Decoding Climate Risk: Corporate Resilience under Triad of risks in India

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Abstract

This study examines the impact of climate risks on firm performance, focusing on the moderation analysis by firm size, supply chain strength, financial leverage and firm age, as well as heterogeneity between high carbon-intensive firms and low carbon-intensive firms. The result is robust to difference -in-difference analysis (DID), dynamic GMM, instrumental variable approach and Heckman two-stage model. It supports that different dimension of climate risks and carbon exposure erode firm performance, support supply chain resilience theory and financial fragility channel. Robustness checks using Tobin's Q, INFORM risk index, and project level data confirm these findings. It integrates El Nino Southern Oscillation (ENSO) and internal carbon price (ICP) to highlight different aspects of climate risks It shows that while carbon-intensive firms are more penalized, proactive low-carbon firms can convert environmental capital into a competitive advantage under climate uncertainty scenario.

***Keywords*:** Climate risk, Physical risk, Transition risk, CRI, Carbon emission, ENSO, ICP

JEL Classification: *C36, C33, G30, Q54*

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1. Introduction

Climate risk has emerged as a multidimensional threat that directly and indirectly influences firm performance, productivity, and valuation (Alessi et al., 2021; Aharon et al., 2024). Climate risk is associated with rising emission of greenhouse gas, shocks in the temperature and precipitation levels as well as volatile environmental performance of firms (Krueger et al., 2020). With new developments in technology and increasing economic expansion firms put more emphasis on shareholder wealth maximization, underscores the importance of carbon risk management into operational performance of firms (Golgeci et al., 2019; Krueger et al., 2020; Bolton and Kacperczyk, 2023). The non-conventional shocks not only affect the cost of capital, cash flows but also the firm performance at large as well as increases the expenditures for the projects undertaken by the firm. Investors are using transition risk pathways to evaluate the performance of corporate firms (Aharon et al., 2024). Whereas physical risk component of climate risk such as temperature shocks, extreme precipitation level is rarely explored in the context of firm performance (Deng et al. 2025). Though climate risk is multifaceted, but its very bedrock lies in the large-scale climatic oscillations such as ENSO (El Nino Southern Oscillation) which at times act as transmission channel for physical risk through climatic variables like temperature and precipitation (Ardia et al., 2023).

Unlike conventional financial risk, the impact of non-conventional risks such as climate risk is manifold and dynamic as it impacts the firm performance through many channels like physical disruptions, supply chains, mechanism of transition towards green economy, carbon risk driven by greenhouse gas emission and shocks amplified by events of el nino southern oscillation (ENSO). Current literature provides the dominant focus on the single dimension of non-conventional risks from climate change such as transition risk, physical risk and climate risk (Somanathan et al., 2021). But firms rarely face such risks in isolation. The resilience of the corporate firms would be based on how the firms would sail through interaction of different types of climate risk simultaneously. For instance, ENSO (El- Nino southern oscillation) event would affect the precipitation levels. Therefore, it affects the firm performance through

robustness of supply chain of corporate houses (Deng et al., 2025). In the upcoming century climate risk would be global as well as material risk if the events from the climate change is not tackled properly (WEF, 2022).[1] Particularly, 5th report of Intergovernmental Panel on Climate Change (IPCC) forecast that in the 21st century extreme weather periods would be common. The paper also highlights that emissions from anthropogenic activities already impacts people and society.[2]

The approach of internal carbon price (ICP) is quite new and rare in the growing literature of climate finance. Through ICP, firm integrate regulatory and transition pressure into explicit internal cost and modifies their operations accordingly.[3] Its impact on firm operating performance and moderating role is rarely studied (Somanathan et al., 2021)**.** Venturini (2022) bifurcate the climate risk into two main parts such as physical risk and transition risk. Physical risk refers to the temperature shocks, volatile weather trends, fluctuating sea level, increasing storms at the oceans, etc. Transition risks associated with the challenges that arise from the transition to the sustainable economy (Ai and Gao, 2023). Furthermore, recent studies such as Deng et al. (2025) and Nguyen and Phan (2020) explore climate risk as well as carbon risks suggests that investors demand extra premium from firms having higher emissions (brown firms) compared to the firms with lower emissions (green firms) (Jung et al., 2018; Bolton and Kacperczyk, 2021). Integrating physical risk with firm performance Addoum et al. (2020) and Bolton and Kacperczyk (2023) suggest that temperature shocks do not significantly affect the firm productivity and transition risk**.** Few recent studies has explored how the climate risk can affect the firm performance and pricing of securities in capital market of emerging economies using greenhouse gas emission as primary variable (Aharon et al., 2024; Alessi et al., 2021;

[1] World Economic Forum. (2022). The Global Risks Report 2022 (17th ed.)
[2] Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change
[3] Rangarajan, K., and Patil, P. Internal Carbon Pricing: A Strategic Tool for Organizational Sustainability and Profitability. Indian Institute of Management Bangalore.

Bolton and Kacperczyk, 2021a, 2021b; Han et al., 2023; Liu et al., 2023), but does not bifurcate between physical risk and transition risk of climate risk.

The conventional financial risks are often diversifiable, climate risk remains systemic, uncertain, and deeply intertwined with firms' physical operations and strategic transitions (Venturini, 2022; Ai and Gao, 2023). Despite its growing influence and relevance, it's impact on firm performance remains insufficiently documented, particularly within emerging economies where climate vulnerability of carbon-intensive sectors is high (Bolton and Kacperczyk, 2023; Somanathan et al., 2021). Understanding this interplay is critical to underscore how firms adapt to climatic volatility and regulatory changes, manage financial constraints, and sustain long-term value in the face of intensifying global climate challenges (Alessi et al., 2021; Aharon et al., 2024).

From the extant literature, it was not clear whether climate risk significantly affect the performance of the firms of emerging markets (Addoum et al., 2020; Ardia et al., 2023; Pankratz et al., 2023). Majority of the literature discount the role of supply chain, climate risk index and ENSO which can trigger physical disruptions for the firm (Addoum et al., 2020; Ehlers et al., 2022; Somanathan et al., 2021). It is ambiguous whether environmental performance of the firms protect themselves from the rising climate risk or increase their vulnerability towards the carbon risk (Chava, 2014; Lioui and Tarelli, 2022; Deng et al., 2025). Despite increasing managerial relevance, the angle of carbon tax and internal carbon price seldom been investigated as proxies of climate risk. However, the interaction of different aspects of climate risks and their cumulative effect on firm-level outcomes such as productivity, profitability, and resilience are still underexplored (Lioui and Tarelli, 2022). The current literature of climate finance also devoid of the supply chain as transmission channels of physical risk as well as the relationship of corporate governance and climate risk is not properly documented in the field of finance.

Though increasing awareness of financial vulnerability is connected to climate change, but significant research gaps still exist. It is not properly structured in the literature about how the climate would affect the financial performance of firms in emerging markets (Addoum et al., 2019; Chaudhry and Kumari, 2024). The less efficient audit environment, coupled with frequent fluctuations in government policy and unexpected economic policy shocks, further destabilizes the corporate landscape, reducing trust and predictability for external stakeholders (Jiang et al., 2010; Ding et al., 2007). The methodology of long-short portfolios underscores the importance of extreme climate or weather events on the firm's financial performance (Somanathan et al., 2021). Nevertheless, the relationship between the climate risk, physical risk, transition risk and firm performance along with supply chain, and ENSO is not comprehensively addressed in the literature (Bolton and Kacperczyk, 2023). More evidence-based studies are required to build consensus among the international community. Firms across the world disclose their information related to carbon emissions, ESG criteria, and other related factors, discounting the fact that threats from global warming and sea level rising is real (Bolton and Kacperczyk, 2021). Integrating ICP (Internal Carbon Price), it is observed that firms which incorporates emissions of greenhouse gases into cost of production has positive impact on the firm performance. Also, ICP helps the firms to accommodate the social cost of carbon emission. ICP transform the future regulatory cost into present operating cost, showing its role as future oriented cost of production of the firm.[4]

India provides a unique geographical positioning to exploit the interplay between transition and physical risks for several reasons. Firstly, it is among the top climate-vulnerable economies due to recurrent floods, cyclones, and heatwaves emphasizing the need to study the physical risk of climate change.[5] Also, the role of climatic shocks in India in its firm's productivity cannot be further discounted (Somanathan et al., 2021). Secondly, corporate houses in India faces simultaneous climatic as well as transition interactions: severe local

[4] Aldy, Joseph E. National Climate Policies and Corporate Internal Carbon Pricing. Harvard Kennedy School.
[5] Climate Risk Country Profile: India, World Bank Group

temperature shocks and increasing regulatory concern for decarbonization (Narula et al., 2024). The diversity of Indian corporates from green innovators, firms with higher emission levels, and globally linked supply chains and ENSO makes it a natural laboratory for testing how different types of climate risk affect corporate resilience.[6] Thirdly, unlike advanced economies where ESG transitions are driven by advocacy of institutional shareholders, in India the state plays a predominant role through policy modifications making the Paris Agreement a genuine exogenous policy shock to ponder upon the performance of firms with higher and lower emission.[7] Fourth, the corporate sector is highly heterogeneous: many firms are highly supply-chain dependent, so disruptions from physical and climate risk can affect the firm performance through its logistics management. Fifth, disclosure quality and firms' environmental performance remains uneven, creating variation as how transition risks are internalized across firms. Sixth, the economy is still carbon-intensive and growth-driven, so firms must balance expansion with climate commitments, exposing them to trade-offs unseen in developed markets.[8] In India, till now there is no proper reporting framework for climate risk. It makes it difficult for the institutional owners to assess the climate risk performance of the corporate houses (Borghei, 2021).

Our final sample consist of 25,476 observations from the year of 2010 to 2024. India introduced National Action Policy on Climate Change, 2008 and Clean Environment Cess (CEC) was a tax introduced in 2010 address the climate risk, which justifies the beginning year of 2010. We measure climate risk through intensity of greenhouse gas emission (*GHG INT*). Further, we also explore physical and transition risk dimension of climate risk. For physical risk we use temperature and precipitation. For transition risk we use environmental score of firms. We also use carbon tax (*CTAX*)and internal carbon price (*ICP*) to provide a comprehensive of climate risk. For robustness check, our paper also uses el nino southern

[6] CEEW, Climate Change Vulnerability Index and District-Level Risk Assessment (2022)
[7] NCEEF Brief – Post-BE 2017-18, Ministry of Finance, Government of India
[8] Mohan et al. (2019), GHG Platform India Report.

oscillation index (ENSO), interact supply chains mechanism of the firm with precipitation and exploits climate risk index (*CRI*) that not only amplifies physical risk but also represents real time disruptions to firm performance through various channel including supply chain and temperature shocks (Huang et al., 2018). The data of *CRI* is at country level. Additionally, our paper also uses market-based measures TobinsQ as a proxy for firm performance. Task force on climate related disclosure (TCFD, 2017) integrates the climate risk into financial mainstream reflecting more emphasis on four core parameters: governance, strategy, risk management and targets. We have addressed the endogeneity through dynamic GMM and difference-in-difference analysis (DID) using propensity score matching (PSM) and Paris Agreement as relevant policy shock for climate risk.

We demonstrate that physical, transition and climate risk is more pronounced for firms with higher leverage. It is also observed that for larger firms the impact of physical, transition and climate risk is quite weaker compared to firms of smaller size. It shows that larger firms can transform risk into opportunity and reflect that the impact of climate risk is not uniform across firms (Pankratz et al., 2023). We also shown that firms with higher financial leverage are more affected by climate risk. It shows that capital structure of a firm act as a relevant channel through which climate risk affect firm performance. As earlier studies shows that highly leveraged firms are subject to lower shock absorption capacity (Pankratz and Schiller, 2024, Zhang and Kong, 2025). Additionally, we have shown that the impact of physical and climate risk is positive or less negative for firms with stronger supply chain mechanism in place as such firms can convert the shock into opportunity. It shows that the management of climate risk and physical shocks can be operational efficiency problem. Firms with weak supply chain has higher production cost and more volatile revenue (Huang et al., 2018; Pankratz et al., 2023). Furthermore, the impact of ENSO is addressed along with the moderating role of supply chain and intensity group to provide a comprehensive picture of climate risk and firm performance. In addition to firm performance, we also examine earning volatility, corporate governance, financial constraint of a firm for climate risk. We also provide real economic evidence of

increasing cost of projects undertaken with increasing climate risk. We also show that global climatic variability affects the performance of non-financial firms. The results are robust to instrumental variable approach, Heckman two-stage model, matched sample analysis and dynamic GMM.

Our study adds to the finance literature in multiple ways. Firstly, our study contributes to the field of climate finance that provides comprehensive view on impact of climate risk on firm performance. By exploring different aspects of climate risk, examining the unique regulatory framework faced by Indian corporate houses, our study enhances this group of literature by investigating the effect of climate risk on firm performance. Our research shows the negative impact of climate risk on firm performance. Furthermore, this relationship strengthens for firms with higher leverage, weak supply chains, higher earnings volatility, higher emission of greenhouse gas (GHG), higher financial constraints and of lower size. Secondly, the earlier empirical work on climate risk discounts the role of ENSO (El Nino Southern Oscillation) and robust supply chain of firms (Addoum et al., 2020; Deng et al., 2025). Earlier paper finds no significant impact of climate risk on firm performance (Addoum et al., 2020; Homroy, 2023). Secondly, we also contribute to this literature on emerging market (Chaudhry and Kumari, 2024; Ding et al., 2024; Zhang and Kong, 2025) by showing firms with higher emission of GHG are more affected by climate risk as in emerging countries, where the climatic variability is more frequent. Thirdly, earlier paper includes single variable for climate risk (Addoum et al., 2020; Bolton and Kacperczyk, 2021; Somanathan et al., 2021), we along with climate risk, explore physical and transition risk to provide a more comprehensive view regarding climate risk. Fourthly, as a novelty, we also explore new dimensions of climate risk such as carbon tax and ICP, which is completely discounted in earlier literature of climate finance (Bolton and Kacperczyk, 2023). Fifthly, we also investigate the impact of twin threat of climate risk on firm performance to complement the study of (Borsuk et al., 2026) via the interaction of different dimension of climate risk.

Furthermore, our empirical work is one of the first to explore project level data as additional robustness test in the field of climate finance. Our paper provides supporting evidence on the negative impact of firm level physical, transition and climate risk on the firm's project level outcomes. Additionally, our paper is the first one in the literature of climate finance to dissect climate risk into two parts and exploiting supply chain as relevant transmission of physical risk. We also incorporate ENSO index and internal carbon price (ICP) as valid and relevant proxy that drives regional temperature, precipitation and emission levels respectively. We have also interacted ENSO index with supply chain and firms' intensity group to address firms' heterogeneity as well as to observe which kinds of firms are more vulnerable to systemic climate variability to explore firm fragility channel. Earlier paper like Addoum et al. (2023) and Huang et al. (2018) explore only one dimension of climate risk in supply chain mechanism and cash flow volatility/earning volatility respectively. We explore physical risk and transition risk dimension for the supply chain framework and earning volatility along with firms' financial constraints.

Additionally, we have also explored the complex and dynamic relationship between climate risk and cost incurred on various project undertaken by firms. Also, it is shown that supply chain positively moderates the relationship between climate risk and expenditures incurred on various projects undertaken. While prior finance research has primarily examined climate exposure through firm-level aggregates, but very little is known about how climate risks materialize in the costs of investment projects of firms. By linking project-level investment costs to environmental transition risk (*ENV SCORE*) and supply chain resilience, we show that firms with robust supply chains can mitigate the cost escalation induced by climatic shocks.

The remainder of the paper is structured as follows. Sections 2 discuss the literature review and hypothesis development, Section 3 provides framework for data collection, Section 4 discusses the research methodology, Section 5 provides empirical results, Section 6 discuss

the additional tests and robustness tests, and Section 7 provides the conclusion for the empirical paper. Appendix I provides the description of the variables used in the paper.

2. Literature Review and Hypothesis Development

The existing literature explores textual mining, media coverage analysis and corporates earning call reports to measure climate risk, but such methodology is subject to reporting biases, noisy and often capture perceptions regarding climate risk. It also helps to ensure the empirical evidence is rooted in observable climate dynamics rather than analysis of words mentioned in the media or news reports.

2.1 Climate Risk and Firm Performance

Goodell et al. (2024) investigate the relationship between carbon emission and liquidity management. It uses net working capital ratio for the liquidity parameter, argues a negative relationship between firm level carbon emission and firm liquidity. It argues uncertainty related to higher carbon cost puts negative pressure on firm cash flow and increases the default risk. Liu et al. (2023) explores the legitimacy theory to investigate the relationship between carbon emissions and organisational performance for UK firms. It argues that firm level carbon emission is negatively associated with firm performance, but carbon disclosure moderates the relationship between carbon emission and organisational performance. As the customers provides more emphasis on the lower carbon energy-efficient appliances, it would weaken the profitability of the firms with higher emissions (Pastor et al., 2021; Siddique et al., 2021).

Siddique et al. (2021) argue about the positive link between greenhouse gas emission and environmental performance and carbon disclosure (Liu et al., 2023). It explores legitimacy theory as investors rewards firms with carbon disclosure as license to operate in the society (Han et al., 2023; Siddique et al., 2021). Wang and Yang (2023) argue positive relationship between greenhouse emission and operating performance for Australian firms in mining industry. Earlier studies also focused on the relationship between equity market risk and greenhouse gas emission such as (Aharon et al., 2024; Alessi et al., 2021; Aswani et al., 2024; Bolton and Kacperczyk, 2021; Reboredo and Ugolini, 2022). They argue carbon premium quite

underpriced in the equity market. Griffin et al. (2017) founds a significant negative relation between firm level emissions and stock prices as the firm with higher carbon emission would face litigation and reputational risk, more regulatory intervention as well as it signals negative perception for the investors.

Han et al. (2023) explore the relationship between greenhouse gas emissions (GHG) and firm value. The authors suggest that firm's that disclose GHG emissions are less valued compared to firms which do not disclose GHG reduction commitments. In contrast, Liu et al. (2023) investigate S and P 500 firms and observes firm disclosing carbon emission are valued $2.3 billion higher compared to non-disclosure firms. Han et al. (2023) argue that the negative relationship between firm level emission and firm value becomes more pronounced after 2015 as investor become more aware of climate risk after the Paris Accords (Bolton and Kacperczyk, 2021; Liu et al., 2023). Prakash et al. (2011) argue that the market has a negative perception of the firms disclosing their value of emission and more penalty is imposed on the non-disclosing firms. Choi et al. (2020) argue that "investors are pricing the risk associated with environmental performance because of the uncertainty of the future cash flow effects of the consequences of poor performance such as lawsuits and regulatory exposure" (Connors and Silva-Gao, 2008).

Very few literatures are available for the role of climate risk on firm performance in emerging markets (Park et al., 2020; Xue et al., 2026). Wang et al. (2026) investigate the impact of climate risk on cash holding of firms. It was found that post Paris Agreement, there is increase in cash reserve, influenced by perception of climate risk. Xue et al. (2026) investigate climate transition risk and energy companies in China. It finds that climate risk increases the stranded assets for firms in the coal, electricity and oil and gas industry. Zhang and Kong (2025) found that climate risk affects firms operating cost positively, thereby it affects firm performance negatively. Similarly, Jung et al. (2018) observe that with increasing climate risk, there is increasing cost of debt in the emerging countries. Similarly, Tran et al. (2024) find thar climate risk increases firms distress risk which influence firm performance negatively.

Based on the above literature, we have formulated the following hypothesis

H1: Climate risk affects firm performance negatively.

2.2 Alternative aspect of Climate Risk

To explore different aspect of climate risk, we also consider physical risk and transition risk.

Addoum et al. (2020) provide empirical evidence based on the temperature shocks and establishment sales, argues that firm sales, productivity and profitability is not significantly affected by the temperature shocks. Somanathan et al. (2021) investigate Indian manufacturing factories and textile firms, for the period from 1998 to 2012, suggests that temperature shocks affect not only labour productivity, but also warmer temperature affects firm output by 2.1%. It also argues that warmer temperature shocks affect labour productivity through absenteeism. Even climate control in the firm can neutralize weak productivity but not sufficient to reduce the absenteeism of employees. It argues the real options theory as physical risks can enhance uncertainty and it can scale down investments in affected regions (Dixit and Pindyck, 2012).

Earlier literature like (Addoum et al., 2023) argue about temperature shocks and economic growth suggests that negative effect of physical risk and economic growth is mostly relevant for developed countries. Addoum et al. (2023) argue about negative effect of extreme temperatures on firm profitability for US based firms across different industries. It argue that physical risk through its negative effect on labour productivity and output, affects firm profitability (Somanathan et al., 2021). It observes a non-linear relationship between temperature shocks and financial performance. It argues that at the point of inflection, the reflection of temperature shocks on the firms turns from positive to negative. It also argues that temperature shocks do not significantly relate with the ESG performance of firms. Benincasa et al. (2024) argue that for the most profitable firms 1^0 C increase in temperature is relate with 1.30% increase in operating profit for the european firms in the energy and gas sector.

Choi et al. (2020) document how the temperature shocks can affect the belief and perception of investors. It argues that in the event of abnormal temperatures firms earn lower returns (Bolton and Kacperczyk, 2021). Investors tend to avoid the firms with highly exposed

to carbon emission as a responsible investor. Bernstein et al. (2019), and Burnside et al. (2016) explore the impact of physical risk on the valuation of coastal property. It argues that discount rates are mostly influenced by the belief of sophisticated investors. It is observed that coastal property highly vulnerable to sea level risk witness drop in valuation by 7% in the period of floods, inundation and hurricanes, etc. Exploring salience theory it was observed that with increasing in abnormal trend in precipitation levels, it can lead to exaggerated asset pricing and affect the firms with weak supply chain management (Bordalo et al., 2012; Rao et al., 2022; Pankratz and Schiller, 2024; Yang et al. 2026).

Earlier papers such as Yan, Guo, and Wen (2025) show a positive relationship between carbon risk and the cost of equity capital and the existence of a carbon premium through information asymmetry, cash flow volatility and agency cost. Arian and Sands (2024) document negative relationship between cost of capital and carbon risk. Similarly Nguyen and Phan (2020) argue about positive relationship between carbon disclosure and carbon performance. In contrast Deng et al. (2025) show negative relative between environmental disclosure of toxic elements and environmental performance of 131 sample US firms.

Duque-Grisales and Aguilera-Caracuel (2019) provide the empirical evidence of the negative impact of ESG scores on the firm performance of multinational firms in emerging markets particularly Multilatinas Latin American multinational corporations. It has exploited the sample of 104 Latin American multinational firms from 2011 to 2015. Financial slack and geographic international diversification moderate the relationship between ESG scores and financial performance (Lee et al., 2009). It argues that the main objective of the firms is to maximise the wealth of shareholders (Friedman, 1970). When the firms shift its focus from core operating activities to sustainable and environmentally conscious business practices it dilutes firm value (Venturini, 2022; Friedman, 1970).

Deng et al. (2025) argue the significant negative relation between environmental performance and environmental disclosure based on the toxic release data in consistent with

socio political theories It also argues agency theory (Jensen and Meckling, 1976) as when the manager provides emphasis on the environmental parameters for personal gains, empire building it leads to agency cost as shareholders may not align with the same. Wang and Yang (2023) argue a positive relation between firms' environmental disclosures and environmental performance in aligned with economics disclosure theories as ESG score has more weightage on governance score (Narula et al., 2024) discounting firms environmental performance. Venturini (2022) argue after dissecting of ESG into three parts the environmental score shows a negative relationship with financial performance. Social and governance scores also showed a negative or statistically insignificant impact, challenging the assumption that ESG components universally drive value. It argues that ESG investing theory (Pastor et al., 2021), the excessive spending on sustainability can reduce operating profit thereby affecting firm performance.

Narula et al. (2024) investigate the impact of Environmental, Social, and Governance (ESG) disclosures on various performance metrics such as operational, financial, and market of 220 Indian firms listed in Bombay Stock Exchange (BSE) during the critical COVID-19 period. The pandemic has heightened awareness of ESG issues, yet the tangible impact on firm performance remains unobservable during this period. The study finds that all components of ESG disclosures do not have a significant relationship with firm performance. It has concluded that in the context of carbon-neutral initiatives, the ESG investment has a positive significant impact on the firm's performance as per the social impact hypothesis (Venturini, 2022). Consistent with the stakeholder theory (Wang and Yang, 2023), the disclosure of ESG scores reduces the information asymmetry, enhances confidence regarding the long-term sustainability of the firm, thereby attracting more investments, and reduces the overall cost of capital. It has also cited that the ESG score may not be positively reflected in the financial performance of corporations of developing economies. It was also observed a negative relation between ESG performance and return on assets (ROA) for environmentally sensitive industries.

Chen et al. (2023) explore the time-variant impact of ESG disclosure on firm financial performance of Chinese A firms for the period of 2010-2020. It has exploited the institutional theory and advises that firms disclose their ESG performance to gain legitimacy and a license to operate in the society. It has concluded that ESG performance impacts the performance of the corporates significantly in a positive way. Other papers also provide empirical evidence of a negative relationship between corporate social performance and firm operating performance (Aupperle et al., 1985; Lee et al., 2009; Statman and Glushkov, 2009; Zhao and Murrell, 2016). Several researchers also observed a negative relationship between firm return on equity and governance disclosure score (Core et al., 2006). Smith et al. (2007) observed that corporate environmental reporting also has a negative relationship with firm performance, as voluntary disclosure of environmental standards does not necessarily imply improvement in corporate environmental performance (Wang and Yang, 2023). Previous literature also provides for mixed views regarding relationship between environmental performance and environmental disclosures. Some research paper exploits the inverse relationship environmental disclosure and firm performance (Hossain et al., 2024) as environmental performance controls for firm risk which is material for the investors while taking into account cost of equity capital.

Corporate environmental reporting shows to what extent the initiatives of the corporations are aligned with their corporate responsibilities. Even the cost-concerned school of neoclassical economics observed a negative association between environmental performance and market value of firms in Nordic countries (Hassel et al., 2005). It has been observed that an increase in environmental investment would increase the operational cost, leading to a reduction in firm operating revenue and market value. Core et al. (2006) provides an empirical study on the relationship between weak shareholder rights and firm performance, measured by return on equity. It contrasts with the (Gompers et al., 2003) which cites better governance scores and strong shareholder rights providing better stock returns, reduced capital expenditures, higher revenues and net profits, fewer corporate acquisitions, and higher agency

costs. It has been observed that a poor governance score does not necessarily lead to poor market performance.

Based on the above literature, we formulate the following hypothesis

H2: Transition Risk affects firm performance negatively.

H3: Physical Risk affects firm performance negatively.

2.3 Moderating role of Firm Size and Leverage

Firm-level characteristics such as size, leverage or financial risks and strength of supply chain play a significant moderating role in how climate risk impacts firm performance. Larger firms, due to their economies of large scale and diversified operations are more resilient to climate shocks than smaller firms, which often lack adaptive capacity. Leverage can make the firms highly vulnerable to financial risks during temperature and precipitation-induced operational disruptions, particularly for the firms with liquidity constraints (Krueger et al., 2020). Furthermore, strong supply chain capabilities—such as sustainable and climate-resilient logistics can neutralize operational risks from both physical and transitional climate risks, stabilizing profitability. Firms of larger size is expected to have lower amount of stranded assets (Xue et al., 2026). It is also observed that in emerging markets, climate risk drastically affects financing structure of corporate houses (Zhang and Kong, 2025).

H4: Firm size positively moderates the relationship between firm performance and physical risk, transition risk and climate risk.

H5: Leverage negatively moderates the relationship between firm performance and physical risk and climate risk.

2.4 Moderating role of Supply Chain

The strong management of supply chain can act as strategic defence against the negative impact of temperature shocks, transition risk as well as climate risk. Physical risk could disrupt firm operations through delay in production process, procurement disruption and logistics issues. Firms with flexible and robust supply chain infrastructure can efficiently absorb

regulatory, reputational as well as adaption cost pressures. Thereby, firms with diversified sourcing as well as strong supplier relationships are better positioned to withstand climatic shocks (Golgeci et al., 2019; Wang and Sarkis, 2013). Under resource-based view, strength of supply chain of firms help to overcome environmental disruptions, also to transform potential penalties into manageable organisational performance (Deng et al., 2025; Pankratz and Schiller, 2024).

Based on the above literature, we hypothesize the following:

H6: Strong supply chain positively moderates the relationship between climate risk, physical risk and firm performance.

3. Data

The financial data is collected from Prowessdx database, the data for temperature and precipitation is collected from the Ministry of Earth Science (MoES) and Indian Meteorology Department (IMD) respectively at district or sub-state (district) level following the approaches of Ai and Gao (2023), Pankratz and Schiller (2024), Venturini (2022), and Zhao et al. (2024). Data related to greenhouse gas emission amd carbon emission are collected from Refinitiv workspace. The score of climate risk index (*CRI*) is collected from Germanwatch annual reports. The project level data are extracted from Capexdx database of CMIE (Centre for Monitoring Indian Economy). We have excluded financial firms as they have distinct rules and regulation (Flannery and Rangan, 2006; Avezum et al., 2022). The data of plants and factories of firms are collected from Prowessdx. The sample period for the paper is 2010 to 2024 to measure physical risk and transition risk. The data of greenhouse gas emission is available from 2016 to 2024 to measure climate risk. In India the regulations for greenhouse gas emission (GHG) evolved after 2015 (Narula et al., 2024). A total of unique 25,476 firm-year observations from 5,029 firms constitute the final sample. The index of El nino (*EN*) is collected from National Oceanic and Atmospheric Administration (NOAA). Also, our paper provides empirical framework for different dimensions of climate risks for different time frames along with exploring *CRI* and *ENSO* as well as supply chain (*SCM*) to provide a comprehensive

coverage for climate risk. The continuous variables are winsorized at 1st and 99th percentiles to nullify the effect of outliers.

Physical risk is measured by temperature and precipitation as followed by Addoum et al. (2023), Balvers et al. (2017), and Somanathan et al. (2021). Following Guo et al. (2024), Nandy and Lodh (2012), and Venturini (2022) transition risk is measured though environmental performance.[9] Climate risk is measured by emission intensity (greenhouse gas emission scaled by net sales), as followed by Aharon et al. (2024), Bolton and Kacperczyk (2021), and Han et al. (2023). Industries are classified based on section level national industrial classification as followed by Chaudhry and Kumari (2024). The data of temperature and precipitation were assigned to factory and plant houses of firms as the factory units are the most affected through physical climate risk (Addoum et al., 2023; Benincasa et al., 2024; Pankratz et al., 2023; Somanathan et al., 2021, Yang et al., 2026). The data of factory and plant units for the firms is available district wise which justifies collecting the climatic variable for each relevant district.

Panel A of table 1 shows the descriptive statistics of *TEMP, ENV SCORE, GHG INT by* industry. Panel B reflects the descriptive statistics by year. Panel C descriptive statistics of *ROA* is defined as operating profit before interest and taxes scaled by book value of total assets, Panel D shows the correlation matrix which reflects that *TEMP, PERCP, ENV SCORE, GHG INT* are negatively related to *ROA.*

4. Research Methodology

We measure climate risk using greenhouse gas emission. We bifurcate climate risk into two primary parts of physical risk and transition risk. Additionally, we also explore role of carbon tax and internal carbon price in firm performance. Single measure of climate risk is

[9] Pricing of climate risks in financial markets: a summary of the literature, BIS Papers No. 130 (Bank for International Settlements, Dec. 2022).

sufficient but not provide comprehensive picture of climate risk and not cover all dimensions of climate risk.[10]

Many studies follow different approach to calculate climate risk. A large number of studies construct climate risk index by using Google search indexes and news texts to study the impact of climate change on various types of capital markets (Ardia et al., 2023; Engle et al., 2020; Faccini et al., 2021). Climate risk impacts the level and volatility of earnings in publicly listed companies, with firms in countries with higher climate risk holding more long-term debt and cash while paying lower cash dividends (Huang, Kerstein, and Wang, 2017). Kölbel et al. (2024), and Sautner et al. (2023) also exploits natural language processing (NLP) to calculate firm level climate risk from earning call reports, 10-K reports. Some studies such as Chava (2014), and Nandy and Lodh (2012) use environmental scores and environmental performance as measure of climate risk. At the country level, Hong et al. (2019) use the Palmer Drought Severity Index (PDSI), considering temperature and soil moisture, to measure climate risk. Earlier papers such as Bernstein et al. (2019), Burnside et al. (2016) uses natural disaster data to measure climate risk. Earlier literature such as Huang et al. (2018), and Zhao and Parhizgari (2024) used the climate risk index (*CRI*) as indicator for climate risk. *CRI* is published by Germanwatch as an annual score for economic losses based on the temperature shocks and volatility in perception levels. At the country or regional level, Bernstein et al. (2019), and Alok et al. (2020) uses the economic losses caused by disasters for the regions or counties where US firms are located to measure climate risk. Pankratz et al. (2023) also used the temperature anomaly as per the firm's head-quarter location to measure climate risk. Pankratz and Schiller (2024) further used temperature and water-level changes to measure climate risk. Koetter et al. (2020) uses temperature anomalies at city level to measure climate risk. Hsu et al. (2023) considers the sulphate toxics emissions from various industrial clusters, creates a long-short portfolio to measure climate risk. However, such indicators are subject to certain limitations,

[10]https://www.ecgi.global/publications/blog/carbon-emissions-and-bank-lending-a-green-shift-or-just-greenwashing

such as non-applicability to firm level, often not cover various dimensions of climate risk and few studies measure climate risk at firm or corporate level (Zhang and Kong, 2025).

We use the pooled OLS regression to test the formulated hypothesis with following equations:

$$ROA_{i,t} = \beta_0 + \beta_1 X_{i,t} + \beta_2 SIZE_{i,t} + \beta_3 LEV_{i,t} + \beta_4 OCF_{i,t} + \beta_5 SGROWTH_{i,t} + \beta_6 PPE_{i,t} + \beta_7 ITNAG_{i,t} + \beta_8 CASH_{i,t} + \gamma_i + \vartheta_j + \delta_t + \epsilon_{i,t} \quad \textbf{...(1.1)}$$

In the Equation (1.1) *X* refers to *PERCP* and *TEMP* as physical risk, *ENV SCORE* for transition risk, *GHG INT* for climate risk, *EN* for el-nino and *CRI* for climate risk index. To capture direct, immediate and tangible impact of climate risk we use physical risk. Transition risk would capture regulatory as well as investor perception of climate risk. El nino (*EN)* would capture the short-term climatic disturbances that can trigger heatwaves, droughts etc. For firm *i* and year *t, PERFORM* is firm performance, measured through *ROA. ROA* is defined as operating profit before interest and taxes scaled by book value of total assets, *ESG SCORE* is the environmental, social and governance performance score, *ENV SCORE* represents environmental performance score of firms, *SOC SCORE* indicates social performance score of firms, *GOV SCORE* is the governance score of firms, *GHG INT* is the emission intensity derived from greenhouse gas emission*, PERCP* is the average precipitation per year*, TEMP* is defined as the yearly average temperature in ^{0}C, *CRI SCORE* is the score of climate risk index published by Germanwatch*, SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. Equation (1.1) measures physical risk, transition risk and climate risk including firm, year and industry fixed effect. To treat for heteroscedasticity, standard errors were clustered by firm. *TobinsQ* is computed as market value of equity plus long term debt plus current liabilities scaled by book value of assets as

followed by Han et al. (2023), and Liu et al. (2023). The data of INFORM risk index (*CDRI)*, and energy transition index (*TRISK*) are collected from Macroeconomic Climate Indicators Dashboard of International Monetary Fund (IMF). In Equation (1.1) γ_i, ϑ_j, and δ_t shows the firm, industry and year fixed effect respectively.

Table 1 shows the descriptive statistics of *TEMP, ENV SCORE, GHG INT by* industry. Panel B reflects the descriptive statistics by year. Panel C descriptive statistics of *ROA* is defined as operating profit before interest and taxes scaled by book value of total assets, Panel D shows the correlation matrix which reflects that *TEMP* (physical risk), *PERCP* (physical risk), *ENV SCORE* (transition risk), *GHG INT* (climate risk), *EN* (el nino), and *CRI* (climate risk index) are negatively related to *ROA*.

[Insert Table 1 here]

5. Empirical analysis

Table 2 reports the results of baseline regression equation (1.1). Column (1) shows the impact of climate risk. It supports our primary hypothesis that climate risk affects firm performance negatively.

Column (2) to (3) show the impact of physical risk, Column (4) shows the impact of climate risk on firm performance. The coefficient of *GHG INT* (climate risk) is statistically significant at 1% level.

Column (1) shows that 1 standard deviation increase in *GHG INT* would negatively affect the firm performance by 5.8%. Also, the negative impact of *GHG INT* on the firm performance is statistically significant at 1%. Column (2) shows that climate risk affects the firm performance negatively, when controlling for industry by year fixed effects. The baseline result remain unchanged when we control for industry specific trend through industry-year fixed effect. It shows that 1 standard increase in climate risk negatively affect the firm performance by 9.2 percentage points. Column (3) address the cross-sectional dependence

through Fama Macbeth regression. It also holds the negative relationship between climate risk and firm performance. Economically, 1 standard deviation increase in climate risk negatively affect the firm performance by .086 percentage points.

It is observed in the Column (5) that serial correlation or heteroskedasticity do not materially affect the statistical significance of negative relationship between climate risk and firm performance. To explore whether the negative relationship between climate risk and firm performance is driven by manufacturing firms, we divide the sample into manufacturing and non-manufacturing firms. The negative coefficient of *GHG INT* in the Column (6), and (7) is statistically significant at the 1% level, suggests that climate risk negatively affect the firm performance regardless of industry classification of firms. Column (6) shows that for firms belongs to manufacturing industry 1 standard deviation increase in *GHG INT* would negatively affect the firm performance by 10.3%.

We explore impact of carbon tax (*CTAX*) on firm performance. Union Budget of 2016-17 increased the coal cess (Clean Environment Cess) to Rs. 400 per tonne to finance National Clean Energy and Environment Fund (NCEEF).[11] Later it is subsumed under GST compensation cess but the rate of Rs. 400 per tonne remained same until its discontinuation in 2024. This policy aligns with the firm level emission data from 2016 to 2024 to capture the financially relevant phase of climate risk. It helps to transform the variable of carbon emission to the angle of financial cum climate cost. We construct the carbon tax exposure, scaled by firms' net sales to ensure comparability across firms of different sizes. It shows the negative impact of carbon tax on firms' performance at 1% statistical significance level. Column (8) shows the negative impact of carbon tax (*CTAX*) on firm performance. Economically, 1 standard deviation increase in climate risk negatively affect the firm performance by 1.71 percentage points.

[11] https://doe.gov.in/files/circulars_document/NCEF_Brief_post_BE_2017_18.pdf (Ministry of Finance, Government of India.)

The missing values of *GHG INT* addressed through imputation techniques (Kofman and Sharpe, 2003; Chen and McCoy, 2024). Using median imputation method of Freiberg et al. (2020), the missing value of GHG INT are replaced through median values of industry-year values. Exploring multiple imputation analyses we also predict the value of missing observations using linear regression (Kofman and Sharpe, 2003; Chen and McCoy, 2024). Specifically, we use the control variables in Eq. (1.1) to predict GHG INT. These predicted values are used to replace the missing values for *GHG INT*. 25 multiple imputations are used to obtain a sample of 12,853 observations. Using both single and multiple imputation methods, it is observed in Columns (9) and (10) that the coefficients on *GHG INT* are statistically significant at 1% level.

[Insert Table 2 here]

6. Additional Tests

6.1 Endogeneity Test

6.1.1 Two Step Dynamic GMM (generalized methods of moments)

To address endogeneity, we have followed the two-step dynamic GMM to address the problem of endogeneity. Following Arellano and Bond (1991), Siddique et al. (2021), and Nguyen et al. (2023) the first lag of dependent variable treated as instrument variable to address the concern of endogeneity. We conduct the Hansen (1992) J test to check the crucial assumptions that instruments are valid as well as not endogenous. Table 7 also reports the results of diagnostic test (Hansen and Sargan test). The value of Hansen test (0.602), and Sargan test (0.819) failed to reject the null hypothesis of insufficient exogeneity at 1% significance level. It also reflects that identification strategy is valid and not affected by endogeneity. Table 3 shoes the results of dynamic GMM.

[Insert Table 3 here]

6.1.2 Two Stage Least Squares (2SLS) Estimation

Additionally, we address the endogeneity concern through second stage lease square method. The primary requirement for 2SLS is that the valid instrument should meet the

exogeneity as well as relevance condition. For the relevance condition, the instrument should be correlated with the endogenous variable (*GHG INT*). Similarly, for the exogeneity condition, the instrument variable should not be correlated with the error term of structural equation model and should not directly influence the dependent variable of interest.

Following Homroy (2023), we instrument the climate risk through lagged, industry average values of Scope 2 emission (*IV1*) and upstream Scope 3 emission (*IV2*) (excluding the focal firm for both instruments). Through this approach, industry level Scope 3 emission captures industry wide production technologies used by the supplier orthogonal to firm level performance. Similarly, Scope 2 emission reflect grid level emission values, not directly affecting the firm performance.

Column (1) and (2) of panel B Table 4 reports the results of first and second stage regression of second stage least square estimation (2SLS). In the first stage, two instrument variables are regressed on climate risk (*GHG INT).* The coefficient on both the instruments is significant at 5% level, suggesting that scope 2 and scope 3 emission influence climate risk. The fitted values of *GHG INT* are used to estimate Eq. (1) in the second stage. The coefficient on the climate risk *GHG INT* is significant at 1%. The negative coefficient on the Column (2) shows that climate risk significantly affects firm performance.

6.1.3 Difference in Difference Analysis

Table 4 shows the difference in difference analysis for green firms (firms with lesser greenhouse gas emissions). The *ENV SCORE* was divided into two quantiles, Firms in the lower 50% of the distribution were labelled as '*BROWN*', and those in the upper 50% were labelled as '*GREEN*' as followed by Bua et al. (2024). Panel A shows the table of propensity score matching wherein, *GREEN* firms were treated firms and *BROWN* firms were controlled firms. It shows that *POST PARIS, BROWN* (control group) firms have negative impact on firm performance, but *Treat* (GREEN) firms experience positive impact on the firm performance quite consistent with Table 4. Similarly, *GREEN* group of firms also face negative impact of

climate risk on firm performance, consistent with shareholder theory and ESG investing theory as explained earlier and in aligned with studies of Han et al. (2021), and Nguyen et al. (2023).

Following (Nyborg and Woschitz, 2025), we also presented the results of weighted difference-in-difference analysis (DID) which also confirms the same result at 10% statistical significance level to complement the column (3) of panel B in Table 4. In a standard DID, equal weight is provided to matched treated and controlled firms. It gives equal importance to the matched units. We additionally employ weighted-DID estimation to account for firm heterogeneity. The results of weighted DID also suggests that post Paris Agreement, *Treat* (GREEN) firms has positive impact on firm risk due to climate risk.

The parallel trend of *ROA* of treatment and control firms is shown in Appendix 2. Before the exogeneous shock of Paris Agreement, both the treatment and control firms show same parallel trend. But the Paris Agreement of 2015, consistent rise of *ROA* is observed for the treatment firms than for the control firms.

6.1.4 Placebo Test

Furthermore, we run a placebo test to test whether false treatment timing shows an effect. For the placebo test, actual treatment year 2015 is replace by 2019 (*POST2*) with two-year pre and post event window. Column (5) of Table 4 reports the placebo test. The insignificant interaction between *TREAT* and *POST2* supports additional evidence that positive firm performance of *TREAT* firms is not driven by time trend. It can be concluded that, the positive firm performance of green (*TREAT*) firms after the year 2015 is attributable to the event of Paris Agreement.

6.1.5 Matched Sample Analysis

Additionally, we estimate Eq. (1) using matched sample of treatment and control firms. We obtain 2,500 matched pairs of control and treatment firms. Using propensity score matching (without replacement, nearest neighbour with 1% caliper), we match treatment and control

firms based on firm characteristics. The coefficient on *TREAT* is positive in Column (6) and statistically significant at 5% level.

6.1.6 Heckman test

Furthermore, to evaluate that our sample selection is not influenced by non-random selection process, we also use Heckman 2 stage process. The results are shown in Column (7) and Column (8) of Table 8. We first model the likelihood of firms included in the Eq. (1) based on the firm's characteristics used in the Eq. (1). From first stage equation, it gives the inverse mill ratio (*IMR*). *IMR* is incorporated in the second stage regression to adjust for self-selection bias. The coefficient on *IMR* is statistically non-significant, confirming that the negative relationship between climate risk and firm performance is robust.

[Insert Table 4 here]

6.2 Alternative Measures of Climate Risk

To capture different aspects of climate risk such as physical risk, transition risk, el-nino, we also use different variables for the same. The coefficient on the *TEMP* and *PERCP* is statistically significant at 1% and 5% level for physical risk. The coefficient on *ENV SCORE* is statistically significant at 5% for transition risk. From the result of table 5 it was observed that increasing 1 standard deviation of *ENV SCORE* would reduce the firm performance by 0.54%. Similarly, 1 standard deviation increase in *TEMP* would reduce return on assets by 0.34%, 1 standard deviation increase in *PERCP* would reduce return on assets by 7.3%. It supports our second and third hypothesis that physical risk and transition risk affect firm performance negatively.

In column (4) we explore climate risk index from Germanwatch *CRI* following Ben Abdesslem et al. (2025), Bolton and Kacperczyk (2023), and Huang et al. (2018). For *CRI* following Arian and Naeem (2025); Huang et al. (2018) we multiply the climate risks index score (*CRI*) by negative so that higher score indicates higher risk. It is observed that 1 standard deviation increase in *CRI* negatively affect the firm performance by 3.5%. Similarly, Column

(5) shows that in the period of el nino (*EN*), operating performance of firms negatively affected by 2%.

These findings are consistent with the he earlier findings of Addoum et al. (2023), Bolton and Kacperczyk (2023), Han et al. (2023), and Pankratz et al. (2023). Salience theory propounds by Bordalo et al. (2012), and Rao et al. (2022), Real options theory by Dixit and Pindyck (2020) also suggests that temperature shocks can negatively impact firm performance through increase in uncertainty, whereas abnormal precipitation can lead to operational disruptions causing negative firm performance. ESG investing theory (Pastor et al., 2021), and shareholder theory (Friedman, 1970) also emphasize that firms focusing more on environmental parameters could distract the managers from core operations, leading to agency cost (Jensen and Meckling, 1976) as well as negative firm productivity. Similarly, climate risk could lead to litigation risk, institutional pressures, reputational cost, disinvestment which can negatively affect firm performance (Bolton and Kacperczyk, 2023; Ehlers et al., 2021; Sautner et al., 2022). Table 5 reflects the results of climate risk using different alternative measures.

[Insert Table 5 here]

6.3 Simultaneous Risk Exposure

To capture the impact of twin threats of climate risk on firm performance (when firm exposed to different climate risk simultaneously), we interact between different measures of climate risks in table 6 by following Borsuk et al. (2026). In Column (1) it is observed that both physical and climate risk (*TEMP*×*GHG INT*) negatively impact firm performance. The negative coefficient on the interaction (*TEMP* × *GHG INT*) shows physical risk accelerate the negative impact of climate risk on firm performance.

Also in Column (2), and (3) the impact of *ENV SCORE* (transition risk) is negative on firm performance when there is non-existence of physical risk and climate risk as environmental performance disclosure is related to higher short-term regulatory and compliance burden, investors pressure for decarbonisation and adaption cost (Chava, 2014). It

is observed that higher environmental disclosure of firms realised in long run when there is a existence of physical and climate risk as argued by Zhao et al. (2024).

Similarly, Column (2) shows the interaction of *TEMP* × *ENV SCORE*, shows that in the presence of transition risk, physical risk amplifies negative effects on the firm performance. Likewise, in Column (3) the interaction *GHG INT* × $ENV\ SCORE$ shows transition risk amplifies the negative impact of climate risk on firm performance. The result of any of the variable does not overturn the result of baseline regression in Table 2. The impact of simultaneous risk exposure is reported in Table 6.

[Insert Table 6 here]

6.4 Moderation Analysis

6.4.1 Supply Chain

We explore the role of supply chain (*SCM)* in the relationship between climate risk and firm performance through moderation analysis. Supply chain (*SCM)* is the dummy variable which takes the value one when the firm has robust environmental supply chain. It means when the firm has proper framework regarding environmental rules regulation, procurement of sustainable or green products, supplier code of conduct it has the value of one else zero.

Column (1) shows the positive moderation role of supply chain (*SCM*) in relation to el nino (*EN*). In Column (2), and (3) the coefficient in the interaction variable reflects the positive moderating role of supply chain on the relationship between physical risk, transition risk and firm performance respectively. It reflects that climate risk can negatively affect the firm performance unless firm operations are integrated through robust network of supply chain. In the period of physical climatic shocks, robust supply chain of a firms helps to convert the risk into opportunity.

Column (4) shows the positive moderating role of supply chain. It means in the period of climate risk, firms with strong supply chain in place are less affected. Column (5) shows that robust supply chain helps to mitigate rising cost of goods sold (*COGS*) due to higher emission. The coefficient on (*GHG INT)* shows that with higher emission of greenhouse gas, cost of

goods sold also increases for the firms without supply chain framework. The role of supply chain (*SCM*) as moderator is reported in Table 7.

[Insert Table 7 here]

Consistent with the finding of Arial et al. (2024), and Chen et al. (2023), from Column (1) to (5) it is observed that strong and robust supply chain management positively moderate the relationship between climate risk, physical risk, transition risk and firm performance due to higher capacity to absorb temperature shocks as well as operational effectiveness to mitigate the adverse effects of climate risk and better risk management frameworks**.** Interestingly, supply chain exposure alone does not significantly affect ROA, underscoring its role as a contextual moderator rather than a standalone core driver of firm profitability.

6.4.2 Firm Size

Table 8 shows the moderating effect of firm size (*SIZE*) and leverage (*LEV*) of firms on climate risk, physical risk and transition risk. It shows the impact of greenhouse gas emission is significantly negative for small firms (base effect) as capital market penalize these firms for regulatory risks. Using *SIZE*, we categorize firms into two groups, firms in the lower quantile are treated as firms of lower size, top quantile firms are treated as *HIGH SIZE* firms based on media.

The interaction terms of firms *HIGH SIZE* (higher size) with *GHG INT* (climate risk), *TEMP* (physical risk), *ENV SCORE* (transition risk), at Column (1), (2), and (3) respectively. It shows that large firms not only able to buffer the negative impact of emissions of greenhouse gas but also less marginal cost of green transition per unit of emission The coefficient on interaction terms also statistically significant at 1%, suggesting larger firms are more resilient to physical risk as they can effectively manage costs of abatement, regulatory compliance and innovation compared to small firms, which is in consistent with (Pastor et al., 2021).

6.4.3 Leverage

Column (4) and (5) reflects the moderating role of leverage in climate risk and its components. Where, firms were divided into two quantiles using the variable *LEV* based on

median. Firms in the lower quantiles are treated as firms with lower risk. Whereas firms in the higher quantile are treated as firms with higher financial risk. The interaction terms of *HIGH LEV* (Higher Leverage) with *GHG INT* (climate risk), and *TEMP* (physical risk) (*HIGH LEV × GHG INT*, *HIGH LEV ×TEMP)* is statistically significant and negative at 1% and 10% respectively. Specifically, firms with higher leverage experience exacerbation in performance declines with rising temperature shocks and greenhouse emission as greater debt obligation pose as obstacle to transit to greener economy. Higher leverage amplifies the vulnerability for firms with higher financial risk to climate risks as well as physical risk. The moderation analysis for firm size and leverage is reported in Table 8.

[Insert Table 8 here]

6.5 Brown and Green Firm

To address firm level heterogeneity, we divide the firms based on greenhouse gas emission (*GHG INT*) into brown and green following Andersson et al. (2016), Bolton and Kacperczyk (2023), and Hsu et al. (2023) on 50th percentile or median (two groups). Firms in the lower 50% of the distribution were labelled as '*GREEN*', and those in the upper 50% were labelled as '*BROWN*'.

Table 5 investigates the link between climate risk, physical risk and firm performance for *BROWN* and *GREEN* firms. Column (1) and (2) reflects that brown firms are the most affected by physical and transition risk. The coefficient on the interaction terms is also statistically significant at 5% level, as carbon intensive firms are more vulnerable to abnormal temperature shocks through operational inefficiency. Similarly, Column (3) and (4) indicate that firms with less emission of greenhouse gas are insulated from physical risk as well as transition risk due to dynamic capabilities framework and environmental capabilities. The investments in cleaner technologies, innovation and climate conscious strategies are paid off for green firms to mitigate the negative effect of physical risk as well as transition risk. Table 9 documents the results of firm heterogeneity.

[Insert Table 9 here]

6.6 Financial Constraint Index

This sub-section examines the relationship between climate risk and financial constraint index and internal carbon pricing. Financial constraint index is measured using Hadlock and Pierce (2010). A higher HP index reflects tighter financial constraints. We capture firm heterogeneity based on firm growth (*AGE*). Column (1) show the positive relationship between firms' financial constraints and transition risk. 1 standard deviation increase in *ENV SCORE* can increase *HP Index* (financial constraints) by 1.3%. Column (2) indicates the positive relationship between *HP Index* and (climate risk) *GHG INT,* shows that 1 standard deviation increase in *GHG INT* increase the financial constraint by 9%. Column (3) reflects that 1 standard deviation increase in (physical risk) *TEMP* increase the financial constraint by 3%. Column (4) to (6) shows that older firms mitigate the impact of different forms of climate risk on financial constraints.

Column (7) examines the impact of internal carbon pricing (*ICP*) on firm performance. *ICP* is a dummy variable, it is 1 if company assigns a value to emission of greenhouse gas or else zero. Very few studies explore the *ICP* as part of climate risk.[12] Firms following internal carbon pricing signal their readiness for potential regulatory and policy shocks. Column (7) shows that the coefficient on the *ICP* is positive and statically significant at 1%. Internal carbon price is a managerial discipline that enhance the efficiency of resource allocation. *ICP* plays the role of internal hedging instrument against regulatory, decarbonisation pressure and technology advancement. Firms exploit *ICP* as a forward-looking approach to transition resilience. Column (8) shows the positive moderation role of *ICP* regarding climate risk. Firms with *ICP* associated with lower financial performance penalties as they are configured to absorb transition as well as regulatory shocks. Column (8) shows that *ICP* positively moderated the

[12] Desjardins, M., Gianfrate, G., Ghitti, M., and Sinclair-Desgagne, B. (2024). Internal carbon pricing – A price instrument to cope with organizational failure (*FEB-RN Research Paper No.* 59/2025).

impact of climate risk on firm performance and statistically significant at 5% level. The results are reported in Table 10.

[Insert Table 10 here]

6.7 Corporate Governance and Earning Volatility

The firms highly exposed to more climatic variability has low or negative corporate governance frameworks. Earlier studies on developed market find that investor tries to reduce their exposure to climate risk (Luo and Tang, 2020; Bolton and Kacperczyk et al., 2022).

6.7.1 Corporate Governance

We study the corporate governance through the lens of shareholder ownership pattern of firms. Table 6 examines the complex and dynamic relationship between corporate governance structure, firms earning volatility and climate risk. Column (1) shows the negative relationship between *PROMOTER* and *GHG INT.* It reflects that 1 standard deviation increase in *GHG INT* reduce the share of *PROMOTER* by 13%. Column (2) reflects that institutional investors perception is affected by climate risk. 1 standard deviation increase in *ENV SCORE* leads to decrease in institutional investors participation by 5%. Similarly, Column (3), and Column (4) foreign institutional investors (*FII*), and retail investors (*RETAIL*) are sensitive to climate risk of the firm. 1 standard deviation increase in *GHG INT,* reduce the *FII* and *RETAIL* shareholding by 15% and 11% respectively as consistent with the findings of Chaudhry and Kumari (2024). The results are reported in Table 11.

6.7.2 Earning Volatility

This section examines the negative impact From Column (5) to (7) reflect the negative impact of climate risk on earning volatility of firm. We measure earning volatility as standard deviation of return on assets over 5-year rolling window. The negative coefficient on Column (5) shows the negative impact of climate risk on firm earning volatility. Column (6) shows the negative relationship between physical risk and earning volatility. In the period of higher temperature fluctuations, it does not only affect firms fixed assets bur also the revenue generates from it. Column (7) shows transition risk affects the earning volatility negatively. The negative

effect is statistically significant because transition risk influences expectations about future profitability, leads to higher earnings volatility (Huang et al., 2018, Bolton and Kacperczyk, 2023). The results are reported in Table 11.

[Insert Table 11 here]

Overall, the findings demonstrated in this section suggests that when a firms exposed to simultaneous risks it affects their performance negatively. Firm of higher sizes and with robust supply chain framework in place, would be less negatively affected by climate risk and has the potential to convert climate risk into opportunities with new innovations. Whereas, climate risk along with transition risk more negatively affects the firms with higher leverage due to financial constraints. Similarly, in the period of el-nino, the performance of the firms is negatively affected especially for the firms with higher emission of greenhouse gas.

6.8 Project Level Data

We move beyond the field of balance sheet and have extend the analysis to the project level data of firms to capture real economic manifestations of climatic shocks in the context of supply chain. Beyond firm-level evidence, this study also leverages unique project-level cost data to provide direct insights into how climate risk translates into the real economy. This novel layer of project level analysis strengthens the credibility of our evidence that the observed firm-level negative relationships with climate risks are not merely accounting constructs but also reflect tangible shifts in project financing efficiency. Providing project-level evidence as an additional robustness test alongside firm-level regressions contributes to the corporate finance literature by offering a rare real-economy validation of how climate risk alters investment efficiency and financing frictions. It is observed that projects with higher exposure to climatic volatility, burden the firms' higher costs for its completion. But a firm with robust supply chain can convert the climate risk into opportunity. It underscores that resilient supply chain can help to absorb rising project completion costs with increasing climate risk. It complements the study of Xu et al. (2024) showing increase in investment inefficiency of firms with more exposure to climate risk.

[Insert Table 12 here]

6.9 Robustness Test

To further robust our findings, in table 9 we used market level measure of firm value *TobinsQ* as dependent variable from Column (1) to (3). *TobinsQ* is used as market-based measure for firm performance. Following Nguyen et al. (2023), in Column (4) and (5) we use energy transition index (*TRISK*) and climate driven INFORM risk indicator (*CDRI*) respectively from IMF as proxy for climate risk.[13] It shows that physical risk, transition risk and climate risk adversely affect not only firm value but also firm performance. It is reflected that climate risk and different components negatively affect firm performance. Also, Column (4) and (5) shows that energy transition index and climate driven index does not overturn the negative link between climate risk and firm performance.

[Insert Table 13 here]

7. Conclusion

Our findings confirm that the baseline relationship between climate risks and firm performance is predominantly adverse: both physical climate risk as proxied by temperature anomalies, and transition risk, proxied by environmental performance (*ENV SCORE)*, exhibit negative associations with firm performance, consistent with prior evidence that environmental shocks and carbon exposure erode operational efficiency and financial outcomes (Chava, 2014; Hsu et al., 2023). This baseline effect is nuanced by firm-specific moderators. Larger firms, in line with the resource-based view and economies of scale arguments are better positioned to withstand both physical and transition risks, as firm growth moderate the relation between firms' financial constraints and climate risk positively. Similarly, strong supply chain management attenuates the negative performance effects of rainfall variability and emissions intensity, echoing the supply chain resilience literature (Deng et al., 2025) and reinforcing the strategic value of adaptive network capabilities under climate uncertainty framework. In

[13] International Monetary Fund. 2025. Macroeconomic Climate Indicators Dashboard, https://climatedata.imf.org/pages/access-data

contrast, high financial leverage exacerbates vulnerability to climate risk and its different components, as indicated by significantly negative interaction terms, aligning with the financial fragility channel and prior evidence that debt constraints amplify exposure to adverse shocks (Krueger et al., 2020; Sautner et al., 2023). Furthermore, we have complemented the evidence using the project level data of the corporate houses. For firms and investors, rising entropy or disorder in the climate system would not only amplify uncertainty but also make financial system more volatile. Exploiting the Germanwatch climate risk index (*CRI*) as proxy for climate risk confirms that more profitable firms are generally less exposed to climate-related losses, consistent with adaptive capacity theories (Arian and Naeem, 2025; Bolton and Kacperczyk, 2023; Huang et al., 2018).

Robustness checks further support these conclusions. Using Tobin'sQ as an alternative measure of firm performance and re-estimating models with environmental score, GHG intensity, and temperature as key risk variables yield qualitatively consistent results (Deng et al., 2025). Moreover, reversing the causal lens by employing the climate driven INFORM risk index energy transition, it is shown that climate risk negatively affects firm performance. We have also tested the endogeneity concerns using dynamic GMM and difference in difference analysis and observed similar and highly significant results. Collectively, these results highlight that while climate risks impose measurable financial penalties, the magnitude and direction of their effects are contingent upon firm-level strategic resources and capital structure, offering important implications for corporate governance and climate adaptation policy

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Table 1: Descriptive Statistics

Panel A: This panel the sample distribution by industry.

ENV SCORE represents firms environmental performance score, *TEMP* is defined as the yearly average temperature in ^{0}C. *GHG INT* is the emission intensity derived from greenhouse gas emission. Column (1) reports the number of observations, Columns (2), (3) and (4) reports mean and median *ENV SCORE, TEMP* and *GHG INT* respectively. Columns (5), (6) and (7) reports mean and median *ENV SCORE, TEMP* and *GHG INT* respectively. All variables are winsorized at the 1st and 99th percentile. The sample period is from 2010 to 2024.

Industry	(1) N	(2) Mean *ENV SCORE*	(3) Mean *TEMP*	(4) Mean *GHG INT*	(5) Median *ENV SCORE*	(6) Median *TEMP*	(7) Median *GHG INT*
Aerospace and Defence	441	5.972	27.171	0.010	1.982	2.590	0.006
Automobiles	365	14.605	37.558	0.250	16.128	46.762	0.015
Building Products	437	3.578	38.367	0.036	1.511	48.214	0.014
Chemicals	2,391	4.967	39.743	43.193	3.036	53.300	0.021
Communications Equipment	151	3.789	38.523	0.007	1.279	47.068	0.007
Construction and Engineering	1,344	4.386	46.463	0.190	1.742	53.563	0.009
Construction Materials	537	7.675	36.351	0.937	4.921	26.160	0.127
Diversified Telecommunication Services	109	7.179	44.746	0.008	6.118	48.458	0.005
Electrical Equipment	1,026	4.282	37.952	0.029	1.426	46.762	0.011
Gas Utilities	560	14.056	32.619	0.074	11.950	21.705	0.049
Health Care Providers	208	4.109	49.362	0.006	1.117	54.356	0.003
Hotels, Restaurants and Leisure	705	4.703	34.422	0.011	2.929	24.974	0.008
IT Services	955	4.364	46.197	0.004	1.201	53.857	0.002
Machinery	1,653	3.785	36.626	0.024	1.391	25.425	0.015
Metals, Oil and Mining	1,812	4.832	37.631	0.075	2.153	41.412	0.048
Paper and Forest Products	339	5.695	37.693	0.023	5.127	46.762	0.027
Pharmaceuticals	1,311	5.233	41.471	0.010	2.282	53.300	0.007
Software	591	3.211	45.943	0.003	1.067	53.447	0.002
Textiles	454	3.900	42.556	0.012	2.283	54.231	0.004
Tobacco	245	10.026	39.576	0.027	4.727	47.610	0.003
Transportation Infrastructure	162	6.775	55.497	4.872	5.122	55.134	0.033

Panel B: This panel represents sample distribution by year.

Year	(1) N	(2) Mean *ENV SCORE*	(3) Mean *TEMP*	(4) Mean *GHG INT*	(5) Median *ENV SCORE*	(6) Median *TEMP*	(7) Median *GHG INT*
2010	658	6.791	20.317	-	4.841	20.126	-
2011	786	4.239	20.422	-	2.424	21.387	-
2012	954	3.791	34.591	-	1.483	52.262	-
2013	1053	4.076	33.289	-	1.659	54.551	-
2014	916	3.981	21.269	-	1.608	53.940	-
2015	1130	3.843	26.186	-	1.543	53.915	-
2016	1245	3.859	39.911	5.473	1.397	52.243	0.015
2017	1242	3.781	42.243	6.204	1.322	54.720	0.016
2018	1412	3.815	41.756	2.524	1.339	53.586	0.018
2019	1252	3.944	43.245	2.925	1.551	54.159	0.016
2020	1261	3.880	38.923	1.779	1.568	48.458	0.017
2021	1457	4.045	40.775	1.352	1.622	53.563	0.014
2022	1294	4.116	43.548	0.466	1.750	49.535	0.014
2023	1257	4.490	36.786	5.092	2.093	19.182	0.015
2024	1340	4.733	32.674	0.137	2.295	28.864	0.018

Panel C: **This panel presents descriptive statistics.**

ROA is defined as operating profit before interest and taxes scaled by book value of total assets, *TobinsQ* is computed as market value of equity plus long-term debt plus current liabilities scaled by book value of assets, *CRI SCORE* is the climate risk index published by Germanwatch,. *ESG SCORE* is the environmental, social and governance performance score, *ENV SCORE* represents environmental performance score of firms, *SOC SCORE* indicates social performance score of firms, *GOV SCORE* is the governance score of firms, *GHG INT* is the emission intensity derived from greenhouse gas emission, *PERCP* is the average precipitation per year, *TEMP* is defined as the yearly average temperature in ^{0}C, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets, *SCHAIN* is the composite supply chain measure integrate supply chain policies as well as practices. All continuous variables are winsorized at the 1st and 99th percentile to nullify the effect of outliers. The sample period is from 2010 to 2024.

	Mean	***Median***	***SD***	***Var***	***Min***	***Max***
ROA	0.060	-0.118	0.135	0.018	-0.639	0.479
ESG Score	30.671	25.224	3.965	15.724	23.958	47.044
ENV Score	3.864	0.000	5.399	29.153	3.693	31.284
SOC Score	14.335	8.571	3.852	14.839	6.747	29.535
GOV Score	73.625	68.467	3.414	11.658	63.549	83.594
GHG INT	141.822	14.003	58.620	3300.742	19.07	160.822
TEMP	21.240	14.910	3.451	11.906	8.970	26.160
PERCP	140.934	20.470	93.829	892.625	0.000	321.320
SIZE	7.046	3.086	2.544	6.471	2.303	17.727
LEV	1.916	0.000	18.407	338.816	-0.093	164.000
OCF	0.006	-0.183	4.999	24.985	-232	308
SGROWTH	0.249	0.003	0.216	0.047	-0.010	1.000
PPE	5.785	0.788	2.784	7.752	-2.303	15.263
INTANG	0.055	0.032	1.319	1.739	-0.02	160.000
CASH	0.010	0.023	0.046	0.002	0.001	1.000
CRI SCORE	21.980	17.97	9.013	81.284	3.870	58.482
TobinsQ	2.278	3.598	2.615	7.973	1.453	18.635
SCM	1.793	1.457	1.293	1.705	0.000	1.000
EL NINO	.227	0.102	0.320	0.102	0.000	1.437

Panel D: The table presents correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(1) ROA	1.000																		
(2) TobinsQ	0.626*	1.000																	
(3) ESG SCORE	0.288*	0.395*	1.000																
(4) ENV SCORE	-0.612*	-0.557*	0.212*	1.000															
(5) SOC SCORE	0.244*	0.216*	0.183*	0.184*	1.000														
(6) GOV SCORE	0.214*	0.171*	0.048*	0.221*	-0.061*	1.000													
(7) GHG INT	-0.071*	-0.084*	0.034*	-0.265*	-0.112*	0.737*	1.000												
(8) TEMP	-0.140*	-0.126*	-0.038*	0.150*	0.031*	0.605*	0.600*	1.000											
(9) PERCP	-0.210*	0.144	0.014*	0.236*	-0.057*	0.674*	0.338*	0.361*	1.000										
(10) SIZE	-0.046*	-0.015	-0.080*	-0.055*	0.024	-0.001	-0.007	0.004	-0.019	1.000									
(11) LEV	-0.013*	0.008	0.003	-0.009	-0.037*	0.043*	0.019*	0.008	0.041*	0.059	1.000								
(12) OCF	0.029*	0.030*	0.016*	0.030*	-0.019*	0.069*	0.043*	0.015*	0.058*	0.010	0.574*	1.000							
(13) SGROWTH	0.224*	0.150*	0.096*	0.227*	-0.127*	0.628*	0.577*	0.369*	-0.358*	0.035	- 0.014*	0.067*	1.000						
(14) PPE	-0.034*	-0.030*	0.060*	-0.043*	-0.012*	-0.075*	-0.018*	-0.064*	-0.076*	0.001	0.006	-0.020*	-0.005	1.000					
(15) INTANG	0.042*	0.010*	-0.001	0.038*	0.011*	0.008	0.003	0.006	0.007	0.002	-0.004	-0.021*	0.032*	-0.018*	1.000				
(16) CASH	-0.061*	-0.081*	-0.030*	-0.075*	0.068*	-0.009	0.105*	-0.094*	-0.085*	0.024	0.100*	-0.094*	0.057*	0.022*	0.019*	1.000			
(17) SCHAIN	0.136*	0.098*	0.062*	0.110*	-0.063*	0.512*	0.584*	0.301*	0.234*	0.085*	-0.076*	0.004	0.819*	0.001	0.030*	0.435*	1.000		
(18) CRI SCORE	-0.050*	-0.021*	-0.012*	-0.065*	-0.024*	-0.026*	0.010	-0.016*	-0.023*	-0.025	0.034*	-0.025*	-0.052*	-0.002	0.135*	0.015*	-0.040*	1.000	
(19) EN	-0.002*	-0.004	0.015*	-0.002	0.019*	-0.015	0.058*	-0.087*	0.001	0.009*	-0.001	0.003	-0.001	-0.011	0.003	0.128*	0.491*	0.048*	1.000

Table 2: **Baseline Regression model with firm, industry and year fixed effect**

ROA is defined as operating profit before interest and taxes scaled by book value of total assets, *ESG SCORE* is the environmental, social and governance performance score, *ENV SCORE* represents environmental performance score of firms, *SOC SCORE* indicates social performance score of firms, *GOV SCORE* is the governance score of firms, *GHG INT* is the emission intensity derived from greenhouse gas emission, *PERCP* is the average precipitation per year, *TEMP* is defined as the yearly average temperature in ^{0}C, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets, CTAX denotes carbon tax. All continuous variables are winsorized at the 1st and 99th percentile to nullify the effect of outliers.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Baseline regression	Industry by year FE	Cluster standard error by firm and year	Fima and Macbeth (1973) Regression	Newey and West (1997) standard errors	Manufacturing firms	Non-manufacturing firms	Carbon tax	Single imputation	Multiple imputation
GHG INT	-0.001***	-0.011**	-0.001**	-0.001**	-0.001**	-0.398***	-0.001***		-0.001***	-0.001***
	(-9.846)	(-2.572)	(-2.400)	(-2.641)	(-3.636)	(-3.614)	(-9.845)		(-3.234)	(-5.210)
CTAX								-0.002***		
								(-4.171)		
SIZE	0.017	-0.162***	0.017	0.069***	0.112***	-0.425***	0.017	0.078	0.009	0.019***
	(1.607)	(-3.270)	(1.587)	(3.67)	(4.040)	(-7.328)	(1.606)	(1.618)	(1.172)	(5.050)
LEV	-0.000***	-0.003	-0.000**	0.001	-0.001**	0.001	-0.000***	-0.000***	-0.001***	-0.000***
	(-2.922)	(-0.309)	(-3.198)	(1.500)	(-2.351)	(0.168)	(-2.918)	(-4.409)	(-3.533)	(-2.823)
OCF	0.018	0.989***	0.018	0.090**	0.031**	0.054	0.018	0.023**	0.112***	0.007
	(1.211)	(4.007)	(1.247)	(2.761)	(2.580)	(0.478)	(1.217)	(2.010)	(4.068)	(0.271)
SGROWTH	-0.023	-0.100	-0.023	-0.062***	-0.118***	-0.306*	-0.024	-0.066	-0.126***	-0.033***
	(-1.024)	(-0.396)	(-1.459)	(-4.397)	(-3.406)	(-1.712)	(-1.034)	(-1.351)	(-5.581)	(-3.221)
PPE	-0.013**	0.083*	-0.013**	-0.009***	-0.009***	0.177***	-0.013**	-0.017***	0.002	-0.010***
	(-2.499)	(1.955)	(-2.930)	(-12.302)	(-4.707)	(3.833)	(-2.489)	(-4.269)	(0.390)	(-5.490)
INTANG	-0.096***	-0.202	-0.096***	-0.132***	-0.199***	-0.151	-0.096***	-0.158***	-0.032	-0.074***
	(-3.478)	(-0.745)	(-4.021)	(-9.110)	(-4.530)	(-0.465)	(-3.462)	(-2.923)	(-1.025)	(-4.141)
CASH	1.057***	1.693***	1.057***	1.100***	1.110***	1.614***	1.057***	1.089***	0.093	0.695***
	(26.467)	(5.030)	(16.896)	(19.134)	(17.483)	(7.432)	(26.448)	(27.696)	(0.572)	(7.345)
Constant	-0.052	1.574***	-0.052	0.002	0.001	3.767***	-0.053	0.043	-0.009	-0.088***
	(-0.615)	(5.379)	(-0.588)	(0.281)	(0.948)	(7.793)	(-0.618)	(0.757)	(-0.164)	(-3.299)
Industry FE	Yes	No	Yes	Yes	Yes	No	No	No	No	No
Firm FE	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry - Year FE	No	Yes	No	No	No	No	No	No	No	No
N	2,103	1,544	2,103	2,114	2,105	1,919	294	1,829	11,466	12,853
Adj. R^2	0.640	0.593	0.540			0.543	0.440	0.548	0.559	

Table 3: **Endogeneity test through Dynamic GMM**

Dynamic GMM Regression model with firm, industry and year fixed effect. *ROA* is defined as operating profit before interest and taxes scaled by book value of total assets, *L1* is the lagged of dependent variable (*ROA*), *GHG INT* is the emission intensity derived from greenhouse gas emission, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. All continuous variables are winsorized at the 1st and 99th percentile to nullify the effect of outliers.

	ROA
L1	1.162***
	(10.222)
GHG INT	-0.001**
	(-2.090)
SIZE	0.013*
	(2.186)
LEV	-0.001***
	(-6.897)
OPC	-0.200**
	(-2.971)
SGROWTH	0.060*
	(1.929)
PPE	-0.008**
	(-2.805)
INTANG	-0.019
	(0.828)
CASH	-0.253*
	(-0.842)
Constant	-0.100**
	(-2.106)
Industry FE	Yes
Firm FE	No
Year FE	Yes
N	1,574
Hansen test	0.602
Sargan test	0.819
AR1 (p-value)	0.000
AR2 (p-value)	0.660

Table 4: **Endogeneity test through Difference-in-Difference (DID) Analysis**
ROA is defined as operating profit before interest and taxes scaled by book value of total assets, *TREAT* is green firm, *TREAT*POST PARIS* is the variable of interest, *POST PARIS* is the period after Paris Agreement, *ESG SCORE* is the environmental, social and governance performance score, *SOC SCORE* indicates social performance score of firms, *GOV SCORE* is the governance score of firms, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. All continuous variables are winsorized at the 1st and 99th percentile to nullify the effect of outliers.

Panel A: Propensity Score Matching

Variable	*Green*	*Brown*	*Mean-Diff*	*T stat*
ESG SCORE	30.109	33.828	3.719	4.040
GOV SCORE	74.142	75.087	0.945	2.380***
SOC SCORE	13.263	16.382	3.119	2.060**
SIZE	6.681	9.281	2.600	1.300
LEV	1.835	1.426	-0.409	-1.530
OPC	0.040	0.066	0.026	0.530
SGROWTH	0.211	0.280	0.071	1.270***
PPE	5.156	7.920	-2.764	1.090
INTANG	0.033	0.029	-0.004	-2.420
CASH	0.003	0.001	-0.002	-9.810**

Test of endogeneity

H0 = Variables are exogenous

Robust regression F (1, 132) = 11.745 (p = 0.000)

Test of weak instruments

H0 = Instruments are weak

F (2, 904) = 10.900 (p = 0.000)

Cragg and Donald (1993) test

Minimum eigenvalue statistic = 8828.670

Critical values

H0: Instruments are weak

	5%	10%	20%	30%
2SLS Size of nominal 5% Wald test	19.93	11.59	8.75	7.25
LIML Size of nominal 5% Wald test	8.68	5.33	4.42	3.92

Test for over-identifying restrictions

H0 = Instruments are valid

Sargan χ^2 (p-value) = 0.896 (0.3438)

Basmann χ^2 (p-value) = 0.708 (0.401)

Panel B: 2SLS, Difference-in-Difference (DID), Placebo Test, Matched Sample Analysis and Heckman Test

	(1) 2SLS First stage	(2) regression Second Stage	(3) Weighted DID	(4) Difference-in-Difference (DID)	(5) Placebo test	(6) Matched sample analysis	(7) Heckman Test (first stage)	(8) Heckman test (second stage)
GHG INT		-0.890***						-0.001***
		(-22.337)						(-9.404)
TREAT			-0.019***	-0.004***	-0.001			
			(-5.410)	(-7.895)	(-0.117)			
POST PARIS			-0.018***	-0.014***				
			(-4.085)	(-4.875)				
TREAT × POST PARIS			0.017*	0.012***				
			(1.809)	(3.985)				
POST2					-0.021			
					(-1.876)			
TREAT × POST2					-0.004			
					(-1.018)			
ESG SCORE			0.005**	0.002***				
			(2.502)	(3.908)				
GOV SCORE			0.001	0.001***				
			(0.871)	(3.804)				
SOC SCORE			0.001	0.001***				
			(0.321)	(3.102)				
SIZE	8.586***	0.118***	0.018	0.014***	0.001	0.001**	0.050**	0.026*
	(20.064)	(7.716)	(0.519)	(3.414)	(0.275)	(1.728)	(10.221)	(1.808)
LEV	6.650+***	-0.037***	-0.004**	-0.002***	-0.000***	-0.000	-0.571*	-0.020*
	(8.235)	(-5.408)	(-0.589)	(-3.841)	(-5.467)	(-1.084)	(-1.577)	(-1.421)
OCF	8.717	-0.235***	0.044**	0.031*	0.274***	0.256***	-0.426	-0.032
	(1.226)	(-4.748)	(1.920)	(1.417)	(11.416)	(15.039)	(-0.412)	(-1.269)
SGROWTH	-3.650*	0.156***	-0.110***	-0.083***	-0.084***	-0.065***	-0.001***	-0.018**
	(-2.417)	(2.748)	(-3.040)	(-4.417)	(-7.168)	(-6.869)	(-4.404)	(-2.461)
PPE	-23.660	-0.108***	-0.016**	-0.005*	0.004**	0.001	-0.200*	-0.077**
	(-0.522)	(-7.524)	(-2.407)	(-1.903)	(2.496)	(0.753)	1.784)	(-2.088)
INTANG	2.382**	-0.151	-0.052	-0.003	-0.048**	-0.052***	-0.701*	-0.000
	(1.927)	(-1.230)	(-0.072)	(-0.322)	(-2.525)	(-3.149)	(-1.775)	(-1.462)
CASH	16.348	0.980***	0.223	0.064*	0.208*	0.148	1.751	1.111***
	(0.346)	(5.419)	(0.276)	(1.074)	(1.310)	(1.178)	(0.846)	(32.770)
IMR								14.156
								(1.485)
IV1	-0.008**							
	(-12.440)							
IV2	-0.467**							
	(-9.773)							
Constant	5.609***	-0.232***	-0.136	-0.138***	0.057***	0.077***	2.097	-0.106
	(2.724)	(-3.989)	(0.149)	(-9.739)	(6.912)	(11.083)	(1.166)	(-0.914)
Industry FE	Yes	Yes	No	No	Yes	Yes	No	No
Firm FE	No	No	Yes	Yes	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,001	1,001	10,893	12,527	9,486	10,292	1,609	1,609
Adj. R^2	0.448	0.534	0.550	0.499	0.287	0.342	0.495	0.556

Table 5: **Alternative measures of climate risk**

ROA is defined as operating profit before interest and taxes scaled by book value of total assets, *ESG SCORE* is the environmental, social and governance performance score, *ENV SCORE* represents environmental performance score of firms, *SOC SCORE* indicates social performance score of firms, *GOV SCORE* is the governance score of firms, *CRI* is the climate risk index, *EN* is the el-nino index, *PERCP* is the average precipitation per year, *TEMP* is defined as the yearly average temperature in ^{0}C, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. All continuous variables are winsorized at the 1st and 99th percentile to nullify the effect of outliers.

	(1) Transition Risk	(2) Physical Risk	(3) Physical Risk	(4) Climate Risk Index	(5) El Nino
ESG SCORE	0.002***				
	(4.140)				
ENV SCORE	-0.001**				
	(-2.038)				
SOC SCORE	0.001***				
	(2.923)				
GOV SCORE	0.001***				
	(3.303)				
TEMP		-0.005***			
		(-4.022)			
PERCP			-0.001**		
			(-2.191)		
CRI				-0.001***	
				(-8.720)	
EN					-0.010***
					(-2.942)
SIZE	0.011**	0.250***	0.040*	0.026*	0.025
	(2.534)	(7.920)	(2.042)	(1.715)	(0.723)
LEV	-0.001***	-0.002	-0.000	-0.000*	-0.001
	(-2.069)	(-0.301)	(-1.130)	(-1.430)	(-0.910)
OCF	0.141***	0.602***	0.049**	0.019*	0.024*
	(8.986)	(2.128)	(4.021)	(1.915)	(1.814)
SGROWTH	-0.077***	-0.673***	-0.036***	-0.028	-0.024
	(-3.637)	(-0.836)	(-2.644)	(-1.026)	(-0.524)
PPE	-0.006*	-0.084**	-0.007**	-0.019**	-0.106***
	(-1.803)	(-1.936)	(-4.403)	(-1.078)	(-4.102)
INTANG	-0.054**	-0.447*	-0.071	-0.077*	-0.087***
	(-2.026)	(-1.236)	(1.048)	(-1.840)	(-2.029)
CASH	0.210	2.020	0.358*	-0.008	0.177**
	(0.130)	(1.900)	(0.184)	(-0.029)	(1.325)
Constant	-0.119***	0.973***	0.034***	-0.096	-0.158**
	(-2.041)	(0.833)	(5.965)	(0.723)	(-2.046)
Industry FE	No	Yes	No	Yes	No
Firm FE	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	15,626	2,232	2,163	1,607	5,364
Adj. R^2	0.662	0.583	0.487	0.619	0.595

Table 6: **Simultaneous risk exposure**

ROA is defined as operating profit before interest and taxes scaled by book value of total assets, *ENV SCORE* represents environmental performance score of firms, *GHG INT* is the emission intensity derived from greenhouse gas emission, *TEMP* is defined as the yearly average temperature in ^{0}C, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. *TEMP* × *GHG INT, TEMP* × *ENV SCORE*, *GHG INT* × *ENV SCORE* and *GHG INT* × *EN* show the interaction between physical risk and climate risk, physical risk and transition risk, climate risk and climate risk and el nino respectively. All continuous variables are winsorized at the 1st and 99th percentile to nullify the effect of outliers.

	(1)	(2)	(3)	(4)
	ROA	*ROA*	*ROA*	*ROA*
GHG INT	-0.012*		-0.002***	-0.003**
	(-1.965)		(-9.120)	(-2.509)
TEMP × *GHG INT*	-0.003***			
	(-2.801)			
TEMP	0.003	-0.002		
	(0.370)	(-0.801)		
TEMP × *ENV SCORE*		-0.051**		
		(-2.930)		
ENV SCORE		-0.001**	-0.001***	
		(-2.101)	(-4.329)	
GHG INT × *ENV SCORE*			-0.001***	
			(3.143)	
GHG INT × *EN*				-0.001***
				(-3.168)
EN				-0.006
				(-0.068)
SIZE	0.498**	0.034**	0.101*	0.003
	(2.272)	(2.017)	(1.837)	(0.970)
LEV	-0.003	-0.001**	-0.001**	-0.001***
	(0.994)	(-2.250)	(-2.305)	(-3.060)
OCF	0.424***	0.010	0.421***	0.227***
	(5.084)	(1.119)	(4.091)	(4.933)
SGROWTH	-2.501**	-0.080***	-2.086*	0.011
	(-2.265)	(-2.729)	(-1.943)	(0.170)
PPE	-0.017	-0.010	-0.038	-0.016**
	(-0.841)	(-1.206)	(-1.026)	(-2.038)
INTANG	-2.399**	-0.012	-1.973	-0.091
	(-2.064)	(-0.164)	(-0.509)	(-0.792)
CASH	0.584	0.351**	2.320	0.932*
	(0.215)	(2.169)	(0.296)	(2.116)
Constant	0.337	-0.154	0.323	0.104
	(0.672)	(-1.117)	(0.714)	(0.184)
Industry FE	No	No	Yes	No
Firm FE	Yes	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
N	1,540	4,883	1,782	1,607
Adj. R²	0.725	0.798	0.728	0.627

Table 7: **Moderation Analysis by supply chain (*SCM*)**

ROA is defined as operating profit before interest and taxes scaled by book value of total assets, *ENV SCORE* represents environmental performance score of firms, *GHG INT* is the emission intensity derived from greenhouse gas emission, *TEMP* is defined as the yearly average temperature in ^{0}C, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. *TEMP* × *GHG INT, TEMP* × *ENV SCORE* and *GHG INT* × *ENV SCORE* shows the interaction between physical risk and climate risk, physical risk and transition risk and climate risk and transition risk. *PERCP* × *SCHAIN* and *GHG INT* × *SCHAIN* show the interaction between climate risk and physical risk with with the supply chain All continuous variables are winsorized at the 1st and 99th percentile to nullify the effect of outliers.

	(1)	(2)	(3)	(4)	(5)
	ROA	*ROA*	*ROA*	*ROA*	*COGS*
EN	-0.021*				
	(-1.911)				
EN × *SCM*	0.013***				
	(3.415)				
PERCP		-0.001***			
		(-5.050)			
PERCP × *SCM*		0.001***			
		(3.250)			
ENV SCORE			-0.001		
			(-0.961)		
ENV SCORE × *SCM*			0.001**		
			(2.083)		
GHG INT				-0.001***	7.886***
				(-26.430)	(2.746)
GHG INT × *SCM*				0.003***	-1.251**
				(6.890)	(-2.013)
SCM	0.001**	0.001	0.001	-0.004	-1.392***
	(2.983)	(0.668)	(0.595)	(-1.259)	(-2.647)
SIZE	0.101*	0.053*	0.028*	-0.025***	0.259
	(1.837)	(1.829)	(1.617)	(-6.182)	(0.114)
LEV	-0.001**	0.004***	-0.002*	-0.000***	-8.641***
	(-2.305)	(5.171)	(-1.980)	(-2.714)	(-4.166)
OCF	0.421***	0.002	0.018	0.571***	2.638
	(4.091)	(0.083)	(1.715)	(13.048)	(1.418)
SGROWTH	-2.086*	0.046	-0.014	-0.151***	4.330
	(-1.943)	(0.672)	(0.358)	(-7.266)	(0.153)
PPE	-0.038	-0.031**	-0.018**	0.015***	4.868***
	(-1.026)	(-2.014)	(-2.519)	(4.254)	(2.702)
INTANG	-1.973	-0.196	-0.087**	0.001	-9.130
	(-0.509)	(-1.419)	(-2.442)	(0.045)	(-0.428)
CASH	2.320	1.310***	0.108	3.086**	-8.955
	(0.296)	(3.976)	(0.330)	(2.003)	(-0.908)
Constant	0.323	-0.343	-0.137	0.253***	-1.725
	(0.714)	(-0.963)	(-1.136)	(10.660)	(-0.413)
Industry FE	Yes	No	No	No	Yes
Firm FE	No	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	1,782	1,650	2,082	1,661	2,091
Adj. R^2	0.828	0.660	0.619	0.352	0.681

Table 8: **Moderation Analysis by firm size and leverage**

ROA is defined as operating profit before interest and taxes scaled by book value of total assets, *ENV SCORE* represents environmental performance score of firms, *GHG INT* is the emission intensity derived from greenhouse gas emission, *TEMP* is defined as the yearly average temperature in ^{0}C, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by total assets, firms with *LEV* more than median are classified as *HIGH LEV*, *SIZE (HIGH)* is dummy variable for firms with higher median *SIZE*, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. *SIZE (HIGH)* × *GHG INT, SIZE (HIGH)* × *TEMP* and *SIZE (HIGH)* × *ENV SCORE* shows the interaction between climate risk, physical risk and transition risk with firm. with higher size respectively. *HIGH LEV* × *GHG INT* and *HIGH LEV* × *TEMP* show the interaction between climate risk and physical risk with firm with higher leverage respectively. Continuous variables are winsorized at the 1st and 99th percentile.

	(1) *ROA*	(2) *ROA*	(3) *ROA*	(4) *ROA*	(5) *ROA*	(6) *ROA*
GHG INT	-0.030***			-0.002*		
	(-19.301)			(-2.970)		
SIZE (HIGH) × *GHG INT*	0.030***					
	(20.580)					
TEMP		-0.001***			0.003	
		(-2.780)			(0.874)	
SIZE (HIGH) × *TEMP*		0.001***				
		(4.148)				
ENV SCORE			-0.019**			-0.010**
			(-2.308)			(2.316)
SIZE (HIGH) × *ENV SCORE*			0.021***			
			(2.508)			
HIGH LEV × *GHG INT*				-0.078***		
				(12.816)		
HIGH LEV ×*TEMP*					-0.002*	
					(1.921)	
HIGH LEV × *ENV SCORE*						-0.009**
						(-2.179)
SIZE (HIGH)	-1.712***	-0.005	-0.045			
	(-18.091)	(0.716)	(0.128)			
HIGH LEV				-0.023***	-0.027***	0.036
				(-4.798)	(-6.404)	(1.216)
SIZE	0.002	-0.025	-0.233***	0.003	0.023***	0.013***
	(0.121)	(-1.015)	(-10.522)	(0.421)	(4.137)	(2.873)
LEV	-0.005***	-0.001***	-0.001***	-0.001***	-0.001*	-0.000***
	(-6.320)	(-3.040)	(-3.140)	(-5.170)	(3.170)	(-4.043)
OCF	0.232***	0.237***	0.452***	0.222***	0.125***	0.110***
	(6.337)	(6.045)	(4.948)	(6.738)	(5.822)	(7.184)
SGROWTH	-0.128***	0.036	-0.346***	-0.129***	-0.055**	-0.096***
	(-3.048)	(1.523)	(-5.167)	(-2.745)	(-2.725)	(-5.881)
PPE	-0.009	-0.009*	0.049***	-0.003	-0.007*	-0.002
	(-0.813)	(-1.405)	(3.813)	(-0.410)	(-1.904)	(-0.667)
INTANG	-0.012	0.074	0.054	-0.020	-0.056	-0.046
	(-0.976)	(0.815)	(0.688)	(0.373)	(-1.747)	(-1.571)
CASH	1.302	-0.020*	0.114	1.842	0.134	0.100
	(0.925)	(-2.032)	(0.146)	(1.477)	(1.187)	(1.032)
Constant	1.913***	0.064	1.696***	0.132	-0.042	-0.069*
	(9.204)	(0.435)	(7.158)	(0.890)	(-0.748)	(-1.692)
Industry FE	Yes	No	No	No	No	No
Firm FE	No	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1,607	1,800	1,607	1,800	1,167	1,607
Adj. R^2	0.637	0.560	0.637	0.560	0.861	0.644

Table 9: **Green and Brown Firms (Firm Heterogeneity)**

ROA is defined as operating profit before interest and taxes scaled by book value of total assets, *ENV SCORE* represents environmental performance score of firms, *TEMP* is defined as the yearly average temperature in ^{0}C, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets, *BROWN* × *TEMP, BROWN* × *ENV SCORE, GREEN* × *TEMP* and *GREEN* × *ENV SCORE* show the interaction between physical risk and transition risk with brown and green firms. All continuous variables are winsorized at the 1st and 99th percentile.

	(1) *ROA*	(2) *ROA*	(3) *ROA*	(4) *ROA*
TEMP	0.002		-0.003***	
	(0.530)		(-2.810)	
BROWN × *TEMP*	-0.001**			
	(-2.314)			
BROWN (GHG INT)	-0.026	-0.010**		
	(-1.616)	(-2.845)		
ENV SCORE		0.001**		-0.001
		(-2.850)		(-1.140)
BROWN × *ENV SCORE*		-0.001**		
		(-2.857)		
GREEN ×*TEMP*			0.002**	
			(2.563)	
GREEN × *ENV SCORE*				0.001**
				(2.980)
GREEN (GHG INT)			0.021	0.011**
			(1.653)	(1.895)
SIZE	0.022	0.012	0.028	0.005
	(0.922)	(0.719)	(1.518)	(0.419)
LEV	-0.003	-0.000***	-0.007*	-0.002***
	(0.604)	(-5.847)	(-1.814)	(-5.875)
OCF	0.550***	0.170***	0.378***	0.228**
	(6.683)	(6.441)	(6.656)	(6.741)
SGROWTH	0.072	-0.089**	0.085	-0.122***
	(0.938)	(-2.728)	(1.362)	(-2.728)
PPE	-0.030	-0.008	-0.032**	-0.004
	(-1.519)	(0.910)	(-2.046)	(-0.470)
INTANG	-0.046	-0.005	-0.006	-0.005
	(-0.374)	(-1.473)	(-0.087)	(0.503)
CASH	4.212	1.134	3.667	1.738
	(1.360)	(0.920)	(1.541)	(1.420)
Constant	0.114	0.066	0.008	0.137
	(1.106)	(0.466)	(0.180)	(0.867)
Industry FE	Yes	No	Yes	Yes
Firm FE	No	Yes	No	No
Year FE	Yes	Yes	Yes	Yes
N	873	1,607	873	1,607
Adj. R^2	0.618	0.601	0.807	0.633

Table 10: **Financial Constraint Index, Moderation Analysis by Firm Growth (*AGE*) and Internal Carbon Pricing (ICP)**

HP Index financial constraint index, developed by Hadlock and Pierce (2010). *GHG INT* is the greenhouse gas emission scaled by total sales, *ESG SCORE* is the environmental, social and governance performance score, *ENV SCORE* represents environmental performance score of firms, *SOC SCORE* indicates social performance score of firms, *GOV SCORE* is the governance score of firms, *TEMP* is defined as the yearly average temperature in ^{0}C, *AGE (HIGH)* is the dummy variable for firms age higher than median *AGE, AGE (HIGH) x GHG INT, AGE (HIGH) x TEMP, AGE (HIGH) x ENV SCORE, ICP × GHG INT* shows the interaction between firms growth and climate risk, physical risk and transition risk, climate risk and internal carbon pricing respectively, *ICP* is dummy variable denotes internal carbon pricing, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. All continuous variables are winsorized at the 1st and 99th percentile to nullify the effect of outliers. The sample period is from 2010 to 2024.

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
	HP Index	*HP Index*	*HP Index*	*HP Index*	*HP Index*	*HP Index*	*ICP*	*ICP*
ESG SCORE	-0.001							
	(-0.501)							
ENV SCORE	0.001***					0.005*		
	(2.612)					(1.727)		
GOV SCORE	0.000							
	(0.521)							
SOC SCORE	0.001*							
	(1.786)							
GHG INT		0.001**		0.001*				-0.001**
		(-2.233)		(-2.358)				(-2.428)
TEMP			0.003***		0.001			
			(-2.617)		(1.259)			
AGE (HIGH) × GHG INT				-0.001**				
				(-2.166)				
AGE (HIGH) × TEMP					-0.001***			
					(-3.316)			
AGE (HIGH) × ENV SCORE						-0.006***		
						(-3.900)		
AGE (HIGH)				-0.008**	0.019***	-0.225***		
				(-2.467)	(2.772)	(-7.429)		
ICP							0.150***	0.109*
							(2.876)	(1.896)
ICP × GHG INT								0.001**
								(2.471)
SIZE	-0.048***	0.235***	-0.013	0.237***	-0.015	-0.008	-0.200***	-0.193***
	(-5.698)	(18.131)	(-0.633)	(19.667)	(-1.341)	(-0.401)	(-4.210)	(-4.507)
LEV	0.000*	0.000**	0.000	0.000	0.000	0.001*	-0.001*	-0.001
	(1.848)	(2.562)	(0.485)	(1.247)	(0.922)	(1.857)	(-1.840)	(-1.107)
OCF	0.003	0.021*	-0.019*	0.004	-0.008***	-0.083	-0.244	1.058***
	(0.230)	(1.748)	(-1.906)	(0.311)	(-4.671)	(-1.188)	(-1.230)	(3.000)
SGRWOTH	-0.013	-0.058	0.551***	-0.002	0.008	0.483***	-0.138	-0.138
	(-0.574)	(-1.361)	(4.794)	(-0.040)	(0.246)	(3.861)	(-0.587)	(-0.618)
PPE	0.017***	0.014	-0.069***	0.011	0.015**	-0.108***	1.168***	0.100***
	(2.859)	(1.139)	(-3.530)	(1.303)	(2.225)	(-5.563)	(6.674)	(2.629)
INTANG	0.093**	0.058	0.216**	0.132**	0.151***	0.221*	0.106**	-0.242
	(2.054)	(1.010)	(1.976)	(2.113)	(3.136)	(1.709)	(2.509)	(-0.956)
CASH	0.057	1.142*	-0.179*	-0.021	-0.026	3.241***	0.504	1.151**
	(0.259)	(1.791)	(-1.864)	(-0.914)	(-1.225)	(3.547)	(.909)	(2.039)
Constant	-4.065***	-7.232***	-3.778***	-7.230***	-4.388***	-3.582***	1.939***	1.822***
	(-17.649)	(-11.408)	(-13.142)	(-17.130)	(-13.333)	(-16.631)	(8.455)	(7.296)

Industry FE	No	No	Yes	No	No	No	Yes	Yes
Firm FE	Yes	Yes	No	Yes	Yes	Yes	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	15,816	1,585	12,002	2,068	10,300	2,823	2,172	1,574
Adj. R^2	0.494	0.399	0.322	0.499	0.593	0.405	0.639	0.696

Table 11: Corporate Governance and Earning Volatility

PROMOTER represents the proportion of equity shares held by the controlling shareholders (*PROMOTER*), *INST* represents institutional investors, *FII* represents foreign institutional investors, and *RETAIL* represents non-institutional investors, *EVOL* is the standard deviation of *ROA* over five-year rolling window. *GHG INT* is the greenhouse gas emission scaled by total sales, *ESG SCORE* is the environmental, social and governance performance score, *ENV SCORE* represents environmental performance score of firms, *SOC SCORE* indicates social performance score of firms, *GOV SCORE* is the governance score of firms, *TEMP* is defined as the yearly average temperature in ^{0}C, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. All continuous variables are winsorized at the 1st and 99th percentile to nullify the effect of outliers. The sample period is from 2010 to 2024.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PROMOTER	*INST*	*FII*	*RETAIL*	*EVOL*	*EVOL*	*EVOL*
GHG INT	-0.173***	-0.025***	-0.022***	-0.047***	0.001***		
	(-3.450)	(-4.332)	(-2.772)	(-2.785)	(2.744)		
ESG SCORE						-0.001*	
						(-1.765)	
ENV SCORE						0.001***	
						(2.672)	
GOV SCORE						-0.001	
						(-0.204)	
SOC SCORE						-0.001	
						(-1.020)	
TEMP							0.001**
							(2.021)
SIZE	18.886***	2.135	0.750	-1.988	0.021	-0.023***	-0.005**
	(2.895)	(1.497)	(0.615)	(-0.701)	(1.299)	(-3.202)	(-2.366)
LEV	0.156	0.002	0.012***	-0.018*	0.000	0.000	0.000
	(0.344)	(0.465)	(4.681)	(-1.664)	(1.481)	(0.075)	(0.280)
OCF	0.446	1.891	1.675	-16.357***	-0.017	-0.007*	-0.092**
	(0.046)	(1.093)	(1.274)	(-3.910)	(-0.830)	(-1.749)	(-2.008)
SGROWTH	-23.055***	-6.247	-4.271	2.140	-0.001	0.041**	0.006
	(-3.734)	(-1.085)	(-0.977)	(0.946)	(-0.021)	(2.260)	(0.412)
PPE	2.690**	0.451	-0.321	-0.841	-0.002	-0.009*	-0.001
	(2.320)	(0.604)	(-0.507)	(-0.901)	(-0.205)	(-1.898)	(-0.686)
INTANG	-0.737	0.464	0.060	-0.683**	0.002	-0.001	0.003***
	(-1.195)	(1.330)	(0.251)	(-2.117)	(0.934)	(-0.502)	(3.463)
CASH	27.150**	6.739**	8.939***	-32.480	-0.015	0.078**	0.411*
	(2.201)	(1.971)	(3.050)	(-0.362)	(-0.377)	(2.234)	(1.882)
Constant	77.584***	-4.647	6.942	25.223***	-0.194	0.314***	0.071***
	(6.277)	(-0.299)	(0.580)	(4.842)	(-1.280)	(6.061)	(5.652)
Industry FE	No	No	Yes	No	No	No	Yes
Firm FE	No	Yes	No	Yes	Yes	Yes	No
Year FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Year-Industry FE	Yes	No	No	No	No	No	No
N	1,509	2,076	2,065	1,642	1,233	8,022	5,244
Adj. R^2	0.482	0.510	0.687	0.139	0.483	0.636	0.126

Table 12: **Project Level Data**

ESG SCORE is the environmental, social and governance performance score, *ENV SCORE* represents environmental performance score of firms, *GHG INT* is the emission intensity derived from greenhouse gas emission, *CDRI* is the climate driven INFORM risk indicator, *TRISK* is the energy transition index *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by total assets, *SCHAIN* is the composite supply chain measure, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. *ENV SCORE x SCHAIN* shows the interaction between transition risk and supply chain. Continuous variables are winsorized at the 1st and 99th percentile.

	(1)	(2)	(3)	(4)
	PROJCOST	*PROJCOST*	*PROJCOST*	*PROJCOST*
TEMP	0.283**			
	(2.316)			
PERCP			0.015*	
			(1.947)	
ESG SCORE		-0.046		
		(0.057)		
ENV SCORE		0.059**		0.002*
		(2.932)		(1.711)
ENV SCORE × SCM				-0.001**
				(-3.901)
SCM				0.032*
				(1.718)
SIZE	-6.151*	-1.895**	-4.307*	-3.353
	(-1.987)	(-2.102)	(3.387)	(-1.293)
LEV	0.149	0.145	0.053	-0.001
	(0.875)	(1.307)	(0.431)	(-0.017)
OCF	-8.535	-2.062	-2.919	-0.019
	(-0.915)	(-1.614)	(-0.583)	(-0.167)
SGROWTH	-1.746	-2.285*	-1.481*	3.309
	(9.845)	(-1.981)	(-1.951)	(2.979)
PPE	8.106***	1.723*	4.536***	0.013
	(3.475)	(1.913)	(2.885)	(1.011)
INTANG	-3.396*	-3.481	-3.080*	3.508
	(-1.801)	(-1.313)	(-1.803)	(1.240)
CASH	4.375	1.825	2.931	-3.653
	(1.809)	(0.509)	(0.733)	(-0.369)
Constant	-2.284	8.658*	-8.646	0.443**
	(-1.903)	(1.073)	(-0.693)	(0.180)
Industry FE	No	Yes	No	No
Firm FE	Yes	No	Yes	No
Year FE	Yes	Yes	Yes	No
Industry-Year FE	No	No	No	Yes
N	9,127	6,578	9,127	6,939
Adj. R^2	0.193	0.250	0.294	0.915

Table 13: **Robustness test**

ROA is defined as operating profit before interest and taxes scaled by book value of total assets, *TobinsQ* is computed as market value of equity plus long term debt plus current liabilities scaled by book value of total assets, *ENV SCORE* represents environmental performance score of firms, *TEMP* is defined as the yearly average temperature in ^{0}C, *GHG INT* is the emission intensity derived from greenhouse gas emission, *CDRI* is INFORM risk indicator, *TRISK* is energy transition index, *SIZE* is defined as the natural logarithmic of total assets, *LEV* is defined as ratio of debt to equity, *SGROWTH* is the growth rate of net sales, *OCF* is cash flow from operating activities scales by book value of total assets, *PPE* is defined as gross property, plant, and equipment scaled by total assets, *INTANG* is the ratio of intangible assets and total assets, *CASH* is firms cash holding scaled by total assets. All continuous variables are winsorized at the 1st and 99th percentile

	(1)	(2)	(3)	(4)	(5)
	TobinsQ	*TobinsQ*	*TobinsQ*	*TRISK*	*CDRI*
ESG SCORE	0.041				
	(1.428)				
ENV SCORE	-0.030**				
	(-1.918)				
SOC SCORE	0.030*				
	(1.416)				
GOV SCORE	-0.007				
	(-0.740)				
TEMP		-0.006**			
		(-2.293)			
GHG INT			-0.002**		
			(-2.021)		
TRISK				-0.001***	
				(-3.449)	
CDRI					-0.010***
					(-3.175)
SIZE	0.176	0.136	9.991***	-0.158***	0.004*
	(0.346)	(0.277)	(3.085)	(-11.569)	(1.924)
LEV	-0.004*	-0.001	-0.002*	-0.001	-0.001
	(-0.984)	(-1.370)	(-1.911)	(-1.198)	(-1.226)
OCF	0.462**	1.957***	0.126	0.813***	0.068
	(1.260)	(4.485)	(0.141)	(10.982)	(1.390)
SGROWTH	-0.846	0.437	-1.075***	-0.687***	-0.045***
	(-1.529)	(0.787)	(-2.610)	(-10.214)	(-3.196)
PPE	-0.138*	-0.222***	-0.346	0.082***	-0.003
	(0.858)	(-3.563)	(-1.358)	(6.353)	(-1.568)
INTANG	-2.774***	0.343	10.282***	-0.077	-0.062***
	(-3.011)	(0.321)	(3.924)	(-0.950)	(-4.468)
CASH	5.186	2.939***	3.933***	0.104	0.836***
	(1.047)	(2.617)	(3.932)	(0.165)	(8.960)
Constant	5.854***	0.532*	8.065***	1.980***	0.086***
	(3.021)	(0.107)	(4.910)	(28.934)	(3.494)
Industry FE	No	Yes	Yes	Yes	Yes
Firm FE	Yes	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes
N	10,071	5,160	1,607	8,286	6,672
Adj. R^2	0.642	0.312	0.539	0.468	0.557

Appendix 1

Variable	Description
Return on Assets (*ROA*)	Earnings before interest and taxes scaled by book value of total assets
TobinsQ	(Market value of equity + long term debt + current liabilities)/book value of total assets
CRI SCORE	Climate risk index published by Germanwatch
TEMP	Average of monthly maximum and minimum temperature exposure of firm over a year.
PERCP	Precipitation exposure of the firms
$ENV\ SCORE$	Reflects the environmental performance, carbon emission, energy efficiency policy of the firm.
$GOV\ SCORE$	Reflects a company's ability to manage and control its operations effectively through best management practices
$SOC\ SCORE$	Reflect the social performance and commitment of the firm to the community
$ESG\ SCORE$	It measures a firm performance in three key areas: environmental, social, and governance
CTAX	₹400 per tonne of coal (carbon emission)
SIZE	Natural logarithm of the book value of total assets
SGROWTH	Growth rate of net sales
LEV	Ratio of total debt to total assets
INTANG	Ratio of intangible assets and total assets Gross property, plant, and equipment scaled by total assets
PPE	Property, plant and equipment scaled by total assets
OCF	Cash flow from operating activities scales by book value of total assets
CASH	Cash holding of firms scaled by book value of total assets
SCHAIN	Composite supply chain score
EN	Index for el-nino
PROJCOST	Cost of projects completed.
EVOL	Standard deviation of *ROA* over five-year rolling window
AGE	Firm growth
γ_i	Firm fixed effect
δ_T	Year fixed effect
ϑ_j	Industry fixed effect

Appendix 2

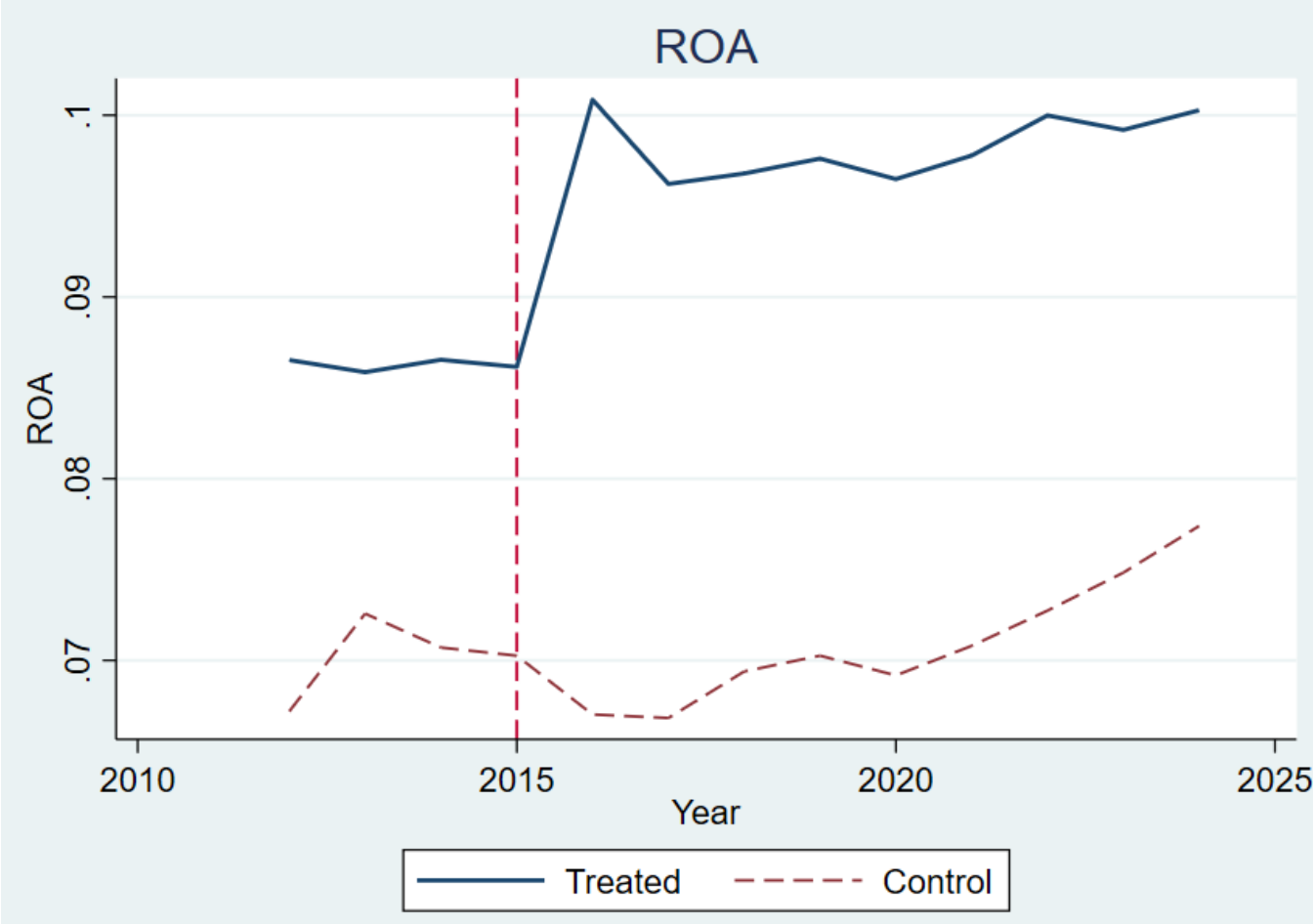


Figure 1: Parallel trend assumption

This picture reflects the parallel trend for matched treated and control firms. *ROA* is measured as operating profit before interest and taxes scaled by book value of total assets. Paris Agreement is a global climate treaty in 2015, focuses on limit global warming and reduce adverse effects of climate risk. The picture shows that before Paris Agreement; the treated and control firms show similar path. But after the Paris Agreement, there is a positive impact of climate risk for treated firms, but it affects the controlled firms negatively.