
Arellano-Bond test (AR-1)		0.003
Arellano-Bond test (AR-2)		0.104
Sargan Test (p value)		0.117
Hansen Test (p value)		0.231
N	4,378	3,980

This Table presents additional robustness tests assessing the impact of Climate Risk Governance (CRG). Column (1) reports the results using firm fixed effects, while Column (2) presents estimates from the Generalized Method of Moments (GMM) regression model. In the GMM specification, the lagged dependent variable (L.Environmental innovation) is considered endogenous. Environmental innovation serves as the dependent variable in both columns. The analysis includes the same set of control variables as in the baseline models. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 14: Channel Analysis

Channel Analysis	(Panel A)	(Panel B)
	Environmental Investment	Environmental innovation
Environmental Investment		2.703*** (0.970)
Climate Risk Governance	0.572*** (0.077)	3.922*** (0.619)
Board Independence	0.020*** (0.007)	0.005 (0.032)
Board Size	0.013 (0.048)	0.979*** (0.213)
Firm Size	0.983*** (0.120)	2.882*** (1.001)
Capital Intensity	0.008 (0.020)	-0.865*** (0.086)
Leverage	0.012* (0.007)	-0.079** (0.031)
Liquidity	0.303** (0.131)	2.907*** (0.616)
MTB	0.051 (0.037)	-0.144 (0.168)
Profitability	0.039* (0.021)	-0.128 (0.099)
Constant	-19.076*** (2.003)	-44.874** (17.938)
Industry FE	Included	Included
Year FE	Included	Included
Adjusted R-squared	0.277	0.309
N	4,378	4,378

This Table presents the results of the channel analysis, examining environmental investment as the mediating variable. Panel A reports the regression estimates of Climate Risk Governance (CRG) on environmental investment. Panel B presents the regression estimates of environmental innovation on CRG while controlling for environmental investment. The analysis includes the same set of control variables as in the baseline models. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 15: Analysis of the impact of CRG components

Analysis of CRG Components	(1)	(2)
	Environmental innovation	Environmental innovation
Climate Risk and Opportunities	8.725*** (1.218)	5.369*** (1.208)
Sustainability/Environmental Committee	12.201*** (1.301)	9.739*** (1.276)
Sustainability Reporting	11.571*** (1.277)	7.847*** (1.274)
External Assurance	2.992*** (1.094)	2.465** (1.074)
Sustainability Linked Incentives	1.432 (0.971)	-0.644 (0.960)
Board Independence		0.042 (0.029)
Board Size		0.929*** (0.212)
Firm Size		4.977*** (0.526)
Capital Intensity		-0.866*** (0.086)
Leverage		-0.048* (0.029)
Liquidity		3.338*** (0.575)
MTB		-0.095 (0.163)
Profitability		-0.058 (0.094)
Constant	4.122* (2.120)	-82.896*** (8.827)
Industry FE	Included	Included
Year FE	Included	Included
Adj R-squared	0.270	0.318
N	4,378	4,378

This Table presents the regression estimates for five specific components of Climate Risk Governance (CRG). The components analyzed include Climate Risk and Opportunities, Sustainability/Environmental Committee, Sustainability Reporting, External Assurance, and Sustainability-Linked Incentives. Environmental innovation serves as the dependent variable in both Columns (1) and (2). The same set of control variables as in the baseline models is included in Column 2. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 16: Analysis of sub-samples (Small vs. large firms)

Sub-sample Analysis	Column 1: Small_Firms	Column 2: Small_Firms	Column 3: Large_Firms	Column 4: Large_Firms
	Environmental innovation	Environmental innovation	Environmental innovation	Environmental innovation
Climate Risk Governance (CRG)	2.935*** (0.418)		3.383*** (0.492)	
Climate Risk and Opportunities		-0.904 (1.143)		3.222** (1.588)
Environmental Committee		7.364*** (1.273)		8.787*** (1.646)
Sustainability Reporting		4.854*** (1.079)		4.796*** (1.615)
External Assurance		3.822*** (1.396)		1.448* (1.255)
Sustainability Linked Incentives		-1.686 (1.062)		-0.956 (1.089)
Board Independence	0.135*** (0.032)	0.141*** (0.032)	0.065 (0.042)	0.060 (0.042)
Board Size	-0.392 (0.257)	-0.467* (0.255)	0.920*** (0.266)	0.844*** (0.265)
Firm Size	-4.393*** (1.106)	-4.495*** (1.097)	1.929 (1.545)	1.685 (1.536)
Capital Intensity	-0.587** (0.248)	-0.575** (0.246)	-0.055 (0.127)	-0.054 (0.126)
Leverage	0.103*** (0.036)	0.113*** (0.035)	-0.101 (0.068)	-0.086 (0.068)
Liquidity	0.091 (0.680)	0.039 (0.675)	-1.341 (1.312)	-1.627 (1.305)
MTB	0.311** (0.148)	0.239 (0.148)	-0.429 (0.295)	-0.457 (0.294)
Profitability	0.077 (0.087)	0.083 (0.086)	0.251* (0.145)	0.235 (0.144)
Constant	103.929*** (17.791)	106.070*** (17.681)	21.080 (27.657)	24.534 (27.490)
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Adjusted R-squared	0.766	0.771	0.740	0.743
N	2,233	2,233	2,156	2,156

This table presents a sub-sample analysis based on firm size, distinguishing between small and large firms. Columns (1) and (3) report the regression estimates of the overall Climate Risk Governance (CRG) index on the small and large subsamples, respectively. Similarly, Columns (2) and (4) highlight the effects of the five individual CRG components on the small and large subsamples, respectively. The same set of control variables as in the baseline models is included across all specifications. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 17: Instrumental variable (2SLS) approach

IV Analysis	(Panel 1)	(Panel 2)
	First stage	Second stage
	CRG	Environmental innovation
UNGC	0.966*** (0.055)	
Climate Risk Governance (CRG) - Fitted		7.683*** (1.317)
Board Independence	0.0160*** (0.00151)	0.0260 (0.0329)
Board Size	0.0664*** (0.0112)	0.897*** (0.230)
Firm Size	0.717*** (0.0255)	4.303*** (0.958)
Capital Intensity	0.0200*** (0.0045)	-0.883*** (0.0877)
Leverage	0.00172 (0.0016)	-0.0551* (0.0296)
Liquidity	-0.0414 (0.0304)	3.608*** (0.580)
MTB	0.00856 (0.00859)	-0.0634 (0.163)
Profitability	0.0226*** (0.005)	-0.0671 (0.093)
Constant	-12.29*** (0.426)	-71.54*** (16.31)
Industry FE	Included	Included
Year FE	Included	Included
N	4,378	4,378
	Model fits	
F-statistic		54.03***
Anderson canon. corr. LM statistic		292.233***
Weak identification test		311.705
Cragg-Donald Wald F statistic:		[0.001]
Stock-Yogo weak ID test critical values:		16.38
10% maximal IV size		

This Table presents the results of the instrumental variable approach used to address potential endogeneity. The United Nations Global Compact (UNGC) is the exogenous instrument in this analysis. In the first stage, CRG is the dependent variable, while in the second stage, the fitted values of CRG are employed to predict environmental innovation. The same set of control variables as in the baseline models is included. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 18 Panel A: Propensity score matching estimates

Propensity Score Matching	Panel A	Panel B
	Industry Above-Avg Dummy	Environmental innovation
Climate Risk Governance		6.241*** (1.471)
Board Independence	-0.009*** (0.0018)	-0.0224 (0.108)
Board Size	0.125*** (0.0120)	3.434*** (0.618)
Firm Size	0.301*** (0.0286)	12.21*** (1.401)
Capital Intensity	-0.013*** (0.0040)	-1.238*** (0.210)
Leverage	0.007*** (0.0018)	-0.245*** (0.0875)
Liquidity	-0.215*** (0.0365)	-1.110 (1.844)
MTB	0.0149 (0.0093)	-0.374 (0.394)
Profitability	0.037*** (0.0058)	0.217 (0.259)
Constant	-6.758*** (0.490)	-212.6*** (27.10)
Likelihood ratio (chi2) / F-statistic	568.88*** [0.000]	11.20*** [0.000]
Pseudo R-squared	0.1501	
Adjusted R-squared		0.221
N	4,378	683

This Table presents the results of the propensity score matching (PSM) analysis. Panel A reports the pre-matching estimates based on the full sample, while Panel B presents the post-match regression results using paired firm-year observations. In Panel A, the outcome variable is a dummy indicating whether a firm's CRG score is above the industry average. In Panel B, environmental innovation serves as the main dependent variable. The same set of control variables as in the baseline models is included across all regressions. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. Statistical significance is denoted by \*\*\*, \*\*, and \* for the 1%, 5%, and 10% levels, respectively.

Table 18 Panel B: T-tests on firm characteristics between the treatment and control groups:

Variable	Mean		Mean Difference	t-statistic	p> t
	Treated	Control			
Board Independence	82.098	83.056	-0.958	-1.39	0.164
Board Size	11.614	11.613	0.001	0.01	0.990
Firm Size	17.06	17.087	-0.027	-0.53	0.599
Capital Intensity	7.1771	7.4992	-0.3229	-0.87	0.384
Leverage	32.232	31.739	0.493	0.62	0.533
Liquidity	1.4017	1.4398	-0.0373	-0.95	0.342
MTB	4.1066	4.0791	0.0276	0.16	0.875
Profitability	8.5139	8.5675	-0.0534	-0.19	0.852

This table reports the t-test statistics and corresponding p-values for firm attributes (i.e., all control variables) comparing the treatment and control groups to assess the quality of propensity score matching (PSM).

Table 19: Heckman model for sample selection

Heckman Selection Model	Stage 1 – Probit Above average CRG	Stage 2 – OLS Model Environmental innovation
Industry_AVG	-0.260** (0.118)	
Climate Risk Governance (CRG)		5.213*** (0.317)
Board Independence	0.013*** (0.001)	0.010 (0.026)
Board Size	0.073*** (0.009)	1.007*** (0.186)
Firm Size	0.652*** (0.021)	6.116*** (0.792)
Capital Intensity	0.013*** (0.004)	-0.987*** (0.117)
Leverage	0.000 (0.001)	-0.107*** (0.035)
Liquidity	-0.038 (0.026)	3.085*** (0.629)
MTB	0.006 (0.007)	-0.019 (0.143)
Profitability	0.017*** (0.004)	-0.086 (0.077)
IMR (Inverse Mills Ratio)		-34.811*** (5.120)
Constant	-11.030*** (0.356)	4.936 (12.658)
Industry FE	Included	Included
Year FE	Included	Included
Wald-chi2	0.000***	
Adjusted R-squared		0.313
N	4,378	4,375

This table presents the results of the two-stage Heckman selection model. Stage 1 reports the first-stage probit model, which uses industry above-average Climate Risk Governance (CRG) values as the exclusion restriction to estimate the probability of a firm having an industry above-average CRG score. To address sample selection bias, the inverse Mills ratio is derived from the estimated coefficients in the first stage. In the second stage, the inverse Mills ratio is incorporated as an additional control variable to explain environmental innovation. The same set of control variables as in the baseline models is included across all regressions. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. Statistical significance is denoted by \*, \*\*, and \*\*\* for the 10%, 5%, and 1% levels, respectively.

Table 20: Investigation of reverse causality

Test for reverse causality	(1)	(2)
Variables	Environmental innovation	Environmental innovation
Climate Risk Governance $t-2$	3.359*** (0.317)	
Climate Risk Governance $t-3$		2.638*** (0.299)
Board Independence	0.069** (0.030)	0.083*** (0.030)
Board Size	0.805*** (0.219)	0.854*** (0.220)
Firm Size	6.523*** (0.536)	7.130*** (0.528)
Capital Intensity	-0.776*** (0.085)	-0.760*** (0.085)
Leverage	-0.034 (0.031)	-0.038 (0.031)
Liquidity	3.699*** (0.598)	3.641*** (0.600)
MTB	-0.121 (0.169)	-0.096 (0.169)
Profitability	-0.039 (0.098)	-0.016 (0.098)
Constant	-117.339*** (9.139)	-126.785*** 0.083***
Industry FE	Included	Included
Year FE	Included	Included
Adj R-squared	0.255	0.249
N	4,376	4,375

This table presents the regression results from the lagged variable analysis conducted to mitigate concerns of reverse causality. In Column (1), the two-period lagged value of CRG is used as the independent variable, while Column (2) employs the three-period lagged CRG variable. Environmental investment serves as the dependent variable in both columns. The same set of control variables as in the baseline models is included across all regressions. Appendix A1 highlights the definitions of the variables used in this study. Standard errors are reported in parentheses. Statistical significance is denoted by \*, \*\*, and \*\*\* for the 10%, 5%, and 1% levels, respectively.

## Appendix A1: Definitions of variables used in this study

Variable name	Definition
Environmental innovation	Environmental innovation score refers to firms' capability to develop new environmental technologies and processes to lower environmental costs and burdens for their customers, which allows firms to create new market opportunities by improving existing environmental technologies and processes or by developing eco-friendly products or services. This score ranges from 0 to 100.
Climate Risk Governance (CRG)	<p>The climate risk governance index embodies firm-specific governance mechanisms to address climate change and sustainability issues. This index comprises the following five indicator components; hence, the possible score of each firm will fall between 0 and 5.</p> <ol style="list-style-type: none"> <li>1. Board's awareness of climate change risk and opportunities: A dummy variable will equal 1 if the firm is aware of the commercial risk and opportunities arising from climate change, and 0 otherwise.</li> <li>2. Board-level Environmental or sustainability Committee: A dummy variable will equal 1 if the firm has an environmental or ESG related committee, and 0 otherwise</li> <li>3. Sustainability or Environmental reporting: A dummy variable will equal 1 if the firm publishes sustainability or environmental impact reports, and 0 otherwise.</li> <li>4. External assurance of disclosures or environmental reporting: A dummy variable will equal 1 if the firm's published reports or disclosures are externally assured, and 0 otherwise</li> <li>5. Executive compensation or incentives for sustainability linked performance and climate activism: A dummy variable will equal 1 if the company provides executive compensation for ESG performance or climate change actions, and 0 otherwise</li> </ol>
Board Independence	The proportion of independent directors relative to the total board size
Board Size	The number of directors serving on the board
Firm Size	The natural logarithm of total assets of the firm
Capital Intensity	firm's capital expenditures scaled by total sales

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Leverage	The ratio of total debt to total assets
Liquidity	The ratio of current assets to current liabilities
MTB Ratio	The ratio of market price to book value of the firm
Profitability	The ratio of net profit to total assets

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**Chapter 5**

**Empirical Essay Three**

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## **Environmental investment, financial leverage, and the cost of debt**

### **Abstract**

A growing body of research has predominantly focused on the association between environmental performance and firm financial outcomes. However, the existing literature distinctly lacks a focused study investigating the specific effects of firm-level actual environmental spending, an essential aspect of environmental activism and risk management, on firm financing decisions. This study examines the relationship between environmental investment and corporate capital structure in the US context. Based on a sample of non-financial S&P-500 firms from 2011 to 2021, we find that firms that spend on environmental engagements appear to increase their use of financial leverage. Further analysis reveals that a higher level of environmental investment is associated with cheaper access to debt financing. However, this negative relationship is more pronounced in small firms than in their larger counterparts. Our results remain robust when we employ instrumental variable approaches and propensity score matching estimates to address potential endogeneity concerns. The empirical findings of this research offer valuable insights for investors, managers, and other stakeholders regarding firm-level substantive environmental engagements and financing choices.

Keywords: Climate Change, Environmental Investment, Financial Leverage, Cost of Debt, Sustainability

## 1. Introduction

In recent years, stakeholders and regulators have increasingly demanded that corporations take substantive measures for environmental conservation in response to escalating concerns about climate change (Altunbas et al., 2022; Haque, 2017; Lee, 2012). The regulatory changes like the 2015 Paris Agreement and increased stakeholder awareness of environmental issues further emphasize the need for sustainability efforts and accompanying investment (Alam et al., 2019; Orazalin et al., 2023). Firms in carbon-intensive industries are induced to go green by considering environmentally safe business policies and practices (Atif et al., 2022; Nadeem et al., 2020; Tolliver et al., 2020). Despite the widespread perception that corporations significantly contribute to global environmental issues and climate change, a growing number of firms are adopting proactive measures to promote environmental well-being and sustainability (Walker and Wan, 2012). Environmental investment generally pertains to the firm-level commitment of funds to develop sustainable business practices in order to reduce adverse environmental impact, thereby helping uphold environmental well-being. Extant literature suggests that environmental investment can accelerate technological advancements directly by improving product design and indirectly via sustainable transformation and innovation (Clarke et al., 2006; Fischer and Newell, 2008). The IEA (2016) projects that an investment of \$250 billion will be necessary over the next decade to facilitate the transition to renewable energy. Moreover, to accomplish the target set by COP26, such as combating global warming, the proportion of renewable energy in the primary global energy supply has to increase substantially, from 14% in 2018 to 74% by 2050 (Liu et al., 2023). The COP29, to be held in November 2024, will track the COP28 consensus on energy outcomes, emphasize monitoring progress towards doubling energy efficiency, and aim to triple renewable energy capacity by 2030<sup>25</sup>. Similarly, the OECD (2016) forecasts that investment in environmentally sustainable projects exceeding \$2.2 trillion will be required by 2035. As a result, managers tend to strongly focus on environmentally sustainable investment, irrespective of industry differences (Meuer et al., 2020), in order for firms to reduce their harmful impact on the environment and make ongoing business operations more sustainable.

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<sup>25</sup> <https://www.irena.org/> (Accessed on June 07, 2024)

It is widely acknowledged that environmental investment enhances environmental or sustainability performance by allocating resources to environmental safety, preventing pollution, and limiting environmental impact or hazards (Betts et al., 2018; Bostian et al., 2016; Li and Ramanathan, 2020). Furthermore, it is evident that environmental investment can help firms implement environment-friendly strategies (Alam et al., 2022). González-Benito and González-Benito (2005) and Klassen and Whybark (1999) also stress that investing in environmental initiatives improves a firm's operational efficiency, thereby reducing its adverse effects on the environment. The existing studies document that environmentally conscious firms further enjoy certain financial benefits, such as the ability to acquire loans with relative ease (Nandy and Lodh, 2012; Sharfman and Fernando, 2008). Moreover, Atif et al. (2022) contend that sustainable investment is an example of a pro-social endeavor that enables firms to enhance environmental and energy performance without affecting their financial returns. According to Pekovic et al. (2018), despite the undeniable linkage between environmental investment and ESG, or environmental performance, environmental investment holds more evident substance and tangibility for corporations as it encompasses all costs associated with environmental-related actions and any financial support required for long-term climate protection initiatives. In addition, the decarbonization transition requires a tremendous amount of capital outlay. Carbon policy risk may on a firm financial health (Nguyen and Phan, 2020). However, investing in environmental activities can help handle financial challenges. In this connection, Atif et al. (2022) claim that investment in environmentally sustainable undertakings can improve financial performance.

Nevertheless, prior research lacks a comprehensive investigation into the impact of environmental investment, which is a more substantive and perceptible indicator of firm-level environmental activism, on financial leverage decisions. A handful of studies have analyzed the nexus between ESG, or other forms of environmental performance, and firm financial leverage (Fernández-Cuesta et al., 2019; Kalash, 2021). However, a typical ESG, or disclosure-based environmental performance measure, may not always reflect substantive environmental engagement. These widespread measures appear to leave spaces for firms with greenwashing opportunities (Mahoney et al., 2013). In turn, ESG greenwashing may lead to equity mispricing (Lin et al., 2023). As a result, the reliability and applicability of ESG information may invite controversy due to the likelihood of greenwashing behavior (Yu et al., 2020). On the other hand, spending on environmental initiatives clearly demonstrates the extent and frequency of the actual allocation of funding at the firm level for the pursuit of environmental projects and

the transition to sustainable business practices. Therefore, in this study, we aim to examine environmental investment as a driver of corporate financial leverage, represented by book and market leverage. We argue that firms tend to be more attractive to lenders when they care about environmental safety and spend on environmental activities. In other words, environmental investment appears to enable firms to take advantage of incorporating financial leverage into their capital structure. Our study thus contributes to the growing literature concerning environmental engagement and firm financial outcomes by analyzing the relationship between environmental investment and corporate capital structure. Furthermore, despite the growing body of research that only looks into the affiliation between environmental performance and the cost of capital (i.e., El Ghouli et al., 2018; Eliwa et al., 2021; Fonseka et al., 2019), there remains a notable gap in the academic literature on whether firm-level employment of funds for environmental activism affects the cost of debt financing. Hence, to narrow the gap, we further investigate the relationship between actual environmental investment and the cost of debt.

In this study, we focus on US publicly listed firms. Even though there is still an absence of a US federal-level mandate for climate change commitments, sustainability engagements, accountability, and disclosure practices, carbon-intensive US firms, among others in highly industrialized countries, have been experiencing mounting pressure from various stakeholders to transition to renewable energy sources and limit carbon footprints (Bui and De Villiers, 2017; Wang and Sueyoshi, 2018). Similarly, regional alliances, policymakers, and environmentalists have been persistently persuading corporations to adopt comprehensive ESG disclosure and environmentally sustainable business practices. For example, the Regional Greenhouse Gas Initiative (RGGI) is a compulsory, market-oriented scheme implemented in the United States that aims to reduce greenhouse gas emissions. This cooperative attempt is comprised of the eastern states, such as New York, New Jersey, Maine, Maryland, Massachusetts, Vermont, Delaware, Virginia, Rhode Island, Connecticut, and New Hampshire<sup>26</sup>. In addition, Gary Gensler<sup>27</sup>, chairman of the U.S. Securities and Exchange Commission (SEC), alluded to the likelihood that firms may be obligated to submit climate disclosures via Form 10-K during the July 2021 webinar titled "Climate and Global Financial Markets." This aligns with the growing trend of firms increasing their environmental activism,

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<sup>26</sup> <https://www.rggi.org>

<sup>27</sup> The Securities and Exchange Commission (SEC) officially enacted climate-focused disclosure rules in March 2024. See also [https://viewpoint.pwc.com/dt/us/en/pwc/in\\_briefs/2024/2024-in-brief/ib202402.html](https://viewpoint.pwc.com/dt/us/en/pwc/in_briefs/2024/2024-in-brief/ib202402.html)

integrating sustainable business practices into organizational strategy, and disclosing CO<sub>2</sub> footprint information in recent times<sup>28</sup>. Lately, the California-based climate accountability package, which was made effective in October 2023, requires private firms and investors to disclose climate-oriented financial risks. This accountability package attempts to ensure corporate responsibility and transparency in dealing with climate change<sup>29</sup>. Given that our sample consists of S&P 500 constituents, which are recognized for their highest market capitalization and strong financial health, they are subject to rigorous scrutiny by investors and persistent societal pressure (Bui et al., 2020). In response to growing stakeholder expectations, societal pressure, and compliance with regulatory requirements, it is thus anticipated that carbon-intensive S&P 500 firms endeavor to formulate environmental strategies, implement measures to reduce the adverse environmental effects and make related disclosures as part of their day-to-day business course of action. Therefore, these firms are expected to focus on investing in environmental undertakings.

Using a sample of 4,376 firm-year observations from non-financial S&P 500 firms from 2011 to 2021, we find evidence that firms' spending on environmental activities is positively associated with their use of financial leverage. Our results further reveal that an increase in environmental investment is associated with more affordable access to debt financing or a lower cost of borrowing. Our results remain consistent after we run a series of robustness checks with alternative variables as well as after we employ instrumental variable (IV) and propensity score matching methods in order to address potential endogeneity issues and the Heckman model to address any bias arising from sample selection.

Our study contributes to the growing body of literature in several ways. First, to the best of our knowledge, this study is the first to present a novel and rigorous empirical analysis of the relationship between firm-level environmental investment and corporate capital structure. The existing literature mainly evaluates the impact of ESG performance on firm-level financial outcomes, often overlooking the most critical aspect of environmental risk management, i.e., investment in environmental activities. As a result, in the academic literature, the impact of actual environmental investment on firm financing decisions remains underexplored. Our study aims to analyze the effects of environmental investment explicitly, the keystone to

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<sup>28</sup> For more information, see <https://corpgov.law.harvard.edu/2021/09/01/the-secs-upcoming-climate-disclosure-rules/>.

<sup>29</sup> <https://www.georgeson.com/us/insights/californias-climate-accountability-package-update#>

environmental safety and risk management, on financial leverage. Second, our study makes a unique contribution to the current body of literature by examining the impact of environmental investment on the cost of debt. Prior studies have not yet addressed the potential influence of environment-related investment on the cost of borrowing. This gap leaves room for a comprehensive analysis to determine whether and how such investments might affect the cost of debt. In essence, our empirical results reveal a negative association between investment in environmental initiatives and the cost of borrowing. Third, we are the first to provide empirical evidence from a US perspective on the nexus between environmental investment and both firm financial leverage and cost of debt. In particular, this study extends the relevant literature by examining firm-level environmental investment, the most fundamental and vital component of corporate environmental activism, as a determinant of financial leverage and cost of debt for the non-financial S&P 500 firms that are responsible for both direct and indirect carbon emissions.

The remainder of this essay is organized as follows: Section two reviews relevant literature and presents the development of our hypotheses. Section three presents the data and empirical models, while section four reports the empirical results. Finally, section five concludes the study with policy implications and future research scope.

## 2. Literature Review and Hypotheses Development

Capital structure theories offer valuable insights into how firms determine their financing strategies based on information asymmetry, board attributes, agency costs, and market dynamics (Harris and Raviv, 1991). These theories explore various standpoints to reach a balance between debt and equity. While Modigliani and Miller (1958) lay the foundation of the capital structure perception, new perspectives could navigate the essentials of actual financial choices by challenging the capital structure approaches predominant in mainstream academic finance (Ardalan, 2017). Two of the most significant capital structure theories, the pecking order theory and the trade-off theory, are widely used in corporate finance. The pecking order theory of capital structure suggests that firms prioritize their financing in a specific order: they first utilize retained earnings, then turn to borrowing externally, and lastly resort to issuing equity if required (Frank and Goyal, 2003; Myers and Majluf, 1984). However, the pecking order behavior is built on the basic notions of asymmetric information (Myers, 1984), and firm financing choices appear to disregard the principal predictions of the pecking

order structure (Fama and French, 2002). While the trade-off theory of capital structure decisions suggests that firms choose the combination of debt and equity financing to establish a balance between the advantages of tax-shield benefits and the potential complications of financial distress related to the use of financial leverage (Bradley et al., 1984; Graham, 2003; Nguyen and Phan, 2020). Debt offers tax-shield benefits and also helps reduce equity agency costs. Excessive debt, however, will likely result in potential financial distress and bankruptcy costs (Bradley et al., 1984; Fama and French, 2002; Frank and Goyal, 2009). Overall, traditional finance theory, particularly trade-off theory (Modigliani and Miller, 1958), posits that firms aim to optimize their capital structure by balancing the tax advantages of debt against the costs of financial distress. From this perspective, the affiliation between environmental investment and financial leverage appears to be ambiguous. Firms may increase debt financing to fund substantial environmental projects, especially given their capital-intensive nature (Flammer, 2021). Debt can be a less expensive source of capital than equity, particularly considering the tax deductibility of interest payments (Myers, 1984). However, the inherent uncertainties associated with environmental projects, including fluctuating future cash flows, evolving regulatory landscapes, and potential environmental liabilities, can make them less attractive to debt holders (Bachelet et al., 2019). Lenders may perceive these projects as having higher risk, potentially leading to higher interest rates or restricted access to debt financing (Goss and Roberts, 2011). Furthermore, firms already burdened with high leverage may be hesitant to undertake additional debt-financed environmental projects due to the amplified financial risk (Leland, 1998). This suggests a potential non-linear relationship, where moderate environmental investments might be financed with debt, while substantial investments might strain debt capacity.

Moving beyond the focus of trade-off theory when it comes to the nexus between environmental investment and firm financing choices, stakeholder theory (Freeman, 2010) provides a reasonably broader framework. It argues that firms should consider the interests of all stakeholders, including shareholders, creditors, employees, customers, and communities. Consumers, stakeholders, and community members apparently value environmentally conscious firms (Nakamura, 2011). Likewise, socially responsible investors and fund providers appear to choose firms that address climate change issues and engage in sustainable business practices (Dutta et al., 2020), especially if the financial gains exceed a certain minimum level they set (Kim and Statman, 2012). Environmental investment can signify a firm's commitment to social responsibility and sustainability, potentially enhancing its reputation and legitimacy

(Carroll, 1979). Positive stakeholder perceptions can lead to improved access to capital, including debt financing, and potentially lower borrowing costs (Morsing and Schultz, 2006). However, if stakeholders view environmental initiatives as mere greenwashing or if the firm has a history of environmental misconduct, these investments may not translate into favorable financing conditions (Lyon and Montgomery, 2015). Furthermore, the increasing scrutiny of ESG (Environmental, Social, and Governance) performance by investors and rating agencies (Eccles and Krzus, 2010) adds another layer of complexity. Firms with discernibly strong environmental performance may attract "green" or "sustainable" funds, potentially lowering their cost of capital (Hong and Kacperczyk, 2009). Conversely, poor environmental performance can lead to increased scrutiny and higher perceived risk, potentially increasing the cost of debt. Therefore, the primary motive for firms to engage in sustainable business practices and increase their environmental investment might be to cater to stakeholders' interests, draw the attention of environmentally responsible investors, and optimize corporate image and standing.

To this end, signaling theory (Spence, 1973) posits that firms use environmental investments to signal their quality and commitment to long-term sustainability to investors. Credible environmental performance can be a signal of good management practices and reduced long-term risk, potentially leading to a lower cost of debt (Hong and Kacperczyk, 2009). However, the effectiveness of this signaling depends on the transparency and verifiability of environmental disclosures (Verrecchia, 1983). If environmental disclosures are opaque, lack standardized metrics, or are not externally verified, the signaling effect may be diminished, and investors, lenders, and fund providers may remain skeptical.

In summary, the relationship between environmental investment, financial leverage, and the cost of debt is multifaceted. While trade-off theory offers insights into the potential link between environmental project financing and debt levels, the inherent risks and uncertainties associated with these investments can influence lenders' perceptions and potentially increase the cost of debt. Stakeholder theory and signaling theory highlight the importance of considering stakeholder interests, the credibility of environmental disclosures, and the increasing influence of ESG factors on investors' perceptions and access to capital under more favorable conditions. Therefore, to fully capture the intricacies of how environmental investment influences financial leverage and the cost of debt, the above-mentioned theoretical predictions come into play.

A growing body of research has analyzed the intricate relationship between firm environmental performance and financial performance (e.g., Kalash, 2021; Liu, 2020; Nakamura, 2011; Semenova and Hassel, 2016; Zhou et al., 2023). Interestingly, only a limited number of studies have examined the impact of environmental performance on capital structure, such as Chang et al. (2021), Fernández-Cuesta et al. (2019), and Ulph and Valentini (2004). Nevertheless, existing evidence on the relationship between environmental performance and corporate capital structure choices offers inconsistent findings. For example, it is often argued that environmental liabilities are likely to substitute for firm financial liabilities. Based on this notion, Chang et al. (2021) provide evidence that firms with greater environmental liabilities tend to have a lower debt-to-equity ratio. On the contrary, the imposition of environmental liabilities would result in the use of debt financing. Accordingly, Ulph and Valentini (2004) document that when environmental liability is enforced upon polluting firms with limited liability, it prompts them to take advantage of more bank borrowing. Further, Fernández-Cuesta et al. (2019) show that substantive carbon performance is only positively associated with financial leverage. However, this nexus is applicable when firms manage to increase their sales.

Empirically speaking, it is argued that environmental engagement requires firms to allocate more funds toward capital expenditures and operating expenses, potentially impacting firm-level financing decisions (Dangelico and Pujari, 2010). Interestingly, the vast majority of previous studies employ combined ESG scores as a proxy for measuring environmental performance (e.g., Eliwa et al., 2021; Ho et al., 2021) or based on firm participation in CDP (Kalash, 2021), a worldwide environmental disclosure undertaking that works on the voluntary participation of firms. However, substantial inequality exists in allocating a firm's overall ESG performance across all three pillars (de la Fuente and Velasco, 2024). Besides, greenwashing practices can distort ESG ratings, and the tendency to greenwash tends to be more pronounced among large-cap firms (Yu et al., 2020). Acknowledging the potential for firm-level ESG-related controversies that are not explicitly accounted for in determining firm environmental performance is crucial. ESG controversies may hinder a firm's ESG performance. They can raise suspicion about the firm's ESG practices and challenge its institutional legitimacy (Palazzo and Scherer, 2006). Subsequently, such issues will likely increase the cost of equity (La Rosa and Bernini, 2022). Although environmental performance is subject to factors that extend beyond environmental investment, environment-related investment is the cornerstone of determining sustainable or environmental performance. These factors include the size and

nature of the business, plant technology, educational qualifications of employees, regulatory responsibilities, managerial tactics, and public investigation (Dasgupta et al., 2000). Based on the above line of reasoning, unlike diverging prior environmental performance measures, we uniquely explore firm-level actual environmental spending, a more substantive indicator of firms' genuine involvement in environmental and sustainable actions as opposed to mere disclosure-based symbolic arrangements, as a determinant of capital structure.

Environmental investment encourages innovation in green products and services by developing new ones or upgrading existing ones while leaving no or minimal negative environmental impact (Ali et al., 2016; Wong et al., 2012). In this context, Stucki (2018) contends that environmentally sustainable investment induces low-carbon and clean-energy technology. Rissman and Marcacci (2019) also stress that firm-level spending on environmental activities promotes cost-effective technology and knowledge, thereby improving energy efficiency and productivity. In contrast, carbon-intensive firms, which struggle to implement environmental safety measures and maintain sustainability standards consistently, are subject to strict environmental rules and regulations. Therefore, these firms are likely to experience more stringent borrowing conditions and, in turn, employ lower leverage (Fard et al., 2020). Further, investing in environmental initiatives significantly impacts a firm's abilities and thus gives it a clear edge over competitors. Orsato (2006) stresses that competitive environmental strategies can optimize economic gains and confer a competitive advantage on certain firms. Similarly, Yadav et al. (2016) showed that enhanced environmental practices within businesses uphold competitive advantages and expedite the rebound from financial setbacks. According to Lozano (2015), environmental investment can assist firms in attracting long-term financial leverage by enhancing sustainability and mitigating the risks associated with environmental degradation.

In addition, considering the empirical evidence, the impact of environmental investment on the cost of debt might also appear to be two-sided. On the one hand, it is commonly observed that lenders, including banks, are fully mindful of climate change issues and appear to perform all the required assessments of credit risk with respect to all those issues before making any lending decisions (Fernández-Cuesta et al., 2019; Herbohn et al., 2017; Jung et al., 2018). Firms demonstrating strong environmental stewardship may be perceived as lower-risk borrowers, leading to reduced borrowing costs. Improved environmental risk management has been associated with a lower cost of capital, as it enhances the firm's reputation and reduces

potential liabilities (Sharfman and Fernando, 2008). Similarly, firms with robust Environmental, Social, and Governance (ESG) performance can significantly reduce financing costs and alleviate financing constraints, further supporting the notion that environmental investment can lead to more favorable borrowing terms (Zhou et al., 2023). Nandy and Lodh (2012) also support the fact that eco-friendly firms are likely to benefit from financial advantages such as increased flexibility in obtaining funding. Similarly, lenders do not prioritize environmentally unsustainable businesses in their lending decisions (Eliwa et al., 2021). On the other hand, environmental investment entails significant upfront costs and long payback periods, which can increase financial risk in the short term. Lenders may view such projects as adding volatility to cash flows, leading to higher risk premiums and, consequently, increased cost of debt. Firms that are not aware of their environmental obligations and fail to remain committed to lowering environment-specific risk factors are usually considered risky by lenders and investors (Eliwa et al. 2021; Kalash, 2021). Therefore, as a means of compensating for the additional risk that is associated with environmental concerns, commercial banks, other financial institutions, and debt holders could demand higher interest rates (Li et al., 2014).

By drawing on predictions from multiple relevant theories, we recognize the complexity of the factors influencing corporate financing decisions and refrain from assuming a predetermined directional relationship. This balanced approach enables a more comprehensive empirical examination of the interaction between environmental investments and corporate financial choices, particularly regarding financial leverage and the cost of debt. In addition, given the empirical evidence supporting both positive and negative financial effects of environmental investments, we propose the following hypotheses in a non-directional manner to fully reflect on the theoretical underpinning and the literature-driven arguments.

*H<sub>1</sub>: Ceteris paribus, there is a statistically significant relationship between investment in environmental initiatives and firm-level financial leverage.*

*H<sub>2</sub>: Ceteris paribus, there is a statistically significant relationship between investment in environmental initiatives and the cost of borrowing.*

### 3. Data, Variables, and Empirical Models

As previously stated, S&P 500 firms are considered exemplars of environmental activism globally as the most notable entities quoted on the US stock exchanges. Hence, in this study, we collect data on firms appearing on the S&P 500 index, which covers firms listed on the NYSE or NASDAQ, over the period from 2011 to 2021. We have chosen 2011 as the beginning year of the sample period for two specific reasons. First, by selecting this year, we aim to preclude the probable impact of the global financial crisis and its subsequent aftermath, thereby ensuring the consistency and reliability of our empirical findings. Second, in developed countries, considerable progress has been observed in corporate environmental activism with regard to sustainability practices, disclosure behavior, and the emergence of regulatory directives since the post-crisis period. We focus on firms that release direct CO<sub>2</sub> footprints as part of their business operations and are considered carbon-intensive<sup>30</sup>. These carbon-intensive firms are largely responsible for emissions that fall under Scope One<sup>31</sup> (direct emissions). In this study, we also include non-financial firms that source Scope Two<sup>32</sup> (indirect) emissions. We exclude banks and other financial entities from our sample since they are not involved in the production and manufacturing-based operations and are not responsible for direct carbon emissions. Moreover, the capital structures of banks and related firms are expected to vary considerably from those of non-financial firms (DeAngelo and Stulz, 2015; Diamond and Rajan, 2000; Shu et al., 2023). Furthermore, banks and other financial institutions are subject to specific regulatory frameworks that require them to follow governance mechanisms distinct from those applied to non-financial firms (Luo and Tang, 2020; Orazalin, 2020). The final sample thus includes 4376 firm-year observations from 398 S&P components. All data are collected from the Refinitiv Eikon Datastream database.

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<sup>30</sup> <https://www.greenelement.co.uk/blog/carbon-footprint-scope-1-2-3/> (Accessed on May 30, 2024)

<sup>31</sup> Scope one: This encompasses all types of direct emissions from owned or controlled sources.

<sup>32</sup> Scope two: The reporting firm categorizes indirect emissions, which include the production of purchased electricity, cooling, steam, and heating. Scope two, for example, includes electricity from energy suppliers to power up computers.

### 3.1 Dependent variable

The dependent variables of our study are firm financial leverage (corresponding to Hypothesis 1) and cost of debt (corresponding to Hypothesis 2). To test our first hypothesis, following Nguyen and Phan (2020) and Shu et al. (2023), we employ two measures of financial leverage, namely book and market leverage, for our empirical analysis. The first measure, book leverage, is defined as the total debt (the sum of the short-term and long-term debts) scaled by the book value of the assets. The second measure, market leverage, refers to total debt (which also includes both short-term and long-term debts) relative to the market value of assets. On the other hand, in order to test our second hypothesis, we follow Jung et al. (2018) and Orens et al. (2010) to determine the cost of debt, which is calculated as the ratio of interest expenses to the total value of interest-bearing debt.

### 3.2 Independent variables

In line with Atif et al. (2022) and Pekovic et al. (2018), environmental investment serves as the primary independent variable in this study. Our analysis employs the natural logarithm of total environmental expenditures as the proxy for environmental investment. Environmental investment is regarded as the total expenditures associated with environmental protection, along with controlling and minimizing environmental impacts and hazards. Any treatment, disposal, and clean-up spending is also considered an environmental investment. In this regard, a handful of studies (e.g., Milne and Grubnic, 2011; Okereke, 2007; Simon et al., 2012) indicate that environment-specific investment gives rise to firm-level overall capital expenditures. However, we argue that using capital expenditures as a substitute for actual environmental investment or spending might create ambiguity and inconsistency in reporting, since expenditures for environmental engagements extend far beyond the typical scope of capital expenditures. Furthermore, environmentally conscious, and carbon-intensive firms clearly categorize and disclose environmentally sustainable expenditures to comply with regulatory directives and evaluate their stance on environmental engagement. Still, we incorporate and control for capital expenditures in all of our empirical models (see sub-section 3.3).

### 3.3 Control variables

Past studies (Atif et al., 2021; Detthamrong et al., 2017; Morellec et al., 2012) indicate that board characteristics and governance mechanisms play a pivotal role in determining business strategies and financing decisions. Therefore, we control for the following board and governance related variables in our models. As a commonly employed control variable in the related literature, we control for board size, which is defined as the number of directors serving on the board (Detthamrong et al., 2017; Kang et al., 2007; Lim et al., 2007). According to the extant literature (i.e., Berrone and Gomez-Mejia, 2009; Bui et al., 2020; Haque and Ntim, 2022; Morellec et al., 2012), we also control for board independence, which is regarded as the number of independent directors as a percentage of the board size. Consistent with Alam et al. (2022), Atif et al. (2022), Detthamrong et al. (2017), and Haque and Ntim (2022), we further incorporate CEO duality (a dummy variable taking on the value of one if the CEO of the firm also acts as the chair of the board and zero otherwise) as a control variable. Moreover, in line with Cao and Whyte (2023), Haque and Ntim (2020), Haque (2017), Luo et al. (2012), Orazalin et al. (2023), and Vega-Gutiérrez et al. (2024), we control for gender diversity (the percentage of female directors on the board), firm size (the natural logarithm of total assets), and profitability (which is calculated by dividing net profit by total assets). Furthermore, following prior literature (Albitar et al., 2023; Nadeem et al., 2020), we employ capital intensity, measured as a firm's capital expenditures divided by total sales. According to Konadu et al. (2022) and Leyva-de la Hiz et al. (2019), we further include liquidity (the ratio of current assets to current liabilities) in our models. We also control for EBIT/TA, which is defined as earnings before interest and taxes scaled by the book value of assets (Nguyen and Phan, 2020). Finally, we control for the market to book ratio, i.e. the ratio of market price to book value of equity (Albitar et al., 2023; Haque and Ntim, 2022; Safiullah et al., 2021).

### 3.4 Empirical Models

We investigate the empirical association between environmental investment and financial leverage by first estimating the following baseline model:

$$\text{Financial Leverage}_{it} = \beta_0 + \beta_1 \text{Environmental Investment}_{it} + \beta_2 \text{Board Size}_{it} + \beta_3 \text{Board Independence}_{it} + \beta_4 \text{Gender Diversity}_{it} + \beta_5 \text{CEO Duality}_{it} + \beta_6 \text{Firm Size}_{it} + \beta_7 \text{Liquidity}_{it} + \beta_8 \text{MTB}_{it} + \beta_9 \text{EBIT\_TA}_{it} + \beta_{10} \text{Capital Intensity}_{it} + \beta_{11} \text{Return on Assets}_{it} + \beta_{12} \text{Industry fixed effects}_{it} + \beta_{13} \text{Year fixed effects}_{it} + \varepsilon_{it} \quad (1)$$

We then examine the association between environmental investment and the cost of debt using the following model:

$$\text{Cost of Debt}_{it} = \beta_0 + \beta_1 \text{Environmental Investment}_{it} + \beta_2 \text{Board Size}_{it} + \beta_3 \text{Board Independence}_{it} + \beta_4 \text{Gender Diversity}_{it} + \beta_5 \text{CEO Duality}_{it} + \beta_6 \text{Firm Size}_{it} + \beta_7 \text{Liquidity}_{it} + \beta_8 \text{MTB}_{it} + \beta_9 \text{EBIT\_TA}_{it} + \beta_{10} \text{Capital Intensity}_{it} + \beta_{11} \text{Return on Assets}_{it} + \beta_{12} \text{Industry fixed effects}_{it} + \beta_{13} \text{Year fixed effects}_{it} + \varepsilon_{it} \quad (2)$$

In model 1, the outcome variable is financial leverage. We employ two proxies of financial leverage, namely book leverage and market leverage. In model 2, the cost of debt is our outcome variable. In both models, environmental investment serves as the primary independent variable, accompanied by a number of firm-level governance and financial controls. Table A1 (Appendix) provides the definitions of the variables used in the empirical analysis.

We employ the ordinary least squares estimation method for the baseline regression models while controlling for industry and year effects. The industry-fixed effects let us account for differences that are unique to each industry (Shen et al., 2021; Siddique et al., 2021). The year-fixed effects, on the other hand, allow us to account for changes in macroeconomic trends over time that could have an effect on firm-level financial leverage (Cook and Tang, 2010; Nguyen and Phan, 2020). We further employ different econometric techniques to address endogeneity concerns and check the robustness of our baseline results, as detailed in the next section.

## 4. Empirical Results

### 4.1 Descriptive statistics

Table 22 reports descriptive statistics on the key variables employed in our analysis. With regard to the dependent variables, the mean value of capital structure, as proxied by book leverage (market leverage) is 0.289 (0.284). Moreover, book leverage (market leverage) exhibits a standard deviation of 0.179 (0.151), with these figures indicating variations in capital structure across the sample firms. The respective average and standard deviation values for the cost of debt are 0.075 and 0.092. In relation to the main explanatory variable, our sample firms are found to invest 3.89 on average in environmental activities, with the variability of environmental investment around the mean value being 3.48.

Table 22 further presents summary statistics on the sample firms' board and governance characteristics. The average number of members serving on the boards of the firms in our sample is nine, which is comparable to the findings of Haque and Ntim (2018) and Tauringana and Chithambo (2015). Boards are comprised of 77 percent independent directors on average, a finding that aligns with Alam et al. (2022). Moreover, consistent with Atif et al. (2021, 2022), women account for 19 percent of board positions on average and CEO duality is rather high at 0.628 on average. The summary measures of firm characteristics indicate that firm size is 16.47 on average. The observed mean liquidity (current ratio) value of our sample firms is 1.665. The mean figures for the market-to-book ratio and EBIT/TA are 3.773 and 0.121, respectively, while the capital intensity averages 6.95 percent. Finally, our sample firms exhibit an average return on assets of 8.11 percent. Overall, these findings are comparable to those reported in earlier studies.

The correlations of our dependent variables with our independent and control variables are presented in Table A2 (Appendix). A positive and significant association is found between environmental investment and both the book value and market value of leverage. Therefore, as anticipated, environmental investment is positively associated with financial leverage, which is consistent with our first hypothesis. On the other hand, a negative correlation between environmental investment and the cost of borrowing is found, in accordance with our second hypothesis. We further used the variance inflation factor (VIF) to detect potential presence of multicollinearity. The VIF values for our variables range from 1.14 (CEO Duality) to 3.03 (Board Size), with the average VIF score being equal to 1.73. As any value of VIF beyond 10 signals the presence of multicollinearity (Chatterjee and Hadi, 2006; Matsumura et al., 2014;

Shad et al., 2020), our VIF scores suggest that multicollinearity is not a concern in our study, and the econometric techniques we employ are likely to generate unbiased estimates.

## 4.2 Baseline results

### 4.2.1 Impact of environmental investment on financial leverage

Table 23 reports the baseline regression results. Column 1 shows empirical results where capital structure is proxied by book leverage, whereas column 2 presents the corresponding results for market leverage. The regression models in columns 1 and 2 include industry and year fixed effects. The results consistently support Hypothesis 1: environmental investment has a strong positive relationship with both proxies of capital structure, i.e., the book value of leverage and the market value of leverage, with the relationship being statistically significant at the 1% level. This finding indicates that firms investing in environmental safety and impact reduction tend to use more financial leverage. Prior studies suggest that environment-related expenditures can yield long-term benefits, such as increased operational efficiency, improved corporate image, and regulatory compliance, which collectively contribute to enhanced financial stability and resilience (Ho et al., 2021; Nakamura, 2011; Orsato, 2006). It is also well-documented that firms investing in environmental initiatives gain a competitive advantage over their counterparts (Pekovic et al., 2018). This competitive advantage leads to these firms being perceived as more environmentally responsible and adaptable by lenders and fund providers. Consequently, relying more on the upside potential of environmental investment, this preferential treatment enables such firms to access a broader range of debt alternatives and increase their financial leverage. Our findings are also consistent with Li et al. (2024), who show that environmental investment considerably increases firms' access to trade credit. Overall, the baseline estimates<sup>33</sup> indicate that the higher the firm-level spending on environmental activities, the greater the reliance on debt financing. Among the control variables, board size, board independence, and capital intensity are positively and significantly

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<sup>33</sup> Additional baseline estimates are reported in Table A3 in the appendix. In Columns 1 and 2, we predict book leverage based on governance-related control variables and firm financial control variables, respectively. Further, market leverage is explained using the same two sets of controls in Columns 3 and 4 of Table A3. Consistent with the results presented in Table 2, we observe a strong positive association between environmental spending and firm financial leverage, as the estimated coefficients are statistically significant at the 1% level.

related to firms' usage of debt financing. On the other hand, gender diversity, liquidity, and return on assets are negatively and significantly associated with corporate capital structure.

We further perform the analysis using a firm fixed effects model, which allows us to capture the within-firm impact (Wooldridge, 2012). Columns 3 and 4 of Table 23 display the impact of environmental investment on the book value of leverage and market value of leverage, respectively. The estimation results confirm that environmental investment is positively and significantly associated with both measures of leverage, providing further support to Hypothesis 1.

#### 4.2.2 Impact of environmental investment on the cost of debt capital

Column 5 in Table 23 reports the baseline results from regressing the cost of debt capital on environmental investment and the same set of control variables, including industry and year fixed effects. We find that environmental investment is negatively associated with the cost of debt capital, and the relationship is statistically significant at the 1% level, thus supporting Hypothesis 2. Similarly, column 6 in Table 23 presents the estimation results using firm fixed effects. The results indicate that the negative relationship between the cost of debt and environmental investment remains statistically significant at the 1% level after considering within-firm effects to control for unobserved heterogeneity. Grounded in the assumption of the potential benefits associated with systematic and credible environmental investment, it is perceived that environmental investment helps in reducing environmental risk and improving environmental performance. This leads to a reduction in exposure to environmental risks, including regulatory, physical, reputational, litigation, and production risks. As a result, the lower level of environmental risk reduces the likelihood of default and eventually helps lower the cost of debt capital (Kim et al., 2015; Sharfman and Fernando, 2008). Overall, our empirical results suggest that firms investing in environmental initiatives appear to take advantage of debt financing at a lower cost. Among the control variables, board independence and firm size are found to be negatively related to the cost of debt capital.

### 4.3 Robustness checks

Next, we run robustness tests and report the estimation results in Table 24. We first replace our financial leverage variables with two specific constructs, namely the total liabilities to the book value of assets (TL\_BVA) and total liabilities to the market value of assets (TL\_MVA), following similar studies in the extant literature (Nguyen and Phan, 2020; Shu et al., 2023), while keeping all right-hand side variables the same as in the baseline model. Total liabilities to the book value of assets is the sum of all short- and long-term liabilities divided by the book value of assets, whereas total liabilities to the market value of assets is the sum of all short-term and long-term liabilities scaled by the market value of assets. According to the results, environmental investment positively affects both TL\_BVA (column 1) and TL\_MVA (column 2), with the effects being statistically significant at the 1% level.

To ensure the reliability of our baseline regression results, we further re-estimate the baseline models by substituting our primary independent variable with two others. Specifically, the alternative independent variables are environmental investment intensity, which is calculated as the ratio of environmental investment to sales (Pekovic et al., 2018), and renewable energy intensity, which is the total renewable energy consumption scaled by sales (Atif et al., 2021). The corresponding estimation results are also reported in Table 24, where the book value of leverage (columns 3 and 5) and the market value of leverage (columns 4 and 6) are the outcome variables, while all control variables remain the same as in the baseline models. We find evidence that both alternative measures of environmental investment are strongly and positively related to firms' use of financial leverage, with the relationships being statistically significant at the 1% level. The empirical findings from our robustness checks are thus in line with the baseline regression results, providing further support to Hypothesis 1.

We further employ the same alternative measures of environmental investment as those used above, i.e., environmental investment intensity and renewable energy consumption, to explain the cost of debt, with the estimation results being reported in columns 7 and 8, respectively, of Table 24. We find evidence that higher levels of environmental investment intensity and renewable energy consumption are related to decreases in the cost of borrowing, further supporting our contention in Hypothesis 2.

#### 4.4 Sub-sample analysis

It is reasonable to anticipate that firms or industries with varying levels of environment-related investment may behave differently. Next, we therefore divide our sample firms into two groups based on their level of environmental investment and perform a sample-split investigation. Specifically, we place the top 50% of the sample firms in the high-environmental investment group and the remainder in the low-environmental investment group. Table 25 reports the estimation results for the two sub-samples. It is shown that environmental investment increases the use of financial leverage, as measured by both book leverage and market leverage, in both sub-groups, with the positive association being statistically significant at the 1% level in all cases (columns 1-4 in Table 25). Similarly, our sample-split results reveal no qualitative difference between the two sub-groups in terms of the cost of debt capital (see columns 5 and 6 in Table 25). A possible explanation for this evidence might be that, rather than evaluating the overall extent of environmental investment, lenders and fund providers prioritize firms that spend, even if narrowly, on environmental initiatives as a visible indication of their environmental activism. As a result, firms with both high and low levels of environmental investment benefit from easier and more affordable access to financial leverage.

In addition, the size of the firm may influence the intricate relationship at play. Therefore, to gain deeper understanding of the relationship between our variables of interest, we divide our entire sample into large and small firms based on firm size and perform further sample-split analysis. Table 26 presents the empirical results for these two sub-groups. For the financial leverage measures, the results do not demonstrate any discernible qualitative differences between the two sub-groups, as environmental investment is positively associated with both book leverage and market leverage across the two groups (see columns 1-4 in Table 26). However, for the cost of debt capital, the impact of firm-level environmental investment appears to be more apparent for small firms compared to their larger counterparts. Specifically, for small firms, the coefficient of environmental investment is negative and statistically significant at the 1% level (column 5 in Table 26). One plausible explanation to support this empirical evidence is that, over our sample period, small firms have been observed to emit less CO<sub>2</sub> than their larger counterparts. Consequently, small firms benefit from a reduced cost of debt as a reward for their lower emission levels.

## 4.5 Addressing endogeneity concerns

Our empirical outcomes are likely to show a correlation instead of a causal relationship, potentially influenced by endogeneity bias. Our primary explanatory variable (environmental investment) could be subject to a self-selection issue. Consequently, the results might not accurately portray a consistent association with the dependent variables. To address this identification challenge, we apply two distinct econometric methodologies to examine the causal link between environmental investment and financial leverage or cost of debt, namely propensity score matching and instrumental variable (IV) analysis.

### 4.5.1 Propensity score matching

We first use a propensity score matching estimate (Albitar et al., 2023; Atif et al., 2021; Lennox et al., 2011) to mitigate endogeneity issues that may arise from the misspecification of the empirical models. We start by computing the above-average industry binary variable, which takes the value of one if a firm's environmental investment exceeds its industry average value and zero otherwise. Then, we employ the Probit model to explain the above-average industry dummy variable. Column 1 in Table 27 reports the respective results of the pre-match estimation for the full sample. Next, following Shipman et al. (2017), we determine the propensity score using nearest neighbor matching with a 1% radius matching technique. Therefore, this propensity score matching technique leaves us with 861 firm-year observations after matching with environmental investment values above the industry average. Finally, using the firm fixed effect model, we conduct post-match regressions based on the paired firm-year observations. The PSM estimates are demonstrated in Panel A of Table 27. Similar to the baseline models, we employ the same set of right-hand side variables in both the pre-match and post-match regressions. The post-match regression results show that environmental investment is positively and significantly associated with both book leverage (Column 2, Table 27) and market leverage (Column 3, Table 27). We also find evidence that environmental investment has a negative impact on the cost of debt (Column 4, Table 27). As observed, both the likelihood ratio in the Probit model and subsequent F-statistics in the post-match regressions are statistically significant with a p-value of 0.000, thus confirming the model fit and validity of the link between our variables of interest (Chib, 1998). The t-test results, presented in Panel B of Table 27, indicate that the treatment and control groups are well-balanced. The firm characteristics show no significant differences between the groups after

matching, as evidenced by the higher p-values. Overall, the univariate comparisons confirm that the matching process has successfully eliminated observable differences between the two groups in terms of firm characteristics (i.e., control variables). The findings from our Propensity Score Matching (PSM) analysis suggest that our initial estimates remain unaffected by any potential endogeneity bias and confirm that firm-level environmental investment significantly increases financial leverage while also reducing the cost of debt financing.

#### 4.5.2 Instrumental variable (IV) analysis

We further perform instrumental variable (IV) analysis using a 2SLS approach to extract the exogenous component of environmental investment. IV analysis calls for an instrument correlated with the endogenous regressor (i.e., environmental investment in our study) which does not exert any direct impact on the explained variable(s) except through that endogenous regressor. In our analysis, we examine the presence of an environmental or sustainability committee as an instrument for conducting the 2SLS regression. We obtain data pertaining to the environmental or sustainability committee, a dummy variable, from the Refinitiv Eikon Datastream. This committee, typically a specialized sub-committee at the board level, is responsible for overseeing climate change concerns, minimizing adverse environmental impacts, addressing environmental risks, and making necessary investment decisions (Dixon-Fowler et al., 2015; Orazalin et al., 2023). Hence, it is anticipated that the presence of a sustainability or environmental committee significantly affects a firm's environmental expenditure. Furthermore, since this committee is primarily responsible for enhancing environmental activism, it is unlikely that it directly influences capital structure decisions and the cost of debt. There is, therefore, scant evidence to suggest that such a committee plays a direct role in determining a firm's financial leverage and cost of debt capital.

The 2SLS regression results with the presence of a sustainability or environmental committee binary variable considered as the instrumental variable and the same set of control variables and fixed effects as in the baseline models are reported in Table 28. The results of the first stage regression as reported in column 1 suggest that the sustainability committee is positively associated with environmental investment and this association is statistically significant at the 1% level. Then, we use the fitted values of environmental investment as obtained from the first-stage regression to regress book leverage, market leverage, and the cost of debt, with the estimation results of these second-stage regressions being reported in columns 2, 3, and 4 in Table 28, respectively. We find that the fitted environmental investment values are positively

associated with both measures of financial leverage, i.e., book leverage (statistically significant at the 5% level) and market leverage (statistically significant at the 1% level). In addition, the fitted environmental investment values are negatively related to the cost of debt, with the relationship being statistically significant at the 1% level. Moreover, the values of the F-statistics and the Cragg-Donald F weak instrument test are high, suggesting the rejection of the null hypothesis that the instrument is weak (Cragg and Donald, 1993; Stock and Yogo, 2005), thus confirming the validity and acceptability of the instrument. Therefore, our empirical results remain robust when employing the 2SLS approach, suggesting that they are not driven by endogeneity concerns.

We have further employed firms' CSR strategy as an instrument for conducting the 2SLS regression and repeated the analysis, employing the same set of control variables as in the baseline models. Following Orazalin (2019), we use the firm-level CSR strategy score as an exogenous component to conduct another instrumental variable analysis. The CSR strategy score is categorized as a firm's CSR principles and practices, which reflect the firm's overall strategy and vision and integrate environmental, social, and economic aspects into its daily decision-making processes. We collect CSR strategy scores from the Refinitiv Eikon Datastream. We assume that the CSR strategy score is not correlated with the error term and may not have any straightforward relationship with the outcome variable. Accordingly, to verify the relevance of our instrument, we run the first-stage regression, with the results being reported in column 1 of Table 29. Consistent with the requirements of a valid instrument, environmental investment is positively related to the CSR strategy, and this association is statistically significant. This suggests that a stronger corporate social responsibility strategy drives firm-level spending on environmental engagements. Moreover, the second-stage regression results presented in columns 2 and 3 of Table 29 reveal that the fitted environmental investment values are positively associated with both book leverage (statistically significant at the 10% level) and market leverage (statistically significant at the 1% level). Finally, column 4 in Table 29 confirms the negative relationship between the fitted environmental investment values and the cost of debt. Similarly, we find that the values of the F-statistics and the Cragg-Donald F weak instrument test are high, suggesting thus the rejection of the null hypothesis that the instrument is weak (Cragg and Donald, 1993; Stock and Yogo, 2005). Overall, the empirical outcomes from this second IV analysis also align with the baseline estimates, confirming that our results are not affected by endogeneity bias.

#### 4.6 Heckman selection model

Another potential issue that may arise is the sample selection bias. In order to address the possible sample selection bias, we use the two-step Heckman selection approach. In the first stage, as shown in column 1 of Table 30, we use the Probit model, which uses the above-average dummy of environmental investment as the outcome variable. Following Orazalin et al. (2023), we rely on all the industry average values of our primary independent variable (environmental investment) as the exclusion restrictions to remedy the potential sample selection issue. Then, we derive the inverse Mills ratio (IMR) based on the estimated coefficients from the first stage and incorporate it as an additional explanatory variable in the second stage. Finally, in the second stage, the firm financial leverage and cost of debt are explained by both environmental investment and IMR using ordinary least squares estimates and the same set of control variables as in the baseline models. The second-stage estimation results for financial leverage are reported in column 2 (book leverage) and column 3 (market leverage) in Table 30. We find a positive and statistically significant (at the 1% level) relationship between environmental investment and financial leverage measures, consistent with the baseline regression results. Additionally, column 4 in Table 30 provides the second-stage regression coefficients for the cost of debt, which is negatively related to environmental investment, with the relationship being significant at the 1% level. Therefore, Heckman selection model outcomes affirm that sample selection bias is unlikely to affect our empirical results.

## 5. Conclusion

Climate change concerns have compelled businesses around the world to strategically reconsider and reorganize their typical methods of business. In response to ever-increasing regulatory pressure and stakeholders' expectations, firms seek to adopt environmentally appropriate business practices that reduce environmental impact, improve energy efficiency, and limit their CO<sub>2</sub> footprint. Further, successful execution of sustainable business models and adherence to sustainable standards necessitate rigorous firm-level planning, supported by financial investment in environmental initiatives. To address corporate environmental activism, prior literature has predominantly focused on the association between environmental performance and firm financial outcomes. However, the existing literature clearly lacks a focused study investigating the specific effects of firm-level actual environmental spending, an essential aspect of environmental activism and risk management, on firm financing decisions. In this study, we investigate the effects of firm-level actual environmental spending on firm financing decisions and the cost of debt. . Based on 4,376 firm-year observations from non-financial S&P 500 firms between 2011 and 2021, we provide evidence that investment in environmental initiatives is positively and significantly related to financial leverage decisions. Our findings suggest that firms investing in environmental projects have a competitive advantage over others and the capacity to better handle environmental challenges, thereby helping them increase their financial leverage. We further show that firm-level environmental investment is linked to a lower cost of debt financing. Firms that invest in environmental engagements are likely to be better equipped to mitigate and manage environmental risks, enabling them to take advantage of low-cost borrowing opportunities. Our empirical results remain consistent after conducting a sequence of robustness checks.

Our study adds to the current understanding of capital structure by offering novel empirical evidence demonstrating a significant positive impact of environmental investment on firm financial leverage. This study is the first to document a negative link between spending on environmental initiatives and the cost of borrowing. Our sub-sample analysis also indicates that the negative impact of environmental investment on the cost of debt is more noticeable for small firms than large firms. This difference in the sub-sample results could be due to the fact that smaller firms typically release lower carbon emissions than their larger counterparts, which in turn results in a more affordable cost of debt for the small firm sub-group. The empirical findings from this research provide noteworthy insights for executive managers on the

importance of environmental investment in shaping the financing mix. The findings of our study also provide valuable insights for lenders and fund providers. Lenders, bondholders, and other creditors should evaluate carbon-sensitive firms' environmental awareness and track record of related initiatives as part of their analysis prior to making lending decisions. Genuine environmental activism, as understood, requires systematic and credible investments in environmental initiatives. Banks and other financial institutions should place greater emphasis on firms' financial commitments to such projects. One of the effective approaches to this evaluation is to examine the firms' overall environmental investment profile. In addition, it is important to recognize that environmental investments can play a pivotal role in reducing the likelihood of greenwashing practices, which might otherwise be used to mislead investors, lenders, and other stakeholders. Overall, our study contributes to the broader global debate on how corporations can effectively and substantively prioritize environmental stewardship.

However, despite providing unique insights into the positive association between environmental investment and corporate capital structure decisions, this study has several limitations that suggest potential avenues for future investigation. To acquire deeper insights, future research can extend our study by employing a multi-country sample. In addition, our study focuses on the publicly quoted non-financial constituents of the S&P 500. Thus, future research could provide broader insights by examining whether the conclusions from our study hold for small-cap and mid-sized firms once data on environmental spending becomes available. Moreover, it will be interesting for future research to shed light on other potential factors that may influence firm financing decisions, such as climate-responsible governance mechanisms, climate change adaptation, and environmental innovation.

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Table 22: Summary Statistics

	N	Mean	Standard Deviation	Min	Max
Book Leverage	4376	.289	.179	0	.580
Market Leverage	4376	.284	.151	0	.524
Cost of Debt	4376	.075	.092	.007	.388
Environmental Investment	4376	3.887	3.48	0	13.8
Board Size	4376	9.994	3.471	0	18
Board Independence	4376	77.116	23.77	0	100
Gender Diversity	4376	19.38	10.174	0	33.33
CEO Duality	4376	.628	.483	0	1
Firm Size	4376	16.471	1.121	14.687	18.169
Liquidity	4376	1.665	.826	.68	3.29
Market-to-Book ratio	4376	3.773	2.87	.34	9.82
EBIT_TA	4376	.121	.194	-1.484	4.34
Capital Intensity	4376	6.964	6.696	1.31	22.44
Return on Assets	4376	8.107	5.2	.57	17.23

Notes: This table presents the summary statistics for the variables employed in this study. Please refer to Table A1 in the appendix for detailed definitions of these variables.

Table 23: Baseline estimation results

Variables	(1) Book Leverage	(2) Market Leverage	(3) Book Leverage	(4) Market Leverage	(5) Cost of Debt	(6) Cost of Debt
Environmental Investment	2.592*** (0.258)	2.374*** (0.300)	1.220*** (0.233)	1.178*** (0.253)	-0.037*** (0.010)	-0.052*** (0.011)
Board Size	0.227** (0.108)	0.315** (0.126)	0.043 (0.088)	0.190** (0.096)	-0.014*** (0.004)	0.004 (0.004)
Board Independence	0.028* (0.016)	0.051*** (0.018)	-0.008 (0.013)	0.005 (0.014)	-0.003*** (0.001)	-0.002*** (0.001)
Gender Diversity	-0.205*** (0.029)	-0.171*** (0.034)	-0.005 (0.023)	0.028 (0.025)	0.001 (0.001)	0.001 (0.001)
CEO Duality	0.230 (0.460)	1.307** (0.535)	-1.068** (0.447)	-1.423*** (0.485)	-0.074*** (0.017)	0.037* (0.022)
Firm Size	-2.103*** (0.383)	0.176 (0.445)	-1.315*** (0.439)	-1.589*** (0.477)	-0.139*** (0.014)	-0.143*** (0.021)
Liquidity	-3.212*** (0.294)	-3.531*** (0.341)	-0.515* (0.302)	-0.304 (0.328)	0.054*** (0.011)	-0.003 (0.015)
Market-to-Book ratio	0.326*** (0.083)	0.075 (0.097)	0.511*** (0.068)	0.427*** (0.074)	0.002 (0.003)	-0.008** (0.003)
EBIT_TA	-1.650 (1.150)	-3.393** (1.337)	-5.156*** (1.218)	-1.421 (1.323)	0.260*** (0.042)	-0.015 (0.059)
Capital Intensity	0.278*** (0.044)	0.313*** (0.051)	0.046 (0.055)	0.051 (0.060)	-0.002 (0.002)	0.003 (0.003)
Return on Assets	-0.175*** (0.051)	-0.121** (0.060)	-0.292*** (0.039)	-0.382*** (0.043)	0.002 (0.002)	0.003 (0.002)
Constant	55.332*** (6.522)	17.196** (7.579)	42.800*** (7.328)	44.253*** (7.962)	3.066*** (0.240)	3.149*** (0.354)
Industry FE	Included	Included			Included	
Firm FE			Included	Included		Included
Year FE	Included	Included	Included	Included	Included	Included
Adj R-squared	0.191	0.218	0.164	0.205	0.289	0.632
N	4,376	4,375	4,376	4,375	4,376	4376

Notes: This table presents the baseline regression estimates for environmental investment in Columns 1–6. Book leverage (Columns 1 and 3) and market leverage (Columns 2 and 4) serve as the dependent variables, representing proxies for financial leverage. For Columns 5 and 6, the cost of debt is the dependent variable. Control variables include board size, board independence, gender diversity, CEO duality, firm size, liquidity, market-to-book ratio, EBIT\_TA, capital intensity, and return on assets. Table A1 in the appendix provides definitions of these variables. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 24: Robustness check: Estimation results with alternative outcome and independent variables

Variables	(1) Total Liabilities to BVA	(2) Total Liabilities to MVA	(3) Book Leverage	(4) Market Leverage	(5) Book Leverage	(6) Market Leverage	(7) Cost of Debt	(8) Cost of Debt
Environmental Investment	0.0219*** (0.003)	0.0218*** (0.003)						
Environmental Investment Intensity			21.425*** (2.816)	21.128*** (3.265)			-0.339*** (0.103)	
Renewable Energy/Sales					2.908*** (0.705)	3.386*** (0.816)		-0.064** (0.026)
Board Size	0.004*** (0.001)	0.004*** (0.001)	0.274** (0.108)	0.355*** (0.126)	0.319*** (0.109)	0.398*** (0.126)	-0.014*** (0.004)	-0.015*** (0.004)
Board Independence	0.000 (0.000)	0.000 (0.000)	0.049*** (0.016)	0.068*** (0.018)	0.074*** (0.016)	0.093*** (0.018)	-0.003*** (0.001)	-0.004*** (0.001)
Gender Diversity	0.001 (0.000)	0.001 (0.000)	-0.182*** (0.029)	-0.152*** (0.034)	-0.173*** (0.029)	-0.145*** (0.034)	0.001 (0.001)	0.000 (0.001)
CEO Duality	-0.004 (0.006)	-0.004 (0.006)	0.242 (0.462)	1.317** (0.536)	0.196 (0.465)	1.261** (0.538)	-0.074*** (0.017)	-0.073*** (0.017)
Firm Size	0.030*** (0.005)	0.030*** (0.005)	-0.620** (0.313)	1.431*** (0.363)	0.670*** (0.251)	2.668*** (0.290)	-0.158*** (0.012)	-0.177*** (0.009)
Liquidity	-0.103*** (0.004)	-0.103*** (0.004)	-2.983*** (0.293)	-3.335*** (0.340)	-2.857*** (0.294)	-3.223*** (0.340)	0.051*** (0.011)	0.049*** (0.011)
Market-to-Book ratio	0.008*** (0.001)	0.008*** (0.001)	0.375*** (0.083)	0.116 (0.097)	0.427*** (0.083)	0.168* (0.097)	0.001 (0.003)	0.000 (0.003)
EBIT_TA	0.218*** (0.014)	0.218*** (0.014)	-1.653 (1.156)	-3.400** (1.340)	-1.834 (1.163)	-3.618*** (1.345)	0.260*** (0.042)	0.264*** (0.042)
Capital Intensity	-0.003*** (0.001)	-0.003*** (0.001)	0.297*** (0.044)	0.329*** (0.051)	0.307*** (0.044)	0.337*** (0.051)	-0.002 (0.002)	-0.002 (0.002)
Return on Assets	-0.003*** (0.001)	-0.003*** (0.001)	-0.127** (0.051)	-0.080 (0.059)	-0.077 (0.051)	-0.031 (0.059)	0.001 (0.002)	0.000 (0.002)
Constant	0.128 (0.082)	0.126 (0.081)	29.752*** (5.295)	-4.449 (6.139)	7.551* (4.192)	-25.743*** (4.851)	3.391*** (0.194)	3.722*** (0.153)
Industry FE	Included	Included	Included	Included	Included	Included	Included	Included
Year FE	Included	Included	Included	Included	Included	Included	Included	Included
Adj R-squared	0.415	0.416	0.183	0.214	0.175	0.210	0.288	0.287
N	4,376	4,376	4,376	4,375	4,376	4,375	4,376	4,376

Notes: This table presents the results of robustness checks. Columns 1 and 2 report the regression estimates of environmental investment on alternative outcome variables, namely total liabilities to book value of assets (TL to BVA) and total liabilities to market value of assets (TL to MVA), respectively. Columns 3, 4, and 7 display the regression results of environmental investment intensity—an alternative independent variable—on book leverage, market leverage, and cost of debt, respectively. Similarly, Columns 5, 6, and 8 report the regression coefficients of renewable energy intensity (renewable energy scaled by net sales) on book leverage, market leverage, and cost of debt, respectively. The same set of control variables as in the baseline models is employed. Table A1 in the appendix provides definitions of these variables. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 25: Impact on financial leverage and the cost of debt: Sub-sample analysis I

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	High Env Inv. Book Leverage	Low Env Inv. Book Lev	High Env Inv. Market Leverage	Low Env Inv. Market Lev	High Env Inv. Cost of Debt	Low Env Inv. Cost of Debt
Environmental Investment	3.275*** (0.367)	2.691*** (0.540)	2.356*** (0.427)	2.314*** (0.602)	-0.031*** (0.012)	-0.067*** (0.021)
Board Size	0.062 (0.127)	0.320* (0.170)	0.165 (0.148)	0.497*** (0.190)	0.005 (0.004)	-0.028*** (0.007)
Board Independence	-0.003 (0.023)	0.028 (0.023)	0.024 (0.027)	0.034 (0.026)	-0.006*** (0.001)	-0.001 (0.001)
Gender Diversity	-0.251*** (0.035)	-0.152*** (0.045)	-0.210*** (0.041)	-0.133*** (0.050)	-0.001 (0.001)	0.003* (0.002)
CEO Duality	0.133 (0.528)	0.355 (0.736)	0.255 (0.614)	1.835** (0.821)	-0.069*** (0.017)	-0.080*** (0.029)
Firm Size	-4.369*** (0.540)	-0.918 (0.581)	-1.863*** (0.628)	0.841 (0.649)	-0.091*** (0.018)	-0.177*** (0.023)
Liquidity	-1.881*** (0.390)	-4.025*** (0.433)	-1.934*** (0.453)	-4.676*** (0.483)	-0.001 (0.013)	0.092*** (0.017)
Market-to-Book ratio	1.178*** (0.111)	-0.230* (0.120)	0.841*** (0.130)	-0.421*** (0.134)	-0.003 (0.004)	0.002 (0.005)
EBIT_TA	-3.744* (2.138)	-1.680 (1.475)	7.045*** (2.487)	-5.748*** (1.646)	0.494*** (0.070)	0.210*** (0.058)
Capital Intensity	0.289*** (0.048)	0.324*** (0.076)	0.209*** (0.055)	0.456*** (0.085)	-0.005*** (0.002)	0.001 (0.003)
Return on Assets	-0.318*** (0.074)	-0.056 (0.073)	-0.500*** (0.086)	0.068 (0.082)	-0.002 (0.002)	0.002 (0.003)
Constant	92.633*** (10.115)	37.075*** (9.691)	63.851*** (11.765)	6.588 (10.816)	2.278*** (0.329)	3.661*** (0.379)
Industry FE	Included	Included	Included	Included	Included	Included
Year FE	Included	Included	Included	Included	Included	Included
Adjusted R-squared	0.285	0.143	0.209	0.194	0.246	0.255
N	2,189	2,187	2,189	2,187	2,189	2,187

Notes: This table presents the results of the sub-sample analysis I. The full sample is divided into two subgroups based on high and low levels of environmental investment. Columns 1, 3, and 5 report the regression coefficients for high environmental investment on book leverage, market leverage, and cost of debt, respectively. Columns 2, 4, and 6 present the regression results for low environmental investment on book leverage, market leverage, and cost of debt, respectively. The same set of control variables as in the baseline models is employed. Table A1 in the appendix provides definitions of these variables. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 26: Impact on financial leverage and the cost of debt: Sub-sample analysis II

	(1)	(2)	(3)	(4)	(5)	(6)
	Small	Large	Small	Large	Small	Large
	Firms	Firms	Firms	Firms	Firms	Firms
Variables	Book	Book	Market	Market	Cost of Debt	Cost of Debt
	Leverage	Leverage	Leverage	Leverage		
Environmental Investment	3.831*** (0.407)	2.525*** (0.364)	4.089*** (0.425)	3.042*** (0.435)	-0.105*** (0.016)	-0.002 (0.010)
Board Size	0.016 (0.187)	0.511*** (0.127)	0.158 (0.195)	0.457*** (0.151)	-0.013* (0.007)	-0.006* (0.004)
Board Independence	0.029 (0.024)	-0.000 (0.023)	0.043* (0.025)	-0.071*** (0.027)	-0.001 (0.001)	-0.003*** (0.001)
Gender Diversity	-0.102** (0.044)	-0.321*** (0.037)	-0.089* (0.046)	-0.243*** (0.044)	0.000 (0.002)	0.004*** (0.001)
CEO Duality	0.133 (0.721)	-0.320 (0.567)	1.121 (0.752)	-0.564 (0.677)	-0.092*** (0.028)	-0.077*** (0.016)
Firm Size	-3.025*** (0.706)	-3.617*** (0.590)	-1.514** (0.736)	-0.051 (0.705)	-0.339*** (0.031)	-0.051*** (0.018)
Liquidity	-4.430*** (0.422)	-1.036** (0.403)	-4.744*** (0.440)	-2.086*** (0.482)	0.113*** (0.017)	-0.013 (0.012)
Market-to-Book ratio	-0.119 (0.123)	0.881*** (0.111)	-0.247* (0.128)	0.511*** (0.133)	-0.007 (0.005)	0.005 (0.003)
EBIT_TA	2.662 (3.271)	-9.126*** (1.941)	8.744** (3.412)	5.606** (2.319)	0.284*** (0.056)	0.092 (0.072)
Capital Intensity	0.228*** (0.079)	0.297*** (0.049)	0.172** (0.082)	0.287*** (0.058)	-0.002 (0.003)	-0.003* (0.001)
Return on Assets	-0.150* (0.082)	-0.180** (0.074)	-0.214** (0.086)	-0.455*** (0.089)	0.002 (0.003)	0.003 (0.002)
Constant	68.324*** (11.230)	80.309*** (10.569)	39.370*** (11.715)	32.837*** (12.631)	6.055*** (0.487)	1.408*** (0.331)
Industry FE	Included	Included	Included	Included	Included	Included
Year FE	Included	Included	Included	Included	Included	Included
Adjusted R-squared	0.160	0.289	0.212	0.233	0.292	0.077
N	2,188	2,188	2,188	2,188	2,188	2,188

Notes: This table presents the results of the sub-sample analysis II. The full sample is divided into two subgroups based on firm size: small and large firms. Columns 1, 3, and 5 report the regression coefficients for small firms on book leverage, market leverage, and cost of debt, respectively. Columns 2, 4, and 6 present the regression results for large firms on book leverage, market leverage, and cost of debt, respectively. The same set of control variables as in the baseline models is applied. Table A1 in the appendix provides definitions of these variables. Standard errors are reported in parentheses. \*\*\*, \*\*, and \* indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 27 Panel A: Propensity Score Matching results

	(1)	(2)	(3)	(4)
	Pre-Match	Post-Match	Post-Match	Post-Match
Variables	Industry Above_Avg Dummy	Book Leverage	Market Leverage	Cost of Debt
Environmental Investment		2.452*** (0.564)	1.876*** (0.603)	-0.032* (0.017)
Board Size	0.022* (0.012)	0.004 (0.153)	0.394** (0.163)	-0.005 (0.004)
Board Independence	0.016*** (0.002)	-0.038 (0.028)	-0.001 (0.030)	0.001* (0.001)
Gender Diversity	0.004 (0.003)	0.071* (0.043)	0.102** (0.046)	-0.002 (0.001)
CEO Duality	0.159*** (0.052)	-2.125** (0.965)	-3.314*** (1.031)	0.006 (0.028)
Firm Size	0.681*** (0.030)	-3.618*** (1.005)	-2.699** (1.075)	-0.013 (0.029)
Liquidity	-0.071** (0.033)	-0.786 (0.580)	0.163 (0.620)	-0.005 (0.017)
Market-to-Book ratio	0.020** (0.010)	0.570*** (0.132)	0.602*** (0.142)	-0.005 (0.004)
EBIT_TA	-0.636** (0.249)	-10.081*** (2.581)	-6.552** (2.759)	0.053 (0.076)
Capital Intensity	0.057*** (0.004)	-0.097 (0.097)	-0.144 (0.103)	0.003 (0.003)
Return on Assets	0.016** (0.007)	-0.284*** (0.076)	-0.323*** (0.081)	0.002 (0.002)
Constant	-13.306*** (0.524)	75.970*** (16.012)	57.503*** (17.115)	0.566 (0.470)
Likelihood ratio (chi2)	1963.91*** [0.0000]	15.04*** [0.000]	15.46*** [0.000]	2.18*** [0.001]
Pseudo R-squared	0.350	-	-	
Adjusted R-squared	-	0.321	0.327	0.064
N	4,376	861	861	861

Notes: This table presents the results of the propensity score matching analysis. Column 1 displays the pre-match estimates derived from the full sample. Columns 2 and 3 show the post-match regression results from paired firm-year observations. In column 1, the outcome variable is a dummy for industry above-average environmental investment. In columns 2, 3, and 4, the outcome variables are book leverage, market leverage, and the cost of debt, respectively. The same set of control variables as in the baseline models is used across all regressions. Definitions of these variables can be found in Table A1 of the appendix. Standard errors are reported in parentheses. Statistical significance is denoted by \*\*\*, \*\*, and \* for significance at the 1%, 5%, and 10% levels, respectively.

Table 27 Panel B: Quality of propensity score matching (PSM)- t-tests on firm characteristics (e.g., control variables) between the treatment and control groups

Variable	Mean		Mean Difference	t-statistic	p> t
	Treated	Control			
Board Size	11.057	11.11	-0.053	-0.49	0.621
Board Independence	83.503	83.202	0.301	0.49	0.626
Gender Diversity	21.583	21.616	-0.033	-0.08	0.938
CEO Duality	0.6864	0.6713	0.0151	0.67	0.503
Firm Size	16.938	16.953	-0.015	-0.36	0.72
Liquidity	1.5559	1.5473	0.0086	0.23	0.815
Market-to-Book ratio	3.7341	3.7033	0.0308	0.23	0.819
EBIT_TA	0.1102	0.1114	-0.0013	-0.21	0.836
Capital Intensity	7.1639	7.6145	-0.4506	-1.39	0.164
Return on Assets	7.7565	7.6404	0.1161	0.49	0.624

This table presents the t-test statistics and corresponding p-values for firm attributes (i.e., all control variables) comparing the treatment and control groups to assess the quality of propensity score matching (PSM).

Table 28: IV estimation results using the sustainability committee as an instrument

	(1)	(2)	(3)	(4)
	1st Stage	2nd Stage	2nd Stage	2nd Stage
Variables	Environmental Investment	Book Leverage	Market Leverage	Cost of Debt
Sustainability Committee	1.089*** (0.0273)			
Environmental Inv (Fitted)		1.222** (0.498)	1.592*** (0.577)	-0.097*** (0.018)
Board Size	0.0164*** (0.00544)	0.279** (0.109)	0.345*** (0.127)	-0.011*** (0.004)
Board Independence	0.0147*** (0.000772)	0.0505*** (0.0173)	0.0633*** (0.0201)	-0.002*** (0.001)
Gender Diversity	0.00610*** (0.00147)	-0.183*** (0.0298)	-0.159*** (0.0346)	0.002 (0.001)
CEO Duality	0.0103 (0.0231)	0.245 (0.460)	1.315** (0.533)	-0.073*** (0.017)
Firm Size	0.993*** (0.0129)	-0.536 (0.620)	1.071 (0.719)	-0.071*** (0.023)
Liquidity	0.161*** (0.0146)	-2.986*** (0.302)	-3.402*** (0.350)	0.064*** (0.011)
Market-to-Book ratio	0.0348*** (0.00416)	0.378*** (0.0847)	0.104 (0.0982)	0.004 (0.003)
EBIT_TA	-0.0831 (0.0579)	-1.629 (1.150)	-3.382** (1.333)	0.261*** (0.043)
Capital Intensity	0.0102*** (0.00218)	0.298*** (0.0439)	0.324*** (0.0509)	-0.001 (0.002)
Return on Assets	0.0339*** (0.00253)	-0.124** (0.0536)	-0.0923 (0.0622)	0.004** (0.002)
Constant	-17.13*** (0.215)	28.31*** (10.64)	1.767 (12.33)	1.887*** (0.393)
Industry FE	Included	Included	Included	Included
Year FE	Included	Included	Included	Included
<i>Model fits</i>				
F Statistic		33.10*** [0.000]	41.06*** [0.000]	62.05*** [0.000]
Weak identification test:	1594.034***	-	-	-
Cragg-Donald Wald F statistic	[0.000]			
Stock-Yogo weak ID test critical values:	16.38	-	-	-
10% maximal IV size				
N	4,376	4,376	4,375	4,376

Notes: This table reports the results from the instrumental variable (IV) approach. Column 1 presents the first-stage IV analysis results, where the presence of the sustainability committee is used as an exogenous variable to regress environmental investment. In the second stage, the fitted values of environmental investment are employed to explain book leverage, market leverage, and the cost of debt in columns 2, 3, and 4, respectively. The same set of control variables as in the baseline models is used across all regressions. Definitions of all the variables are provided in Table A1 of the appendix. Standard errors are reported in parentheses. \*, \*\*, and \*\*\* indicate the significance at the 10%, 5%, and 1% levels, respectively.

Table 29: IV estimation results using CSR strategy as an instrument

Variables	(1) 1st Stage Environmental Investment	(2) 2nd Stage Book Leverage	(3) 2nd Stage Market Leverage	(4) 2nd Stage Cost of Debt
CSR Strategy	0.018*** (0.000)			
Environmental Investment (Fitted values)		0.759* (0.443)	1.549*** (0.512)	-0.089*** (0.016)
Board Size	0.018*** (0.005)	0.297*** (0.109)	0.345*** (0.126)	-0.012*** (0.004)
Board Independence	0.015*** (0.001)	0.058*** (0.017)	0.064*** (0.020)	-0.002*** (0.001)
Gender Diversity	0.004*** (0.001)	-0.175*** (0.030)	-0.159*** (0.034)	0.002 (0.001)
CEO Duality	-0.030 (0.022)	0.250 (0.461)	1.307** (0.533)	-0.073*** (0.017)
Firm Size	0.917*** (0.013)	-0.006 (0.562)	1.120* (0.650)	-0.079*** (0.021)
Liquidity	0.169*** (0.014)	-2.910*** (0.300)	-3.389*** (0.347)	0.063*** (0.011)
Market-to-Book ratio	0.033*** (0.004)	0.395*** (0.085)	0.107 (0.098)	0.004 (0.003)
EBIT_TA	0.108** (0.055)	-1.622 (1.153)	-3.370** (1.334)	0.261*** (0.042)
Capital Intensity	0.008*** (0.002)	0.304*** (0.044)	0.325*** (0.051)	-0.001 (0.002)
Return on Assets	0.030*** (0.002)	-0.107** (0.053)	-0.090 (0.061)	0.004* (0.002)
Constant	-15.810*** (0.211)	19.175** (9.638)	0.847 (11.149)	2.036*** (0.354)
Industry FE	Included	Included	Included	Included
Year FE	Included	Included	Included	Included
<i>Model fits</i>				
F Statistic		32.83*** [0.000]	41.11*** [0.000]	62.26*** [0.000]
Weak identification test:	2257.048***	-	-	-
Cragg-Donald Wald F statistic	[0.000]			
Stock-Yogo weak ID test critical values:	16.38	-	-	-
10% maximal IV size				
N	4,376	4,376	4,376	4,376

Notes: This table reports the results from the instrumental variable (IV) approach. Column 1 presents the first-stage IV analysis results, where the CSR strategy score is employed as an exogenous variable to regress environmental investment. In the second stage, the fitted values of environmental investment are utilized to explain book leverage, market leverage, and the cost of debt in columns 2, 3, and 4, respectively. The same set of control variables as in the baseline models is used across all regressions. Definitions of all the variables are provided in Table A1 of the appendix. Standard errors are reported in parentheses. \*, \*\*, and \*\*\* indicate the significance at the 10%, 5%, and 1% levels, respectively.

Table 30: Heckman selection model results

	(1)	(2)	(3)	(4)
	1st Stage - Probit	2nd Stage -	2nd Stage -	2nd Stage -
		OLS	OLS	OLS
Variables	Above_Avg Dummy	Book Leverage	Market Leverage	Cost of Debt
Industry Average Env. Investment	0.318*** (0.045)			
Environmental Investment		3.313*** (0.267)	3.130*** (0.311)	-0.076*** (0.010)
Board Size	-0.005** (0.002)	0.151 (0.107)	0.236* (0.125)	-0.010** (0.004)
Board Independence	0.003*** (0.000)	0.017 (0.016)	0.039** (0.018)	-0.003*** (0.001)
Gender Diversity	0.001** (0.001)	-0.215*** (0.029)	-0.182*** (0.034)	0.001 (0.001)
CEO Duality	0.020** (0.010)	0.184 (0.455)	1.257** (0.530)	-0.071*** (0.017)
Firm Size	0.174*** (0.005)	-5.043*** (0.489)	-2.880*** (0.569)	0.021 (0.018)
Liquidity	0.004 (0.006)	-3.442*** (0.292)	-3.763*** (0.340)	0.066*** (0.011)
Market-to-Book ratio	0.010*** (0.002)	0.285*** (0.082)	0.032 (0.096)	0.004 (0.003)
EBIT_TA	0.006 (0.025)	-2.152* (1.140)	-3.918*** (1.328)	0.291*** (0.042)
Capital Intensity	0.008*** (0.001)	0.271*** (0.043)	0.305*** (0.050)	-0.001 (0.002)
Return on Assets	0.004*** (0.001)	-0.176*** (0.051)	-0.123** (0.059)	0.002 (0.002)
Inverse Mills Ratio (IMR)	-	-38.980*** (4.076)	-40.378*** (4.748)	2.119*** (0.148)
Constant	-2.719*** (0.086)	109.011*** (8.599)	72.935*** (10.017)	0.111 (0.313)
Industry FE	Included	Included	Included	Included
Year FE	Included	Included	Included	Included
Wald chi2	0.0000***	-	-	-
Adj R-squared		0.207	0.230	0.320
N	4,376	4,373	4,373	4,376

Notes: This table presents the results of the two-stage Heckman selection models. Column 1 reports the first-stage probit model, which uses industry above-average environmental investment values as the exclusion restriction to determine the probability of being above the industry average in environmental investment. To address sample selection bias, the inverse Mills ratio is derived from the estimated coefficients in the first stage. In the second stage, the inverse Mills ratio is incorporated as an additional control variable to explain book leverage, market leverage, and the cost of debt, as shown in columns 2, 3, and 4, respectively. All other control variables are consistent with those used in the baseline models across all regressions. Definitions of all the variables are provided in Table A1 of the appendix. Standard errors are reported in parentheses. \*, \*\*, and \*\*\* indicate the significance at the 10%, 5%, and 1% levels, respectively.

## Appendix

Table A1: Variable definitions

Variable name	Definition
Book Leverage	The total debt (the sum of the short-term and long-term debts) scaled by the book value of the assets
Market Leverage	Total debt (which also includes both short-term and long-term debt) divided by the market value of assets
Cost of Debt	The ratio of interest expenses to the total value of interest-bearing debt
Environmental Investment	The natural logarithm of the firm-level yearly environmental expenditures
Board Size	The number of directors serving on the board
Board Independence	The proportion of independent directors relative to the total board size
Gender Diversity	The percentage of female directors on the board
CEO Duality	A dummy variable that is set to one if the CEO of the firm also acts as the chair of the board and zero otherwise
Firm Size	The natural logarithm of total assets of the firm
Liquidity	The ratio of current assets to current liabilities
Market-to-Book ratio	The ratio of market price to book value of equity
EBIT_TA	The earnings before interest and taxes scaled by the book value of assets
Capital Intensity	Firm's capital expenditures scaled by total sales
Return on Assets	Net profit divided by total assets

Table A2: Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) Book Leverage	1.000													
(2) Market Leverage	0.862*	1.000												
(3) Cost of Debt	-0.493*	-0.609*	1.000											
(4) Environmental Investment	0.195*	0.220*	-0.304*	1.000										
(5) Board Size	0.230*	0.298*	-0.397*	0.326*	1.000									
(6) Board Independence	0.186*	0.242*	-0.339*	0.308*	0.773*	1.000								
(7) Gender Diversity	0.137*	0.198*	-0.273*	0.146*	0.520*	0.571*	1.000							
(8) CEO Duality	0.084*	0.129*	-0.189*	0.141*	0.308*	0.303*	0.219*	1.000						
(9) Firm Size	0.214*	0.339*	-0.471*	0.496*	0.482*	0.310*	0.348*	0.157*	1.000					
(10) Liquidity	-0.236*	-0.252*	0.199*	-0.195*	-0.088*	0.001	-0.115*	0.011	-0.329*	1.000				
(11) Market-to-Book ratio	0.058*	0.011	0.027	-0.184*	0.114*	0.154*	0.187*	0.110*	-0.144*	0.088*	1.000			
(12) EBIT_TA	-0.043*	-0.056*	0.095*	-0.100*	0.030	0.063*	0.038	-0.004	-0.039*	0.085*	0.106*	1.000		
(13) Capital Intensity	0.181*	0.198*	-0.167*	0.482*	0.110*	0.079*	0.018	0.050*	0.291*	-0.211*	-0.202*	-0.146*	1.000	
(14) Return on Assets	-0.090*	-0.106*	0.117*	-0.220*	0.020	0.091*	0.067*	0.115*	-0.244*	0.329*	0.383*	0.347*	-0.279*	1.000

Note: \* Indicates the statistical significance for the correlation estimates at the 1% level.

Table A3: Additional baseline estimates.

	(1)	(2)	(4)	(5)
	Book Leverage	Book Leverage	Market Leverage	Market Leverage
Variables	with Governance variables	with firm financial variables	with Governance variables	with firm financial variables
Environmental Investment	1.754*** (0.166)	2.580*** (0.219)	2.803*** (0.192)	2.927*** (0.254)
Board Size	0.199* (0.109)		0.413*** (0.126)	
Board Independence	0.031** (0.015)		0.015 (0.018)	
Gender Diversity	-0.174*** (0.030)		-0.149*** (0.034)	
CEO Duality	-0.037 (0.466)		0.882 (0.541)	
Firm Size		-2.038*** (0.367)		-0.031 (0.427)
Liquidity		-2.998*** (0.294)		-3.312*** (0.341)
Market-to-Book ratio		0.314*** (0.083)		0.104 (0.097)
EBIT_TA		-1.482 (1.154)		-3.279** (1.341)
Capital Intensity		0.295*** (0.044)		0.323*** (0.051)
Return on Assets		-0.179*** (0.051)		-0.119** (0.060)
Constant	17.399*** (1.225)	55.046*** (6.164)	15.542*** (1.421)	23.587*** (7.167)
Industry FE	Included	Included	Included	Included
Year FE	Included	Included	Included	Included
Adj R-squared	0.150	0.181	0.181	0.209
N	4,376	4,376	4,376	4,376

Notes: This table presents additional baseline estimates. In all four columns, the estimated coefficients of environmental investment are reported. In columns 1 (with governance controls only) and 2 (with firm financial controls only), book leverage is the dependent variable. Similarly, columns 3 (with governance controls only) and 4 (with firm financial controls only) use market leverage as the dependent variable. Definitions of the variables are provided in Table A1 of the appendix. Standard errors are reported in parentheses. \*, \*\*, and \*\*\* indicate the significance at the 10%, 5%, and 1% levels, respectively.

## Chapter 6

# Conclusions

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## Summary of the Findings

The purpose of this research is to examine the ways in which non-financial firms can actively participate in environmental and climate change initiatives. The essays within this thesis concentrate on identifying the key drivers—specifically, climate risk governance and green transformation initiatives that influence firm-level environmental performance, such as carbon performance and eco-innovation. By investigating these determinants, the research seeks to enhance the understanding of climate change issues and encourage non-financial firms, specifically those sensitive to carbon emissions, to engage in meaningful environmental activism. Additionally, this research looks into the effect of environmental investments on corporate financial choices, such as the use of financial leverage and the associated cost of debt.

In the first essay, we build on a multi-theoretical model using the projections of agency theory, resource-based view, and institutional theory, where empirical analysis is performed using a panel of 2050 firm-year observations from non-financial UK-listed firms between 2011 and 2020. We provide empirical evidence that climate risk governance (CRG) enhances carbon performance by reducing actual carbon emissions. This finding is compatible with Bui et al. (2020) in that they demonstrate how climate governance influences carbon-related disclosure. In addition, green transformation initiatives (GTI) are negatively related to carbon emissions, confirming that firms that implement a higher level of transformation initiatives can lower actual carbon emissions, thereby improving carbon performance. This empirical result aligns with previous studies (such as Moussa et al., 2019; Shaukat et al., 2016) that report how a carbon-oriented strategy reduces actual GHG emissions, and a CSR strategy drives social and environmental performance. This study also reveals that the combined effect of CRG and GTI (CRG\*GTI) reinforces carbon mitigation performance. This finding implies that the combined effort of CRG and GTI enables firms to advance the quality of their firm-level comprehensive transformation, which eventually helps maintain sustained carbon mitigation performance. This result aligns with Moussa et al. (2019) in that they show how carbon strategy mediates the negative link between board environmental orientation and actual GHG emissions. Similarly, the empirical outcome of the combined effect of CRG and GTI provides empirical validation for the conclusions drawn from related research (for example, de Villiers et al., 2011; Dixon-Fowler et al., 2017; Shaukat et al., 2016).

Earlier studies related to climate-focused governance shed light on whether those governance mechanisms explain carbon disclosure and climate change commitments. However, the relevant literature has not yet included eco-innovation in the discussion, which is without question a crucial prerequisite for sustainable business practices, climate change mitigation, and effective carbon control. To fill this vacuum in the current body of knowledge, the second essay looks into the affiliation between climate risk governance and eco-innovation using a sample of 4,378 firm-year observations obtained from non-financial firms that are components of the S&P 500 capital market index over the period between 2011 and 2021. We draw on resource-based view and agency theory to justify the intricate relationship between the variables of interest. The empirical results reveal a significant positive association between climate risk governance and eco-innovation. Firms with sound climate risk governance mechanisms tend to be more environmentally cognizant and committed, and as a result, their target-oriented and resilient climate-focused actions within the boardroom drive the potential for environmentally sustainable innovation. The findings are in line with prior research indicating that effective climate risk governance is related to firm-level commitments to implementing climate change initiatives (Albitar et al., 2023) as well as increased carbon disclosure (Bui et al., 2020). Following the empirical evidence showing the substantial impact of climate risk governance on eco-innovation, a pertinent follow-up question arises regarding the channel through which climate risk governance might affect eco-innovation. To answer this, this study reveals that a well-implemented climate risk governance framework increases firm-level investment in environmental initiatives. This increased investment, in turn, supports the advancement of environmentally sustainable innovations. Further analysis indicates that this positive association is more pronounced in large firms that focus strongly on climate risk governance measures compared to their smaller counterparts. This study also delves into the individual climate risk governance components as part of the further analysis. In an attempt to attain more insights, each CRG component is examined separately to assess its impact on firm-level environmentally sustainable innovation. Accordingly, the empirical results indicate that awareness of climate risk opportunities and risks, the existence of a board-level environmental committee, sustainability reporting, and external assurance are positively related to eco-innovation.

Prior literature primarily analyzes the effect of environmental or sustainable performance on firm financial performance, often ignoring the importance of a key factor to substantive environmental activism and risk management, such as spending on environmental initiatives. Therefore, we shed light on firm-level spending on environmental initiatives, the keystone to environmental safety and risk management, and investigate its impact on firm financial leverage as well as the cost of debt capital. The third essay, utilizing a panel of 4376 firm-year observations collected from non-financial S&P-500 firms from 2011 to 2021, provides evidence that US firms' spending on environmental activities is positively associated with firm financial leverage. This study employs both book leverage and market leverage as proxies for financial leverage. The results suggest that environmental investment enables firms to pursue environmental projects that give them a competitive advantage (Pekovic et al., 2018), making them perceived as more responsible and compliant by lenders and fund providers. As a result, firms that commit to environmental investment benefit from a wider range of debt options and are likely to increase their reliance on debt financing. Moreover, related literature documents the impact of carbon emissions (Li et al., 2014), carbon risk (Jung et al., 2018), and firm-level ESG practices (Eliwa et al., 2021) on the cost of debt. However, no single prior study has yet evaluated the potential effect of environmental investment on the cost of borrowing. This research fills the void in the existent literature by examining the effect of environmental investment on the cost of debt capital, thereby showing that firm-level environmental investment is negatively linked to the cost of debt capital. However, the negative association is more noticeable for small firms relative to their larger counterparts. As already explained, environmental investment is vital to reducing environmental risk and enhancing environmental performance, which results in a reduction in exposure to environmental risks, such as physical, reputational, and litigation risks. As a result, lower environmental risk and higher environmental performance create a better impression and help firms secure a lower cost of debt (Kim et al., 2015; Sharfman and Fernando, 2008).

## Policy Implications

All three essays in this thesis provide several significant pragmatic and policy implications. The first essay presents two distinct drivers of substantive carbon performance: CRG and GTI. To begin with, executive management must be acutely aware of the harmful effects associated with excessive carbon emissions, because persistent emissions are likely to result in a decrease in market value (Orazalin et al., 2023). Besides, our empirical evidence delivers a strong insight for board members, top-level management, and other concerned major shareholders to implement verifiable and target-based initiatives for green transformation while keeping long-run carbon commitments in mind. A climate-focused governance structure reduces the propensity for greenwashing because it focuses more closely on environmental accountability, systematic compliance, and transparency in climate change initiatives (Bui et al., 2020). Hence, it is vital for corporate boards to appropriately use climate risk governance mechanisms to oversee any potential greenwashing attempts by management.

In addition, the conclusions drawn from this research provide environmentalists, social workers, and policymakers with a novel perspective on fostering institution-wide transformation aimed at achieving substantive carbon reduction. The findings of this study underscore the need for tax authorities to implement adequate tax incentives to encourage carbon-sensitive firms to improve the quality and effectiveness of such transformation. Further, regulators, standard setters, and policymakers recognizing the broader implications of this study may consider revising policy directives to reinforce climate-focused governance activism. They could also develop comprehensive guidelines to support firm-level green transformation initiatives, ensuring a more structured and impactful approach to sustainability.

The empirical findings from the second essay, from a policy point of view, emphasize the importance of the climate risk governance framework and offer it as a robust determinant of firm-level eco-innovation. This study provides noteworthy insights to corporate board members, Chief Executive Officers, and other senior executive managers about the likely review and reorganization of the conventional governance structure, with an explicit focus on climate change issues, compliance with the regulatory framework, and implementing environmentally sustainable business actions.

Moreover, this study makes a valuable contribution to the ongoing global discussion regarding corporate climate-focused governance and its impact on managing real-world climate change issues. Considering the empirical evidence, regulatory bodies and policymakers may implement a comprehensive climate policy to mandate firms—particularly those operating in high-carbon-risk industries—to strengthen their commitment to genuine climate governance initiatives. Further, the insights from this research are expected to persuade relevant government authorities to provide targeted support and incentives for carbon-conscious firms that prioritize environmental innovation, thereby fostering long-term sustainability and advancing decarbonization efforts.

The empirical results from the third and final essay provide unique insights for top-level management regarding the importance of environmental investment as part of substantive environmental activism. Moreover, both executive and independent directors can obtain a more nuanced understanding when it comes to deciding on the capital structure. We also give a clear direction to lenders and fund providers, who prioritize environmental safety and sustainability, to aid their investment decisions. To this end, based on the empirical findings, banks and other financial institutions could prioritize carbon-sensitive firms' financial commitments to environmental projects as one of the criteria in their lending and investment decisions. Further, lenders, creditors, and other concerned stakeholders need to understand the critical role of environmental investment, as it can significantly reduce the scope of greenwashing practices regarding a firm's substantive sustainability efforts.

Currently, no specific regulatory requirements direct the extent or frequency of environment-related expenditures. Therefore, regulators and policymakers could benefit from the empirical evidence presented in this research. They may need to carefully consider the necessity of actual spending on environmental initiatives as a critical component of environmental policy or climate change legislation. For carbon-sensitive firms, such expenditures could enhance substantive engagement in environmental protection and contribute to the long-term sustainability of business operations.

## Limitations of this Research

While the three essays in the thesis offer significant policy implications, readers are advised to be aware of several limitations. Future research initiatives may aim to address these limitations. In the first essay, one of the limitations is the lack of sufficient firm-level data regarding the green transformation initiatives (GTI) variable. To develop green transformation initiatives, this study first goes through sustainability reports to hand-collect the actual data. We also look into the sustainability reporting section embedded in the annual reports, particularly in cases where separate sustainability reports are not directly available. However, we have observed that many publicly quoted firms fail to prepare and publish sustainability reports and other related information as required. Because of this missing data problem, we have excluded those non-financial listed firms in order to arrive at the final sample. In addition, it is challenging and time-consuming to manually collect firm-level data for a large number of firms. Therefore, this study does not concentrate on a multi-country sample encompassing other highly industrialized and polluting countries, such as the G7 nations. Further, due to data limitations, our analysis in the first and second essays relies on the maintenance of a board-level environmental committee as one of the components of climate risk governance (CRG) rather than looking at the specific attributes of the committee members, such as age, cultural and gender diversity, education, experience, and religion.

The second essay does not account for the impact of climate-related legislation or environmental regulation as a moderating factor to influence the nexus between climate risk governance and eco-innovation. Moreover, in this study, we have not looked into the potential influence of climate risk governance on shareholder value and firm financial outcomes, which could be an avenue for future research. In this essay, we have broadly investigated climate risk governance mechanisms and also shed light on the components underlying the governance index separately. However, we have not looked into the actual climate-related risk or empirically tested the effect it might have on both firm financial metrics and sustainability performance.

The second and third essays in this thesis are based on the publicly traded, non-financial firms within the S&P 500 that are responsible for scope one and scope two carbon emissions. Hence, the empirical findings are unlikely to be generalizable to small-cap, mid-sized, and privately held companies. In the third essay, we present evidence based on US non-financial firms that are subject to direct and indirect CO<sub>2</sub> footprints. However, we are not able to perform a cross-

country analysis with different institutional settings due to the unavailability of data, particularly in terms of firm-level environmental investment. Finally, while the third essay essentially investigates whether environmental investment drives capital structure decisions and the cost of debt, it has not analyzed the effect of environmental investment on the speed of leverage adjustment, which may be a probable direction for upcoming research.

### Scope of Future Research

Prospective research can address the limitations of the research outlined above. In the first essay, we rely on the UK-listed firms and gather hand-collected data on one of the variables of interest. However, owing to the dearth of necessary data for many publicly quoted firms, our sample size is restricted to 276 compliant non-financial UK firms. Hence, further investigation can revolve around European countries and the USA to validate whether the takeaways of this study remain compatible with a larger sample from a multi-country perspective and also achieve more insights.

In the second essay, we examine how climate risk governance affects firm-level environmental innovation within the US context. Future research might explore additional determinants of eco-innovation, such as CEO demographic characteristics, board member qualifications, and board cultural diversity. Moreover, future studies could investigate the impact of artificial intelligence and robotics on eco-innovation capacity and environmental sustainability once the necessary data becomes available. Finally, our empirical findings may not apply to small-cap or unlisted firms. As a result, further research could yield valuable insights by exploring whether the conclusions drawn from the second essay are relevant to these types of firms. Further studies can also extend this stream of research by employing a global-level sample, including G6 and Asian countries.

Finally, in the third essay, we evaluate the intricate association between environmental investment, firm financial leverage, as well as the cost of debt. However, it will be intriguing if future research sheds light on other probable factors that may influence firm financing decisions, such as the impact of the circular economy, pollution prevention measures, and restoration of both biodiversity and ecosystems. Future studies might also look into the potential association between environmental investment and the cost of equity capital to offer additional insights and extend the findings of our study. To advance this area of research, it

would be beneficial to conduct additional studies comparing emerging and developed nations. This could be accomplished through a cross-sectional dependence analysis.

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