Climate Change Risks, Capital Structure Dynamics, and ESG-Driven Financial Flexibility: International Evidence from Top Emerging Economies

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Abstract:

The current study examines the impacts of climate change risks on capital structure dynamics with international evidence from the top polluting emerging market economies, including Brazil, China, and India. The study shows that corporate climate risk exposure induces firms to rely more on debt financing for financial flexibility balances. The climate treatment effects on capital structure decisions remain robust when the study accounts for corporate sensitivity to global warming phenomena. Broad-based financial development, environmental policy stringency, and corporate sales growth are the ESG-driven financial flexibility mechanisms. While debt financing choices play crucial roles in financial flexibility, ESG-driven channels jointly affect corporate financing policies, leading to corporate deleveraging incentives to mitigate potential financial distress risk. Corporate dividend payout policy mediates the relationship with predicted mitigated climate exposure risk effects on corporate leverage. Furthermore, corporate sales growth and national aggregate financial developments mitigate financial constraints, with corporate proactive leverage increasing when firms are exposed to climate risks. Our international empirical evidence from the world's top polluting emerging markets offers insightful predictions on the dynamic capital structure decisions for firms' financial flexibility choices under the growing climate risk exposure effects with the thorough assessments of the tested ESG-driven mechanisms.

Keywords: Global warming, climate change risks, ESG factors, financial flexibility choices, corporate decisions.

JEL code: G3.

I. Introduction

Climate change due to rising carbon dioxide (CO_2) concentrations is the ultimate challenge to the world economy (Nordhaus, 2019). CO_2 concentrations have been a major challenge for the green transition in the world's emerging economies, such as China, Brazil, and India, which are among the top polluting countries, as shown in Figure 1. The figure shows that, as of 2023, China, India, and Brazil are the leading emerging polluting economies that have records of 15.9B, 4.1B, and 1.3B for the total greenhouse gas emissions (GHG), respectively, and are displayed in equivalents of millions of tons of CO_2 (Mton CO_2eq), as reported in Figure 2. As GHG emissions rise, the global climate transition commitments have become highly sensitive to corporate financial decisions through multiple mechanisms. For advanced economies like Australia, the Kyoto Protocol ratification has been an exogenous policy shock to carbon-intensive firms, leading to degraded financial performance with adaptive financing policies due to financial distress risks (Nguyen & Phan, 2020; Nguyen et al., 2025; Nguyen., 2018). Australia's climate commitment induces an increasing cost of capital for polluting firms, leading to financial deleveraging and decreased probability of dividend payouts. The prior studies for Australia highlight that the effects of carbon risk due to the exogenous climate transition policy are specifically pronounced for highly financially constrained firms. For leading advanced economies like the US, forward-looking physical climate risk could also lead to corporate deleveraging, specifically in the post-2015 Paris Agreement (COP21) event (Ginglinger & Moreau, 2023). Corporate deleveraging due to climate risk could be driven by both the demand and supply sides for a firm's optimal leverage levels, as well as the increasing awareness of stakeholders to diverse climatic consequential outcomes for the US markets (Dang et al., 2023; Ginglinger & Moreau, 2023; Huynh et al., 2020; Kovacs et al., 2025; Nguyen et al., 2022). Internationally, there is mixed evidence regarding the effects of climate risks on corporate financing decisions (Huang et al., 2018; Pankratz et al., 2023). However, the

GHG exposure risks and corporate sensitivity to climate risk drivers that exacerbate uncertainty in firm performance and lead to volatile financial decisions seem inevitable, as evidenced by prior literature. The current study complements the growing literature with international evidence on corporate climate exposure, liquidity risk, and financial decisions of listed firms for the top emerging polluting economies, namely Brazil, China, and India.[2] The study adds to the prior literature with a comprehensive assessment of ESG-driven financial decisions when firms are exposed to liquidity risks due to climate change in the top-polluting emerging markets. The choice of international sample also presents the world's top emerging markets, along with their environmental sustainability perspectives.[3]

The motivations for the current research are at least threefold. First, while there is growing literature on quantifying firm-level climate change exposures using textual analyses of annual 10-K reports (Li et al., 2024; SAUTNER et al., 2023), corporate climate sensitivities may significantly rely on exogenous risk drivers. For instance, a recent study documents the local GHG exposure effects on corporate financial decisions with a prediction of severe liquidity shrinkages (Trinh, 2025). Under the sovereign statewide GHG exposure, the study offers comprehensive evidence on controlling endogenous climate risks (i.e., firm-level climate risk exposure measures) and exogenous climate risk drivers (i.e., local climate policies, national climate policy uncertainty). The study empirically proves its theoretical predictions that endogenous climate risk drivers follow the severity levels of exogenous GHG exposure effects as the long-lasting roots of climatic change phenomena. Such arguments are aligned with the established literature on the ultimate challenge of climate change for economics (Nordhaus, 2019). The heat-trapping GHG exposure levels lead to global warming (warmer temperature change anomalies) worldwide due to human activities, primarily from fossil fuel burning.[4] As

[2] See World's Top Emitters Interactive Chart I World Resources Institute (wri.org)
[3] The Top Emerging Markets in the World | Nasdaq
[4] What Is Climate Change? - NASA Science

presented in Figure 3, the top polluting emerging countries (Brazil, China, and India) have experienced abnormal warming temperature changes compared to their 1951-1980 baseline temperature values. The speed of global warming in those top polluting countries has been even faster than the global average, as shown in Figure 4. The figures might imply that the treatment effects of corporate climate risks on financial decisions in those polluting countries could have been significantly driven by temperature change. This current study captures corporate climate risks by both the firm-level climate risk measure offered by Sautner et al (2023) and the treatment effects of temperature change on financial decisions for listed firms in the top-polluting emerging countries.

Our cross-country evidence from the top emerging polluting countries shows a strong positive and significant association between corporate climate risk (CC-Risk) and corporate leverage. The baseline ordinary least squares (OLS) estimates show that a unit change in CC-Risk induces a predicted increase in leverage of 0.20 units. The predicted associations are constant when the study controls corporate ESG performance ratings in our baseline estimations. The baseline estimates present adverse associations between ESG ratings (specifically the Environmental performance) and financial leverage. The adverse and statistically significant associations are also presented for the predicted relationships between dividend yield (Yield), operating cash flows (OCF), quick ratio, and leverage decisions. On the other hand, there is a predicted positive relationship between firm size and leverage. Our OLS estimates present robust evidence, controlling multiple fixed effects (FE) for time (Year FE), industries (Industry FE), and country (Country FE) levels with robust standard errors clustered by firm levels. The positive relations between CC-Risk and leverage remain robust when the study tests for the treatment effects of temperature change on corporate climate risk exposure effects on leverage decisions. The regressions on treatment show that treated firms are likely to increase leverage by a 0.05-unit change, compared to control firms. The treatment effects on leverage remain robust when the study tests on the matched sample of firms between treatment and control groups with the propensity scores matching (PSM) method. The treatment regressions reaffirm the predicted relationships between leverage decisions and firm characteristics. The findings show that larger firms with higher tangibility are likely to have higher leverage. On the other hand, firms with higher profitability, innovation investment (R&D expenditure), dividend yield, operating cash flow, and quick ratios are likely to have lower leverage. Our treatment regressions remain robust when the study includes macroeconomic fundamentals, including GDP annual growth and inflation (GDP deflator %) rates for both the full and matched-sample regressions. Figure 5 visualizes the yearly-mean trends of corporate climate risk and leverage ratios by country for the past decades. The visualization shows relative co-movements between corporate climate risk and leverage ratios over the years across the sample countries. Figure 6 presents the trends of the global-mean monthly, seasonal, and annual means of the temperature values. The figure offers further information on the Combined Land-Surface Air and Sea-Surface Water Temperature Anomalies (Land-Ocean Temperature Index, L-OTI), showing the escalating global warming phenomena worldwide. Visualization supports our empirical settings to validate our assumptions on the treatment of effects of corporate sensitivity of temperature change as reflected via corporate climate risk measurement. The study hereby makes use of temperature change of the sample countries to capture the climate treatment effect on corporate climate-induced dynamic capital structure decisions for the current research.

Our in-depth analyses offer critical contributions to related literature. Broad-based financial development (FD), environmental policy stringency indexes (EPSI), and sales growth (Sales/Assets) are the reliable ESG-driven mechanisms of corporate financial flexibility decisions. Controlling the multidimensional developments of financial institutions (FI) and markets (FM), with the joint effect of FD, treated firms present proactive leverage increase. On the other hand, controlling the FD and climate treatment exposure risks both have direct adverse effects on corporate leverage decisions. Similar evidence is observed for the joint positive effect of EPSI and climate treatment effects on leverage decisions. However, under the joint effect of stringent environmental policies in our models, treated firms show their leveraging incentives. Sales growth presents an adverse joint effect on leverage decisions for firms treated, with its direct negative effect. With the joint effect of sales growth, treated firms present a positive leverage increase. Mediation analyses show the mediating effect of corporate dividend payouts on the relationship between climate treatment risk exposure and leveraging decisions for financial flexibility. For all fitted models used in our mediation analyses, treated firms maintain a proactive increase in leverage. Also, treated firms present positive dividends commonly paid to shareholders.

Our quasi-experimental designs with the difference-in-differences (DID) analyses show that financial flexibility decisions of treated firms have become even more divergent since the Paris Agreement (COP21) event. At first glance, broad-based financial development supports the leverage incentives of treated firms to choose financial flexibility. On the other hand, the global climate transition risk (COP21) and stringent environmental policies hinder corporate incentives to increase expected leverage. Comprehensively controlling all the risk drivers altogether, our findings support the expected theoretical notion that leverage jumps remain critical to firms in coping with the climate treatment risk exposure effects. However, optimal leverage levels of firms in their capital structure mix rely on sales growth as well as exogenous risk drivers that have been thoroughly tested throughout the study. The findings support the complex supply and demand side effects of climate exposure risks on corporate financial flexibility decisions for listed firms in the sample countries. The current research offers critical implications to theoretically support growing empirical evidence in the related niches of literature as follows.

First, our international evidence from the world's top emerging market economies highlights the increasing importance of debt financing leverage decisions in securing the financial flexibility of firms. Our findings support international evidence on the increasing likelihood of long-term debt-leverage decisions when firms face increasing physical risks. Notably, the current research employs global warming as a proxy to capture the treatment effects of climate risks on capital structure decisions among listed firms. Our empirical settings are built on the challenging fact that the top emerging markets have been experiencing fast-growing abnormal warming phenomena due to enormous greenhouse gas emissions (GHG) exposure effects in recent decades. While firms may respond significantly and promptly to event-based disaster risks, tracking firm-level climate exposure risk conditioning on the levels of global warming phenomena brings us additional insights into the long-term risk exposure of climate change on corporate financial decisions. The capital structure decisions for the study have been assessed by the three important mechanisms, including i) broad-based financial development, ii) environmental policy stringency index, and ii) corporate sales growth. As elaborated throughout the study, the tested channels offer in-depth insights into how ESG-driven mechanisms may have affected corporate financing decisions under climate risk exposure for the top emerging market economies. Regarding the pecking order theory, debt financing offers favorable financing choices for firms' financial flexibility conditions for operating needs, especially in the face of long-term climate risk exposure in the top polluting economies. Our evidence has been supported further when the study tests corporate sales growth and dividend payout policy from firms' risk management decisions. The findings show that sales growth supports firms in relying less on debt financing when firms are exposed to climate risks. Additionally, firms with maintained free cash flows being distributed to shareholders also present a lower level of debt reliance on operational financing needs. For such circumstances, for financial flexibility conditions, firms could optimize their capital structure mixed between equity and debt options with tax benefits over the potential financial distress risk under climate risk exposure drivers, along with nationwide environmental and economic conditions. Our international evidence may imply that climate treatment effects may have induced firms to increase leverage for tax shields' benefits, with expected optimally effective cost of capital, regarding the trade-off theorem of capital structure.

Second, the current research offers critical insights into the incentives of corporate deleveraging practices, for which firms may face risky financial distress when raising debt financing proportions in the face of chronic climate risk exposure. Corporate deleveraging practices have been observed when firms are facing evolving, stringent environmental policies, specifically for treated firms in the post-period of the Paris Agreement since 2015. However, controlling for the corporate ESG performance ratings, corporate deleveraging may imply the historical financial flexibility conditions of firms with their lower debt leverage needs for investments and operating needs. Notably, for the world's top emerging markets, even though dividend payout policies show a mediating effect of the predicted lower leverage levels, treated firms have maintained positive free cash flows to be distributed to shareholders. Therefore, our thoroughly tested ESG mechanisms explain the multifaceted incentives that firms may opt for corporate deleveraging practices. Our adverse evidence from the ESG-related factors offers critical insights into the reliable impacts of sustainability perspectives on corporate financing policies. The adverse relationships between corporate leverage and climate treatment effects through the lens of the tested ESG-related channels show that capital structure mixes could have been dynamically adjusted by firms for coping with climate risk exposure effects, as well as their financial flexibility incentives. Furthermore, the levels of the aggregate developments of financial institutions and markets, with their depth, access, and efficiency, also impose multifaceted joint contributions to corporate leverage decisions when firms are being exposed to climate risks. For the direct effects, listed firms are less likely to rely on leverage increases in the top emerging markets. On the other hand, aggregate financial developments support treated firms with increasing access to credit sources with proactive leveraging practices for their business operations.

The remaining parts of the study are structured as follows: Section 2 elaborates on the data and methodology with its sub-sections that provide detailed variables, sources, and empirical model settings. Section 3 provides empirical findings and a detailed discussion with supporting references for the contributions of the study. Section 4 offers conclusions on the main findings, policy implications, and future directions for related literature streams. Additional findings and supportive figures for the study are provided in the appendices.

II. Data and methodology

2.1. Variables and data sources.

2.1.1. Firm-level climate change risk measure.

The study collects data from multiple sources. We collect data on firm-level climate change risk (CC-Risk) from SAUTNER et al. (2023) for the top three polluting emerging markets, namely Brazil, China, and India.

2.1.2. Temperature change.

The study extracts temperature change data for the selected countries from the Climate Change Indicators Dashboard of the International Monetary Fund (IMF). Temperature change is used as a measure to capture the sensitivity of corporate climate risk (CC-Risk) to nationwide climate change. Regarding the IMF, the temperature change presents the annual estimates of the mean surface temperature change measured with respect to the baseline climatology, corresponding to the period 1951-1980. The temperature estimates of the mean surface temperature are presented, in degrees Celsius, for the sample countries. The study uses temperature change to construct a treatment dummy for our empirical analyses at a later stage to support our theoretical notion.

2.1.3. Corporate ESG performance ratings and financial accounting data.

The study collects corporate ESG data from the LSEG workspace, formerly known as the Thomson Reuters DataStream and Refinitiv Eikon (formerly Asset 4), for the sample firms with headquarters operating in the selected countries. The study also extracts corporate financial accounting fundamentals from the LSEG workspace.

2.1.4. Broad-based financial development (FD) index.

The study extracts data on the broad-based financial development (FD) index from the IMF database. Overcoming single proxies in the prior literature, the study uses the FD database offered by Svirydzenka (2016). The FD index captures the multidimensional developments of financial institutions (FI) and financial markets (FM) for the selected countries, including their depth, access, and efficiency sub-index measures.

2.1.5. Environmental policy stringency index (EPSI).

The study extracts the Environmental Policy Stringency Index (EPSI) from the OECD statistics. The study employs an updated EPSI database offered by Tobias et al. (2022). The updated EPSI database offers updates on non-OECD countries for the selected economies for the current study, including Brazil, China, and India. The ESPI database offers data back to 1990. EPSI includes a new sub-index that captures the capacities of the sample countries' technology support policies, complementing the comprehensive structure of market-based and non-market-based sub-indexes for the aggregate EPSI measure.

2.1.6. Macroeconomic fundamentals.

The study extracts macroeconomic fundamentals for the sample countries from the World Development Indicators (WDI) of the World Bank Group. The macroeconomic fundamentals include the annual GDP growth (%) and the inflation rate (GDP deflator %). After merging several databases, our merged panel data includes 3,834 country-firm-year observations for the period 2002-2020.

2.2.Methodology

2.2.1. OLS estimates

The study first establishes the association between CC-Risk and corporate leverage with the following baseline regression model:

$$TDA_{i,j,t+1} = \alpha + \beta_1 CCRisk_{i,j,t} + \beta_2 ESG_{i,j,t} + \beta_k \sum_{i=0}^{n} Controls_{i,j,t} + \varepsilon \quad (1)$$

$TDA_{i,j,t}$ is the fraction of total book debt to book assets that measures the corporate leverage for firm i in country j in year t. TDA is the widely used measure of corporate leverage in the corporate finance literature (Ellul & Pagano, 2019; Hovakimian & Hovakimian, 2021; Saretto & Tookes, 2013). Regarding SAUTNER et al. (2023), our main independent variable $CCRisk_{i,j,t}$ is the firm-level climate change risk that presents the frequency with which bigrams associated with climate change are referenced in the transcripts of earnings conference calls in the same sentence as the terms "risk" or "uncertainty". We include a diverse set of corporate and macroeconomic controls, including firm size, profitability, R&D, tangibility, dividend yield, operating cash flow (OCF), quick ratio, GDP growth, and inflation rate. The details of the variables are provided in Appendix A1. $ESG_{i,j,t}$ indicates corporate overall ratings on environmental (E), social (S), and governance (G) performance. We also test for the sub-pillar scores for the baseline estimates. To validate the impact of climate-related risk on financial leverage, we further use the national carbon emissions per capita for our robustness test, reported in Appendix A3. The Environmental Policy Stringency Index database is extracted from the OECD statistics.[5]

2.2.2. Propensity Scores Matching (PSM)

The measure of CC-Risk by SAUTNER et al. (2023) reveals the focus that participants in earnings calls had on the risk of firms to climate change, but what induces firms to pay attention to climate risk? To mitigate the endogeneity issues due to a single biased measure, we employ temperature change with the following regression model:

$$TDA_{i,j,t} = \alpha + \beta_1 Treated_{i,j,t} + \beta_k \sum_{i=0}^{n} Controls_{i,j,t} + \varepsilon \quad (2)$$

Treated is a dummy variable that is set equal to one for firms with an observed increase in ΔTDA experiencing positive temperature change. Temperature change is a fundamental measure for benchmarking climate change (EPA, 2024). A temperature anomaly is defined as a deviation from a long-term average or reference value. In contrast to a negative anomaly, which shows that the observed temperature was lower than the reference value, a positive anomaly shows that the recorded temperature was higher. Therefore, we employ $Treated_{i,j,t}$ as the main independent variable from now onward to mitigate the endogeneity issues when using CC-Risk. The rationale explained by the modern literature on corporate climate risk is that larger firms with fewer financial constraints have higher ESG ratings, but are also more carbon-intensive than younger, smaller firms

[5] OECD Environmental Policy Stringency Index, including emerging markets (e.g., China, Brazil, and India) is publicly accessible at [Measuring environmental policy stringency in OECD countries | OECD]

Prior literature may fail to mitigate such endogeneity issues when using industry-level carbon intensity levels to identify corporate emitters (Nguyen & Phan, 2020). We use propensity score matching (PSM) to test the matched sample on comparable corporate and national controls for firms between the control (untreated) and treated groups.

2.2.3. Channel tests

The study examines the three channels into the relationship between corporate climate risks and corporate leverage decisions. The channels include i) broad-based financial development (FD), ii) environmental policy stringency index (EPSI), and iii) corporate sales growth (Sales/Assets). The regression models for our channel tests are presented as follows.

$$TDA_{i,j,t} = \alpha + \beta_1 Treated_{i,j,t} + \beta_2 FD_{j,t} + \beta_3 Treated \times FD_{i,j,t} + \beta_k \sum_{i=0}^{n} Controls_{i,j,t} + \varepsilon \quad (3)$$

$$TDA_{i,j,t} = \alpha + \beta_1 Treated_{i,j,t} + \beta_2 EPSI_{j,t} + \beta_1 Treated \times EPSI_{i,j,t} + \beta_k \sum_{i=0}^{n} Controls_{i,j,t} + \varepsilon \quad (4)$$

$$TDA_{i,j,t} = \alpha + \beta_1 Treated_{i,j,t} + \beta_2 Sale/Assets_{i,j,t} + \beta_1 Treated * Sale/Assets_{i,j,t} + \beta_k \sum_{i=0}^{n} Controls_{i,j,t} + \varepsilon \quad (5)$$

Models 3-5, respectively, estimate the channeling effects of the selected mechanisms (FD, EPSI, and corporate sales growth) to the treatment effects of corporate climate risks on leverage decisions. For emerging economies, financial developments play a crucial role in firm survival (Tsoukas, 2011). Furthermore, firm growth may rely on access to financing sources, with international evidence (Marcelin & Mathur, 2015). Notably, the study employs a broad-based index of financial development for our sample countries with the channel test. The use of the broad-based FD measure offers an insightful and complex nature of the development of financial systems, including markets and institutions, with an aggregate of nine sub-proxies (Iorember et al., 2020; Nathaniel, 2021; Svirydzenka, 2016; Trinh et al., 2026). For less financially developed economies, firm innovation could have amplified impacts on productivity (Dabla-Norris et al., 2012). Stringent environmental policies could have more prominent effects on corporate leverage incentives due to climate-risk exposure and corruption. For manufacturing firms, stringent environmental policies could have a long-term positive impact on a firm's financial performance, compared to their shorter-term adverse effects (Chomachaei & Golmohammadi, 2023). Stringent environmental policies may have urged increasing innovation investments for sustainable development (Elsayed et al., 2026). Debt financing is crucial to innovation and firm growth (Geelen et al., 2021). Financial flexibility for operating needs could be an important driver for firms with leverage jumps (Denis, 2011; Denis & McKeon, 2016). Corporate financial decisions could be dependent on a firm‘s sales growth as the critical factor to corporate financial distress forecasts (Whited & Wu, 2006). Collectively, the study implements channel tests for the three discussed mechanisms for further empirical insights. Notably, the study employs the treatment dummy to capture the corporate risk sensitivities to leverage decisions for treated firms that are exposed to temperature change, with their observed increasing climate exposure risk. The multifaceted treatment dummies support our theoretical validations of the baseline leverage decisions predicted under climate exposure risks, with the important channels tested in the study. Our channel tests could provide crucial complementary evidence for the related niches of the literature, specifically for our evidence from the world’s top-polluting emerging market economies, namely China, Brazil, and India.

2.2.4. Mediation estimates with Sobel-Goodman tests.

Cash-flow sensitivity could play an important role as a determinant of corporate payout policy (Chay & Suh, 2009). Return volatility may have adverse effects on dividends paid as well as the probability of paying dividends. Corporate payout decisions are also sensitive to the earned/contributed capital mix between debt and equity financing choices. Firms may also consider payout decisions regarding their agency issues, profitable investment opportunities as well as the maturity of the firm's life cycle. For large economies like the US, in the 21st century, firms have been increasingly paying out their free cash flows as they have experienced decreasing capital expenditure since the 2000s (Kahle & Stulz, 2021). To mitigate costly financial distress and underinvestment, payout decisions are crucial to risk management strategies of firms (Bonaimé et al., 2013). Flexible distributions of financing choices are critical to financial hedging for firms 'operations with substitutes. Payout decisions also offer insightful implications to firms' growth prospects with flexibility choices (Brav et al., 2005; Chay & Suh, 2009; Denis, 2011; Lie, 2005). Motivated by the related studies in prior literature, the study implements mediation analyses for the current evidence from the top polluting emerging market economies. Our mediation analyses are presented in the following equations.

$$TDA_{i,j,t} = \alpha + \beta_1 Treated_{i,j,t} + \beta_k \sum_{i=0}^{n} Controls_{i,j,t} + \varepsilon \quad (6)$$

$$DIV_{i,j,t} = \alpha + \beta_1 Treated_{i,j,t} + \beta_k \sum_{i=0}^{n} Controls_{i,j,t} + \varepsilon \quad (7)$$

$$TDA_{i,j,t} = \alpha + \beta_1 Treated_{i,j,t} + \beta_2 DIV_{i,j,t} + \beta_k \sum_{i=0}^{n} Controls_{i,j,t} + \varepsilon \quad (8)$$

Our mediator presents the corporate dividend policy (DIV). $DIV_{i,j,t}$ captures corporate common cash dividends paid to shareholders. First, the study regresses the dependent variable (DV), presenting corporate leverage (debt to assets ratio - TDA) on the independent variable for the treatment dummy (IV – Treated or Treatment) and the control variables (CVs). The coefficient on the IV represents the total effect (TE) on the Treated, removing the portioned effect explained by the mediator, as presented in Equation 5. Second, the study regresses the mediating variable (DIV) on the IV (Treated) and control variables, as presented in Equation 6. Third, the study regresses the DV (TDA) on both the IV (Treated) and the MV (DIV for dividend payout), as well as the same set of control variables used throughout the study. The study hereby reports the Sobel-Goodman tests for our affirmed mediating effects of corporate payout policy on the predicted relationships between corporate climate treatment and leverage decisions of our sample listed firms, following related literature (Dutta & Sobel, 2018; Goodman, 1960; Mize, 2022; Sobel, 1982). For the expected theorem of the mediating relationship, the estimate of the effect of the IV is assumably smaller after accounting for the mediator's effect (c') than in the original estimation model without accounting for the mediator's effect (c).[6]

2.2.5. Difference-in-differences (DID) estimates with interaction terms.

Since the Paris Agreement (COP21) event, global economies have been increasing our climate commitments. The event has imposed widespread effects on corporate behaviors with increasing awareness of stakeholders of corporate sustainability issues worldwide (Al-Ayyoub & Phan, 2026; Aslan et al., 2022; Ben-Amar et al., 2025; Feng et al., 2024; Ginglinger & Moreau, 2023; Lee et al., 2023; Reghezza et al., 2022). The study hereby adopts quasi-experimental designs with the difference-in-differences (DID) estimates using the COP21

[6] Please see also Trenton D. Mize - sgmediation2: Sobel-Goodman Tests of Mediation, for testing indirect effects with Sobel-Aroian-Goodman estimated statistical values.

event as the exogenous shock to our predictions of corporate leverage decisions. Furthermore, our DID models also take into account the tested channels to explain the climate treatment exposure effects with more empirical insights.

$$TDA_{i,j,t} = \alpha + \beta_1 Treated \times COP21 \times Channels_{i,j,t} + \beta_2 Treated \times COP21_{i,j,t} + \beta_3 Treated_{i,j,t} + \beta_4 COP21 + \beta_5 Channels_{i,j,t} + \beta_k \sum_{i=0}^{n} Controls_{i,j,t} + \varepsilon \quad (9)$$

All else remains constant, COP21 is a time dummy variable that is set equal to one for the years after the COP21 event. Otherwise, the COP21 time dummy variable is set equal to zero. Treated is the treatment dummy variable that is set equal to one for treated firms that present observable treatment climate exposure risks to the corporate leverage decision (total debt to assets ratio - TDA). The treatment dummy is the time-varying treatment variable that captures the exposures of listed firms to firm-level climate change exposure risk (CC-Risk) and temperature change exposure (global warming phenomena) for our sample economies. Our channels remain constant with multi-way interactions with the treatment and time dummies. The channels include i) broad-based financial development (FD), ii) environmental policy stringency index (EPSI), and iii) sales growth (Sales/Assets). The DID estimates not only capture the treatment effects of the COP21 event but also consider time-varying joint effects of our tested channels that represent exogenous and endogenous potential drivers to the outcome variables that have been discussed throughout the study.

III. Empirical findings and discussions.

3.1. Descriptive statistics of the firm-level data on the top polluting emerging markets.

[Table 1 inserted about here]

Table 1 reports the descriptive statistics. Our full sample includes 3,834 country-firm-year observations for the top three polluting merging markets, namely Brazil, China, and India. Corporate leverage has a mean value of 0.2334 (23.34%) total debt to assets, with a standard deviation of 0.1957 (19.57%). The temperature change indicates a mean temperature anomaly of 1.0516 degrees Celsius and a standard deviation of 0.1957. A positive temperature change indicates global warming has spread across our sample countries over the past decades. CC-Risk has a mean value of 0.0075 with a standard deviation of 0.0322, indicating firm-level climate change risk. Firms with no information about climate risk in their 10-K reports have a minimum climate risk score of 0.

3.2.Corporate climate risk exposure and financial leverage.

[Table 2 inserted about here]

Table 2 reports the regressions of corporate leverage on CC-Risk and ESG ratings. The findings show that firms with a higher CC-Risk increase are likely to increase their corporate leverage by 0.355-unit change of total debt to assets (Column 1). The findings are robust and statistically significant when we include corporate and national controls (Column 2) and ESG ratings and sub-category scores (Columns 3-6). The OLS estimates show that larger firms have higher leverage, while firms with higher profitability, R&D investment, dividend yield, operating cash flow (OCF), quick ratio, and ESG ratings have lower leverage. The baseline findings are statistically significant at the 1% level for the main independent variable, highlighting the role of corporate debt and free cash flow in dealing with climate change exposure based on the corporate life-cycle theorem (Jensen, 1986; Miller & Friesen, 1984). Consistent with modern ESG literature in corporate finance, our initial findings imply that firms with higher ESG ratings are those larger firms with higher financial flexibility but are also more carbon-intensive than younger firms. In the context of climate risk, the findings strengthen the ESG literature with existing controversies in the prior literature (Gillan et al., 2021). Figure 4 presents the historical trends of firm-level climate change risk and corporate leverage in the sample countries.

Our international evidence from the world's top polluting emerging market economies offers important complementary evidence to the growing literature on the climate risk exposure effects on capital structure decisions (Dang et al., 2023; Ginglinger & Moreau, 2023; Kovacs et al., 2025; Nguyen & Phan, 2020; Nguyen et al., 2022). While prior literature on advanced economies like the US markets argues that climate risks induce firms to leverage to mitigate costly financial distress risk, the current research on the top polluting emerging markets shows that corporate leverage plays a crucial role in financial flexibility decisions for operating needs when firms are exposed to climate exposure risks (Denis, 2011; Denis & McKeon, 2016; Fahlenbrach et al., 2020). Additionally, our baseline findings present the adverse association between corporate ESG performance ratings and leverage ratios. The evidence from the ESG-leverage relationships for our top polluting emerging markets complements prior literature on the implications of corporate ESG performance ratings to corporate financial flexibility conditions of listed firms, with their predicted debt and cash ratios (Trinh, 2026b). The study offers more in-depth empirical analyses for the next stages to support our theoretical predictions with the comprehensive assessment of the reliable mechanisms.

3.3.Treatment regressions with the Propensity Score Matching (PSM).

[Table 3 inserted about here]

Table 3 reports the propensity score matching (PSM) findings. The findings show that treated firms exposed to climate risk are likely to have a higher corporate leverage of 0.0549 (5.49%) compared to untreated firms (Column 1). The predicted coefficient of higher corporate leverage remains for the matched sample, with a higher predicted leverage of 0.0528 (5.28) for the treated firms (Column 2). The PSM findings support our initial OLS estimates, indicating that treated firms exposed to a positive temperature change and leverage increase have higher financial leverage. The endogeneity issues are mitigated when we use a treated dummy and match firms between the untreated groups and comparable matched controls. The findings are statistically significant at the 1% level for the PSM estimates. To support our empirical evidence, we present the firm-level climate change risk and corporate leverage by treatment in Figure 7. We employ the national carbon emissions per capita (CO2PC) for our robustness check (Appendix A3). The findings show that higher national pollution levels induce firms to reduce leverage, whereas firms paying closer attention to climate risk increase financial leverage to mitigate future climate-induced liquidity risks. Our findings are validated using the PSM method, indicating that firms exposed to climate risk are more likely to increase financial leverage. Our findings fulfil contradictory evidence in the literature (Ginglinger & Moreau, 2023; Huang et al., 2018; Nguyen & Phan, 2020). Our baseline findings support related evidence on the implications of corporate ESG profiles for the financial flexibility conditions of firms. The baseline findings show that, for the sample of the world's top polluting economies, leveraging practices are crucial to financial flexibility decisions under climate risk exposure. Our full and matched sample regressions using the treatment dummy reaffirm our empirical baseline predictions. More importantly, our treatment dummy captures the multilayer exposure of listed firms to firm-level climate change and temperature change exposure risk factors.

3.4. Firm-level and national channel tests for the mechanisms.

3.4.1. Broad-based financial developments of institutions and markets.

[Table 4 inserted about here]

Table 4 reports the regressions of corporate leverage with the channel tests for mechanisms. The study tests for the following mechanisms, including i) broad-based national financial development (FD), ii) environmental policy stringency indexes (EPSI), and iii) corporate sales growth (Sales/Assets). The channel tests show statistically significant joint effects of the tested mechanisms on the treatment effect of corporate climate risks on leverage decisions. The findings present the positive joint effect of FD on corporate leverage for treated firms (Treated x FD), as reported in Column 1. Under the joint effect of FD, treated firms are likely to have a predicted decrease in leverage. The findings also report on the direct adverse effect of FD on leverage decisions. Our evidence from corporate climate treatment effects, with firms' sensitivities to climate risk factors, financial development is crucial to corporate financing choices, with multifaceted impacts (Arellano et al., 2012; Grechyna, 2018; Yarba & Güner, 2020). Under climate risk exposure treatment effects, evident from the top emerging markets, the findings show a positive joint contribution of broad-based financial development to leverage decisions of treated firms. On the other hand, the aggregate financial developments of markets and institutions present their adverse direct single effect on corporate leverage decisions. The findings support the rationale that, on one hand, increasing national financial developments lead to a firm's less dependence on debt financing sources, as firms are growing effectively with profitable businesses. On the other hand, under the treatment effects of climate risks, firms could have access to debt leveraging sources for operating needs. Our international evidence from the top emerging markets adds critical complementarities to growing literature on the value of financial development to firm dynamics and financial policies.

3.4.2. Environmental policy stringency index (EPSI).

The findings show that EPSI imposes a positive joint effect on corporate leverage for treated firms (Treated x EPSI). Treated firms remain positive leverage decisions with the direct climate treatment effects, as reported in Column 2. EPSI also shows its adverse direct and statistically significant effect on the leverage decision. Our channel tests through the EPSI offer critical contributions to growing literature on the roles of stringent environmental policies in corporate decision-making (Dang et al., 2023; Kovacs et al., 2025; Lee et al., 2024; Rao & Moyer, 1994). Evolving climate policies may induce incentives for firms to decrease leverage to mitigate costly financial distress risk. On the other hand, treated firms may have an incentive to increase leverage for operating needs under the increasing environmental policy stringency. For instance, debt financing choices could be helpful for firms to enhance corporate innovation investments for green transition and eco-friendly efficiency, as expected by the governments for green growth targets. As debt could foster innovation, leverage incentives could be even more helpful for firms with financial constraints (Geelen et al., 2021; Trinh, 2026a), depending on corporate sustainability profiles. Our international evidence from the world's top polluting and emerging market economies offers crucial complementarities to growing literature on the effects of climate policies on corporate decisions. Figure 8 presents the yearly trends of the environmental policy stringency indexes of the sample countries. The figure shows fast-growing composite stringent environmental policies for China, Brazil, and India, starting from just over 0.5 unit in 1990 to over 3 units for China, followed by India. On the other hand, Brazil's environmental policies remain lower than the other sample world's top polluting emerging markets. Figure 9 shows involving stringent environmental policies for all the OECD-member and non-OECD member countries over the past decades.

3.4.3. Corporate sales growth.

For the sales growth as reported in Column 3, the findings show a joint negative and statistically significant effect on leverage for treated firms (Treated x Sales/Assets). Sales growth presents a direct adverse effect on leverage decisions, and treated firms present their corporate leveraging incentives under the direct climate treatment effect. The study reports the predicted margins for the centered predictions of the financial development and corporate sales growth, as shown in Figures 1A–1B in the appendix. The figures support our estimates, suggesting the differences in corporate leverage between treatment (Treated) and control (Untreated) groups are presented by the different levels of the predictors. The additional robustness tests suggest that treated firms are likely to increase corporate leverage under climate risk exposure, and the effects could vary by the levels of FD and corporate sales growth prospects. Our channel test from sales growth supports our theoretical predictions that financial flexibility choices are driving firms' incentives to leverage decisions. In the context of corporate sensitivities to climate risk treatment effects, firms could sustain sales growth by reducing their dependence on debt financing for operating needs. Our channel tests offer three explainable mechanisms for corporate leverage when firms are exposed to climate risk effects in the world's top-polluting emerging markets.

3.5.The mediation of corporate dividend payout policy,

[Table 5 inserted about here]

Table 5 reports the mediation tests of common dividend cash. The findings suggest the mediating effect of common dividend cash on the association between treatment and corporate leverage. After controlling for the mediation of common dividend cash, the estimated increase in corporate leverage is 0.0530 (Column 3), which is lower than before controlling for the mediating effect of corporate dividend policy with an increased financial leverage of 0.0549 for treated firms (Column 1). Firms with higher dividends, common cash paid, dividend yield, operating cash flow, and quick ratio are likely to decrease financial leverage. The findings with statistically significant Sobel-Goodman tests suggest the mediating effect of dividend policy on treated firms exposed to climate risk. Our theoretical notions are supported by the mediation analyses with the Sobel-Goodman reported tests, showing that firms with potential growth prospects have more flexible financial conditions with less dependence on debt financing choices. Furthermore, for the top emerging markets with higher firm growth prospects, treated firms are also likely to distribute free cash flows to shareholders. Our findings support the established literature on the roles of payout decisions in financial flexibility choices with our international evidence from the leading emerging markets (An et al., 2022; Bonaimé et al., 2013; Brav et al., 2005; Chay & Suh, 2009; Guay & Harford, 2000; Jagannathan et al., 2000), specifically when treated firms are being exposed to climate exposure risks for such top-polluting economies. Our Sobel-Goodman mediation tests reported show that the predicted levels of debt financing dependence are lower than when the study considers the roles of dividend payout policy in our predicted model. Under the climate treatment effects, treated firms in top emerging markets also show their active payout policies, with positive free cash flows being distributed to shareholders. Our findings complement growing literature, as discussed with timely international evidence from the world's leading emerging economies, especially in the context of high exposure of firms to climate risk effects.

3.6. Difference-in-differences (DID) estimates with channels.

3.6.1. The Paris Agreement (COP21) and broad-based financial development.

[Table 6 inserted about here]

Table 6 reports the difference-in-differences (DID) regression of corporate leverage on treatment dummy (Treated) and the Paris Agreement event (COP21). The regressions also include the interactions with the broad-based financial development (FD) of the sample energy countries (Treated x FD) and the COP21 event (Treated x FD x COP21). The findings show that treated firms are likely to have increased leverage, specifically controlling for the joint moderation effect of FD. On the other hand, FD presents a direct adverse effect on corporate leverage. Even though statistically insignificant, the findings show that treated firms are likely to have positive leverage in the post COP21, controlling for the joint effect of FD (Treated x FD x COP21). With the continuous FD index, treated firms have predicted a statistically significant increase in leverage of 0.2061-unit change. The findings offer additional insights into the value of financial development in shaping corporate leverage decisions under climate treatment exposure effects before and after the COP21 event. The DID estimates with interaction terms show the inevitable roles of the broad-based financial developments in supporting firms to access credit sources for operational needs under climate risk exposure. Our DID estimates from the top emerging markets offer novel insights into prior studies on the capital structure decisions when listed firms are being exposed to climate-related risks (Dang et al., 2023; Ginglinger & Moreau, 2023; Kovacs et al., 2025; Nguyen & Phan, 2020; Nguyen et al., 2022; Rao & Moyer, 1994; Trinh, 2025). Debt financing sources are crucial to firms' operating needs and flexibility in their financial decisions under climate risk exposure. The effects for treated firms are conditional on the continuous joint effect of the national broad-based developments of financial institutions and markets. Our findings offer insightful evidence to prior studies with uneven findings from the effects of climate risk drivers on corporate capital structure decisions.

3.6.2. The Paris Agreement (COP21) and the roles of environmental policy stringency.

[Table 7 inserted about here]

Table 7 reports the difference-in-differences (DID) regression of corporate leverage on treatment dummy (Treated) and the Paris Agreement event (COP21). The regressions also include the interactions with the levels of environmental policy stringency indexes (EPSI) for the sample countries. The findings present significant moderation of EPSI in leverage decisions for treated firms. At first glance, treated firms present a statistically significant increase in leverage decisions with a direct effect of 0.0260-unit change. EPSI induces corporate deleveraging with a significant decrease of 0.0272-unit change. The findings show a persistent leveraging incentive for treated firms under the joint effect of EPSI (Treated x EPSI) with a predicted increase of 0.0149-unit change. Similarly, treated firms have positive leverage increments in the post-COP21 period (Treated x COP21). However, the corporate deleveraging behaviors are presented for treated firms in the post-COP21 under the joint effects of EPSI with a predicted and statistically significant decrease of 0.0206-unti change. Our DID estimates with the time-varying moderating effects of EPSI complement prior studies on the changes of corporate decisions to increasingly stringent levels of environmental policies. At first glance, stringent environmental policies induce corporate incentives to debt financing due to potential concern about financial distress risk, and financial constraints may impose a greater burden on firms. Therefore, deleveraging upon increasing stringent policies could be an optimal choice for corporate financial flexibility conditions. On the other hand, debt financing could be reliable for firms to reserve financial flexibility options for continuous operating needs. Our evidence from leveraging practices of firms that are being exposed to climate treatment effects supports theoretical notions that bring crucial insights to growing literature. In the context of the world's top polluting economies, where listed firms are increasingly being exposed to climate risks, our findings show that leveraging practices could be beneficial to corporate financial flexibility with its ESG-driven incentives.

3.6.3. The Paris Agreement (COP21) and corporate sales growth.

[Table 8 inserted about here]

Table 8 reports the difference-in-differences (DID) regressions of corporate leverage on treatment dummy (Treated) and the Paris Agreement event (COP21), controlling for the mediation effect of revenue growth (Sales/Assets ratio). The findings reaffirm the leveraging incentive of treated firms with a strongly statistically significant increase of 0.0707-unit change. Increasing sales growth induces firms to have lower predicted leveraging practices with a predicted decrease of 0.033-unit change. treated firms with continuous sales growth present their corporate deleveraging with a statistically significant decrease in leverage of 0.0216-unit change. For the post-COP21 event, with the joint effect of sales growth, the findings present a positive and statistically insignificant increase in leverage of treated firms (Treated x Sales/Assets x COP21). Our DID estimates, with the joint effects of corporate sales growth, support established theoretical notions posited by earlier literature. Proactive leverage increases of firms are intended for their operating needs when corporate liquidity shocks may emerge. For the current study, our DID estimates show that sustained sales growth allows treated firms to mitigate their reliance on debt financing leverage, which is presumably costly to firms, leading to potential financial distress risk. Even though statistically significant, it is worth noting that, for the top polluting emerging economies, global climate transition risk contributes to a firm's incentive to increase leverage decisions. Our theoretical predictions are persistently supported through the proactive leveraging practices of treated firms when they are exposed to climate risk treatment effects. Such treatment effects become adverse when we control sales growth rates that have been maintained for the post-COP21 period.

3.6.4. The Paris Agreement (COP21) and multi-way joint effects of tested mechanisms.

[Table 9 inserted about here]

Table 9 reports the difference-in-differences (DID) regressions of corporate leverage on treatment dummy (Treated) and the Paris Agreement event (COP21). The study comprehensively controls the tested channels that have been assessed throughout the study.

The findings document positive corporate leveraging incentives for treated firms with the moderation effect of nationwide financial development (Treated x FD), with a highly significant increase of 1.33-unit change. FD offers corporate leveraging incentives for firms in the post-COP21 event (FD x COP21) with a predicted increase of 4.1976-unit change. The leveraging incentives for treated firms remain when those firms are exposed to incremental environmental policy stringency (Treated x EPSI) levels with a predicted 0.3844-unit change. Stringent environmental policies offer firms incentives to have higher leverage when the study accounts for the levels of financial development (FD x EPSI), with a predicted increase of 1.0632-unit change. Corporate leveraging incentives remain positive for the increasingly stringent environmental policies in the post-COP21 period (COP21 x EPSI), with a predicted increase of 1.25-unit change. Multi-way joint effects of the tested mechanisms show that treated firms become conservative with the direct effect of climate treatment risks and broad-based financial development. On the other hand, treated firms show their proactive leverage increases under the joint effects of the national aggregate developments of financial institutions and markets. Similarly, for the post-COP21 period, with the aggregate financial developments, our global transition efforts present great incentives to corporate proactive leverage increase.

Accounting for the other tested channels, treated firms present a statistically significant proactive leverage increase. Similar evidence is observed for the growing developments of financial markets and institutions, with their joint effects under stringent environmental policies. Under the global climate transition efforts, environmental policies induce clear positive leverage incentives for our sample of listed firms. On the other hand, the broad-based developments of financial markets and institutions induce adverse joint effects on leverage decisions for listed firms under evolving environmental policy stringency in the post-COP21 period. Our developed models offer insightful evidence on the capital structure dynamic decisions of firms for their reserved financial flexibility conditions with ESG-driven mechanisms. Our findings empirically offer critical theoretical predictions, supporting prior studies on the climate change effects of corporate financing decisions. Furthermore, with international evidence from the world's top emerging leading economies, the findings present the inevitable roles of debt financing choices in shaping capital structure decisions of listed firms. Our evidence offers critical explanations to firms' optimal debt levels for financial flexibility conditions when they are increasingly exposed to diverse risk drivers, especially the pollution and global warming risks in the sample economies.

IV. Conclusion

The current study employs an international sample of the world's top polluting emerging market economies, including China, Brazil, and India, to examine the corporate capital structure dynamics under climate exposure risks. The study also examines the ESG-driven mechanism to explain the leverage decisions of our listed firms in the face of global warming phenomena, as well as diverse driving factors, including national aggregate financial developments, environmental policy stringency indexes, and corporate sales growth. More importantly, the study employs global warming signals to capture the climate treatment effects of firm-level climate change risks on financial flexibility decisions through dynamic capital structure decisions.

Our baseline findings show that corporate climate risks are positively associated with proactive leverage increases for operating needs. The positive treatment effects of climate change risks remain robust for our theoretical predictions when we control the three important ESG-driven mechanisms. Furthermore, the established relations remain persistent when we conduct treatment panel regressions with full and matched samples using the propensity scores matching (PSM) method. Proactive leverage increases for treated firms to cope with climate exposure risks are supported through the aggregate developments of financial developments and markets, as well as the evolving environmental policy stringency. Our findings support the theoretical predictions of the increasing needs of debt financing decisions for optimal capital structures in the face of climate risk exposure drivers. Treated firms present their persistent proactive leverage increases for financial flexibility decisions. Our mediation analyses support the hypothesized theorem further, showing that dividend payout decisions lower the treatment effects of climate risks on leverage levels. For the world's top polluting economies, treated firms have maintained growing free cash flows distributed to shareholders, implying potential growth prospects. On the other hand, the findings of the current study offer additional complementarities to the growing literature on the climate risk effects on corporate financial decisions. First, stringent environmental policies induce corporate incentives to deleverage debt financing for mitigating financial distress risk with secured ample financial flexibility. As debt financing choices could be hard to reconcile, corporate decisions of the top emerging markets are following the aggregate developments of financial institutions and markets. Finally, debt financing for financial flexibility is not just driven by the ESG factors tested but also depends on the sales growth of firms. Our findings, with thoroughly tested ESG-related channels, support the pecking order theory on the priority of corporate decisions on optimal debt leverage. The findings also highlight the value of debt financing with financial flexibility incentives for firms in the escalating face of climate exposure risks. The study uses global warming phenomena to frame our theoretical predictions with supportive empirical insights for the world's top polluting leading market economies.

The current study provides important findings for policymakers, stakeholders, and executives for financial soundness policies in the face of evolving climate change impacts. First, access to credit sources plays an inevitable role in the flexibility decisions of firms when liquidity shocks emerge. Along with the increasing awareness of stakeholders and financial markets, institutions may have found the increasing value of cash reserves. Environmental policy stringency may deleverage debt financing choices to polluting firms with higher carbon intensity levels for operations. On the other hand, evolving stringent environmental policies may encourage environmentally friendly firms to access debt financing sources to foster green innovation and low-carbon sustainable business activities. Public agencies may have found the increasing importance of the private sector in green-oriented activities, with financial encouraging frameworks for our global climate transition commitments across major industries. For the major economies as well as economic alliances, green transition and sources of credit supplies for growth are important subjects for future directions, with growing studies needed for sustainable development goals.

Table 1: Descriptive statistics

Variable	N	Mean	Min	p50	Max	SD
Corporate leverage	3426	0.2334	0.0000	0.2151	1.0317	0.1957
Temperature change	3834	1.0516	0.2630	1.0620	1.6200	0.3433
CC-Risk	3834	0.0075	0.0000	0.0000	1.1330	0.0322
Firm size	3440	14.4380	9.4042	14.3041	18.2933	1.7275
Profitability	3419	6.0323	-177.29	6.3500	38.9800	12.9270
R&D	3834	0.4799	0.0000	0.0000	1.0000	0.4997
Tangibility	3436	0.2718	0.0007	0.2157	0.9119	0.2245
Dividend yield	3406	1.6461	0.0000	0.6500	12.1700	2.4729
OCF	3413	0.0843	-0.9494	0.0828	0.3821	0.1018
Quick ratio	3407	1.7545	0.1200	1.1700	13.2700	1.8968
GDP growth	3628	3.3509	-9.2704	3.7379	14.2309	4.7028
Inflation rate	3628	4.5646	-2.3115	4.0398	14.0910	2.7078
Sales/Assets	3439	0.7467	0.0000	0.6131	3.8674	0.5281
Dividends Cash/Assets	3313	0.0211	0.0000	0.0067	0.2079	0.0369
ESG	3834	20.2914	0.0000	0.0000	92.4400	26.9164
Environment score	3834	16.9878	0.0000	0.0000	97.3900	26.3120
Social score	3834	21.3794	0.0000	0.0000	98.3700	29.3377
Governance score	3834	21.4733	0.0000	0.0000	96.4800	28.9028
FD	3834	0.5544	0.3814	0.5506	0.6743	0.0802

The table reports descriptive statistics of the sample countries with all the listed sample firms in China, Brazil, and India for the merged sample. Continuous firm-level fundamentals are winsorized at the 1st and 99th percentiles to mitigate the potential effects of outliners in our estimates.

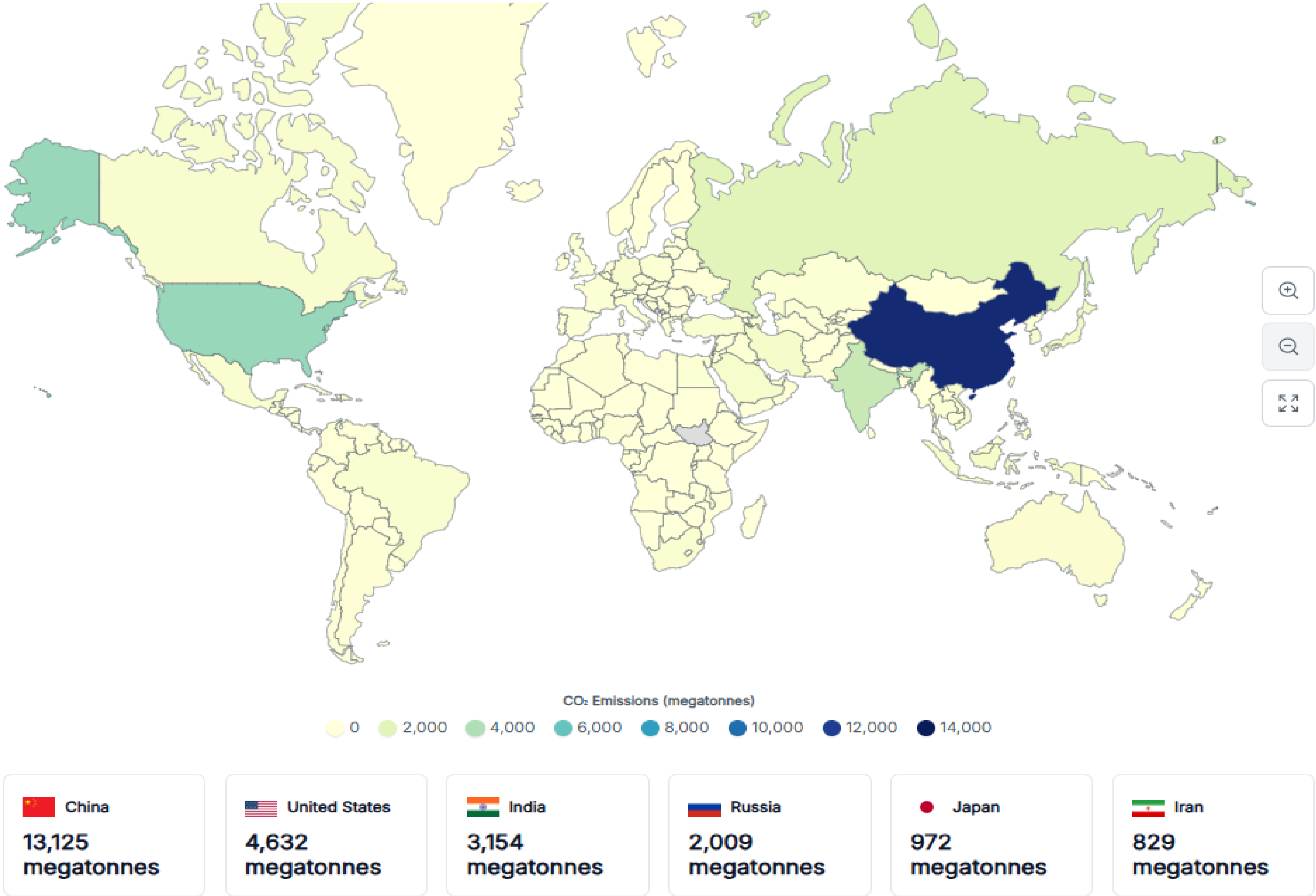

Figure 1: Pollution by Country 2026. Source: Adapted from World Pollution Review (2026)[7].

[7] Pollution by Country 2026, adapted as of 2026-05-30.

COUNTRY	TOTAL GREENHOUSE GAS EMISSIONS 2023 (T CO_2EQ) ↓
China	15.9B
United States	6B
India	4.1B
Russia	2.7B
Brazil	1.3B
Indonesia	1.2B
Japan	1B
Iran	1B
Saudi Arabia	805.2M
Canada	747.7M
Mexico	712.1M
Germany	681.8M
South Korea	653.9M
Turkey	606.4M
Australia	571.8M

- CO_2 emissions are displayed in millions of tons of CO_2 (Mton CO_2)
- Total greenhouse gas emisisons are displayed in equivalents of millions of tons of CO_2 (Mton CO_2eq)

Figure 2: Country rankings by the total greenhouse gas emissions (GHG) exposure, as displayed in equivalents of millions of tons of CO_2 (Mton CO_2eq). Source: Adapted from Adapted from World Pollution Review (2026)[8].

[8] Pollution by Country 2026, adapted as of 2026-05-30.

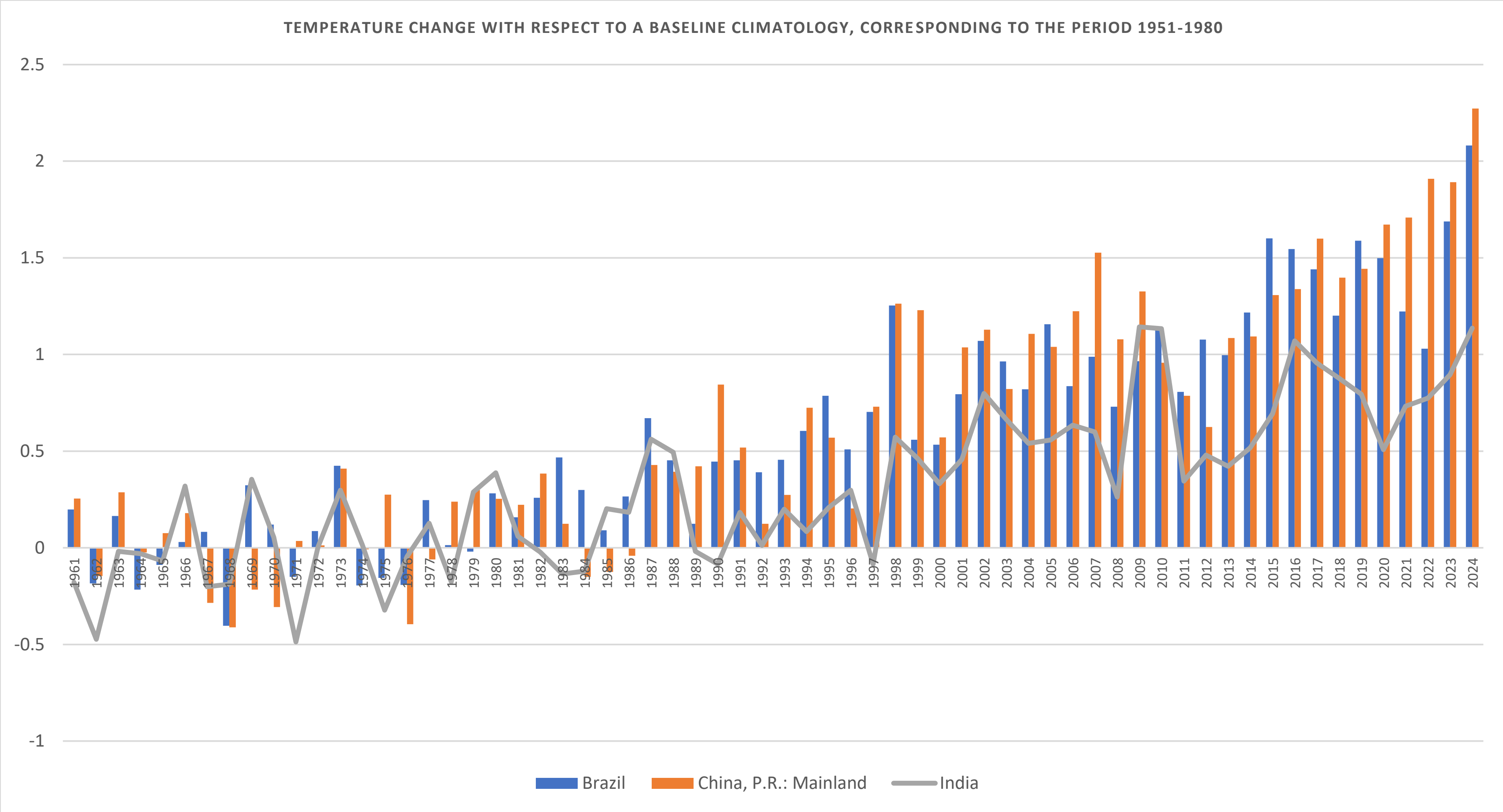

Figure 3: Annual estimates of mean surface temperature change measured with respect to baseline climatology, corresponding to the period 1951-1980. Source: IMF Macroeconomic Climate Indicators Dashboard and Author's work.[9]

[9] Extracted and presented as of 2026-06-03 at Annual Surface Temperature Change | Macroeconomic Climate Indicators Dashboard.

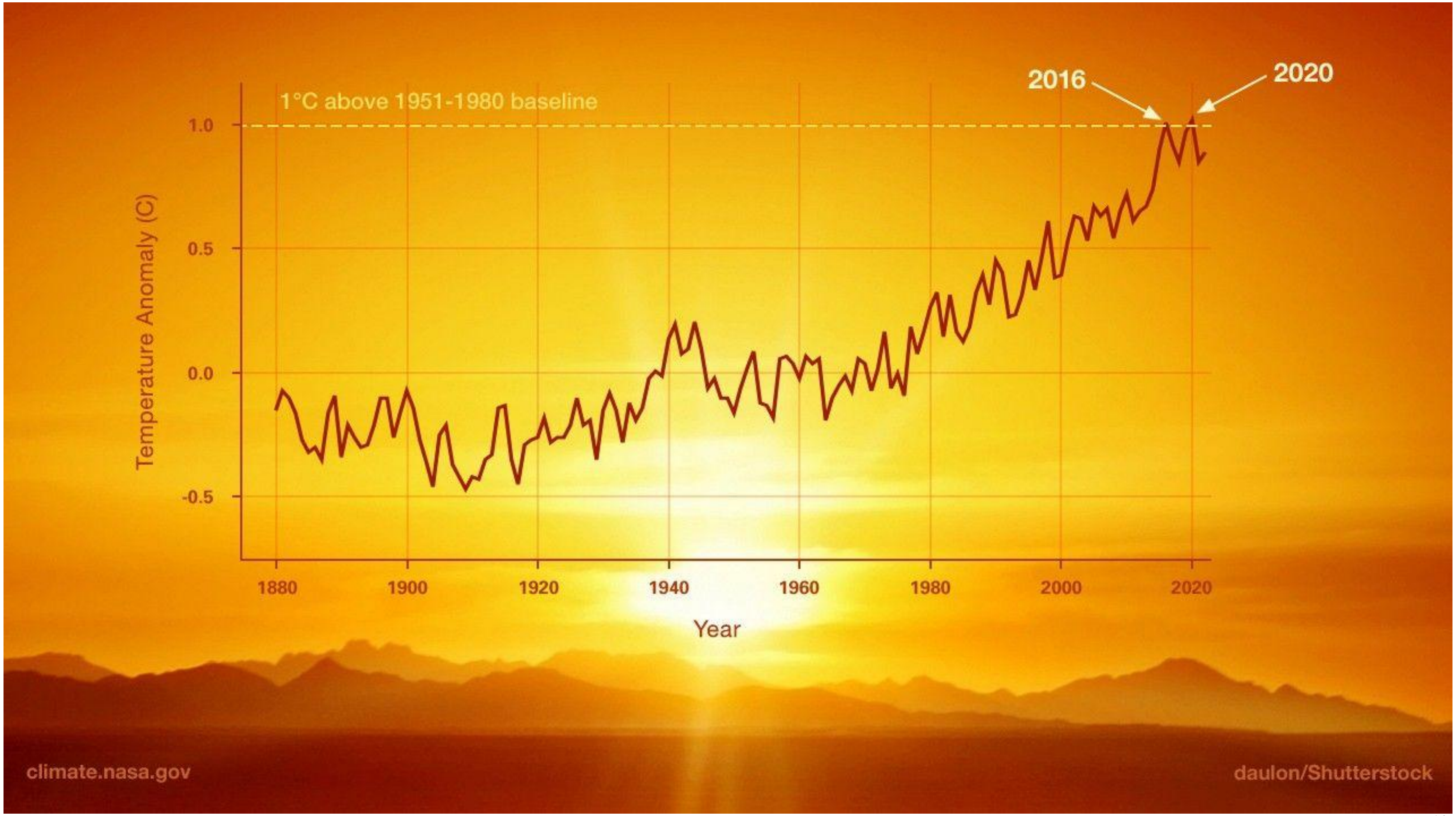

Figure 4: Global surface temperature changes relative to the 1951-1980 average temperatures. Source: Adapted from NASA as of 2026-06-03.[10]

[10] Global Temperature - Earth Indicator - NASA Science; What Is Climate Change? - NASA Science; Data.GISS: GISS Surface Temperature Analysis (GISTEMP v4).

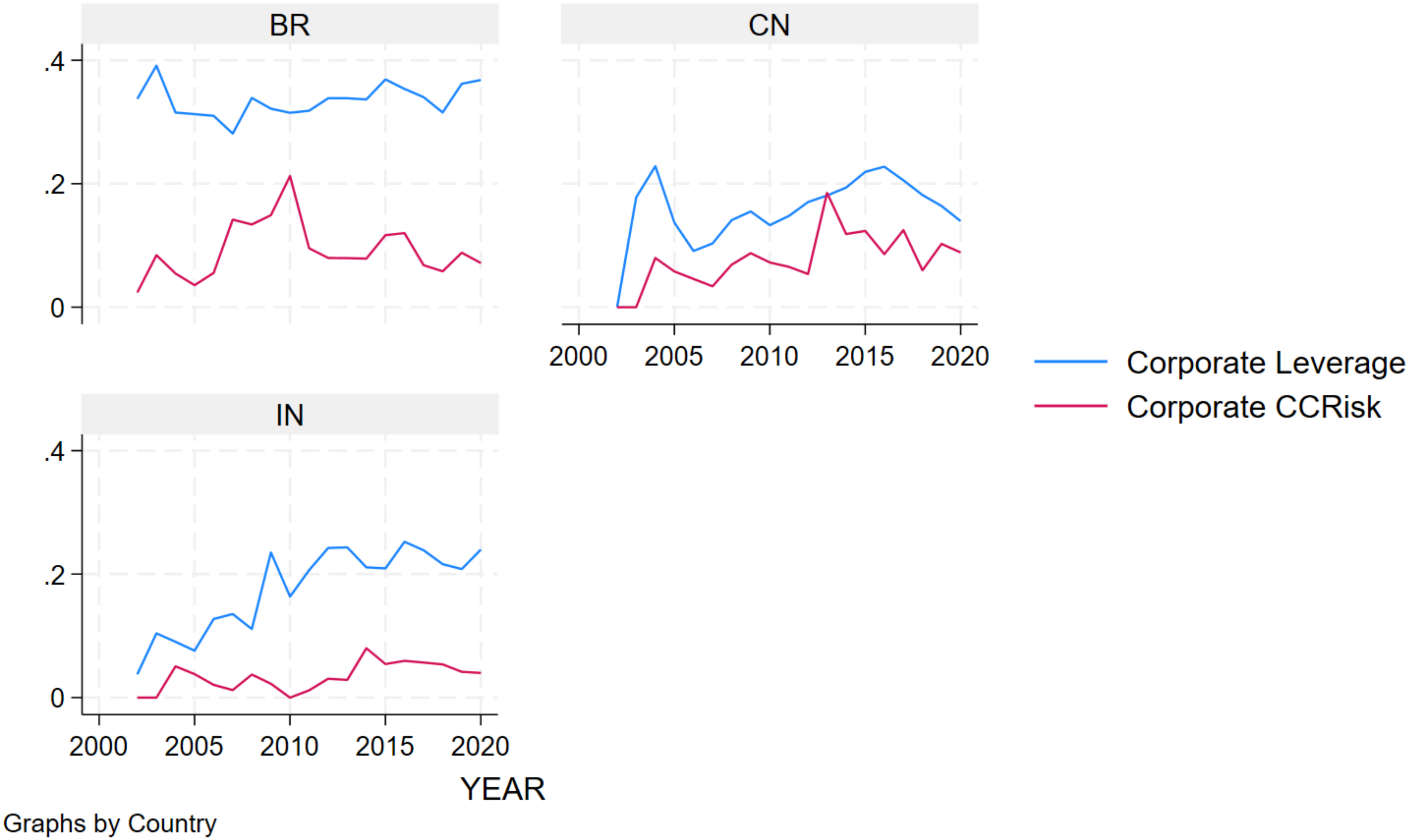

Figure 5: Firm-level climate change risk and corporate leverage. Source: Author's work using databases from LSEG workspace and Sautner et al (2023).

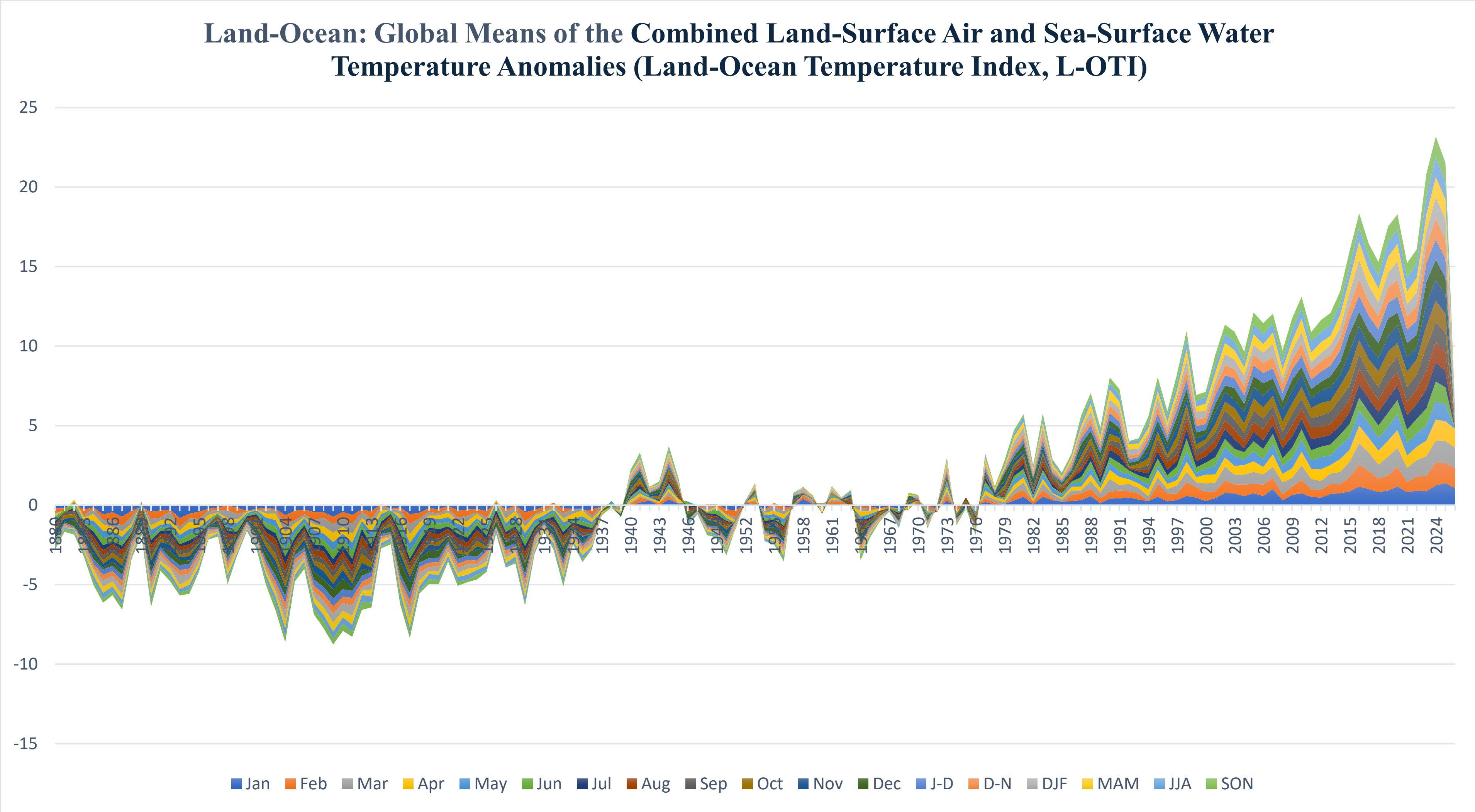

Figure 6: Global-mean monthly, seasonal, and annual means of the Combined Land-Surface Air and Sea-Surface Water Temperature Anomalies (Land-Ocean Temperature Index, L-OTI), 1880-present. Source: Author's work using data extracted from NASA.[11]

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[11] https://data.giss.nasa.gov/gistemp/tabledata_v4/GLB.Ts+dSST.csv; Data.GISS: GISS Surface Temperature Analysis (GISTEMP v4): Data Downloads

Figure 7. Firm-level climate change risk and corporate leverage by treatment. Authors' presentation.

Table 2: Baseline estimates of corporate leverage on firm-level climate change risk (CC-Risk)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
CC-Risk	0.3555***	0.2056**	0.2163***	0.2071***	0.2155***	0.2207***
	(0.1098)	(0.0806)	(0.0796)	(0.0795)	(0.0790)	(0.0810)
Firm size		0.0262***	0.0307***	0.0295***	0.0307***	0.0289***
		(0.0052)	(0.0062)	(0.0063)	(0.0057)	(0.0060)
Profitability		-0.0002	-0.0002	-0.0002	-0.0002	-0.0002
		(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
R&D		-0.0103	-0.0074	-0.0074	-0.0076	-0.0091
		(0.0114)	(0.0114)	(0.0113)	(0.0116)	(0.0114)
Tangibility		0.0628	0.0586	0.0593	0.0587	0.0603
		(0.0549)	(0.0548)	(0.0547)	(0.0547)	(0.0550)
Dividend yield		-0.0068***	-0.0066***	-0.0066***	-0.0064***	-0.0069***
		(0.0021)	(0.0021)	(0.0021)	(0.0021)	(0.0021)
OCF		-0.3078***	-0.3041***	-0.3049***	-0.3051***	-0.3045***
		(0.0688)	(0.0688)	(0.0691)	(0.0684)	(0.0688)
Quick ratio		-0.0152***	-0.0143***	-0.0145***	-0.0141***	-0.0147***
		(0.0032)	(0.0033)	(0.0033)	(0.0033)	(0.0033)
GDP growth		0.0015	0.0013	0.0013	0.0012	0.0015
		(0.0019)	(0.0019)	(0.0019)	(0.0019)	(0.0019)
Inflation rate		0.0013	0.0014	0.0014	0.0013	0.0014
		(0.0020)	(0.0020)	(0.0020)	(0.0020)	(0.0020)
ESG ratings			-0.0004*			
			(0.0003)			
Social score				-0.0003		
				(0.0003)		
Environment score					-0.0005**	
					(0.0003)	
Governance score						-0.0003
						(0.0003)
Constant	0.1449***	-0.0909	-0.1647*	-0.1457	-0.1655**	-0.1341
	(0.0333)	(0.0746)	(0.0884)	(0.0905)	(0.0817)	(0.0867)
Observations	2,659	2,367	2,367	2,367	2,367	2,367

R-squared	0.5518	0.6209	0.6223	0.6217	0.6229	0.6216
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
SE-Clustered Firm	Yes	Yes	Yes	Yes	Yes	Yes

The table reports the ordinary least-squares linear (OLS) regressions of corporate leverage on firm-level climate change risk (CC-Risk) and ESG ratings. The OLS regressions compute cluster-robust standard errors for firms, including the year, industry, and country fixed effects (FE). Robust standard errors are reported in parentheses with the statistically significant 1%, 5%, and 10% levels, respectively, labeled as *** $p<0.01$, ** $p<0.05$, and * $p<0.1$.

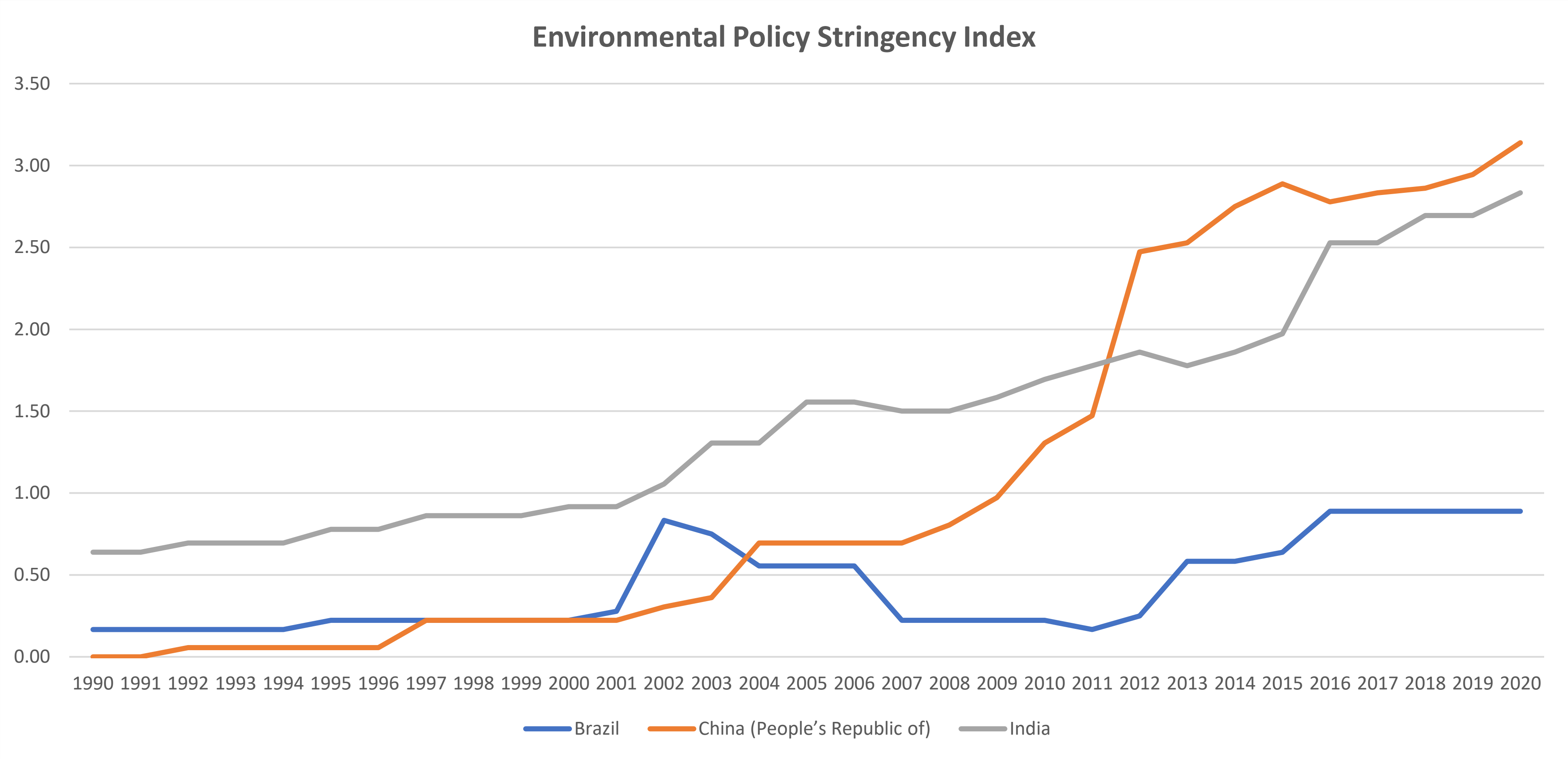

Figure 8: Environmental Policy Stringency Indexes of China, Brazil, and India. Source: Author's work using data from OECD statistics[12].

[12] OECD Data Explorer • OECD Environmental Policy Stringency Index, extracted as of 2026-06-04.

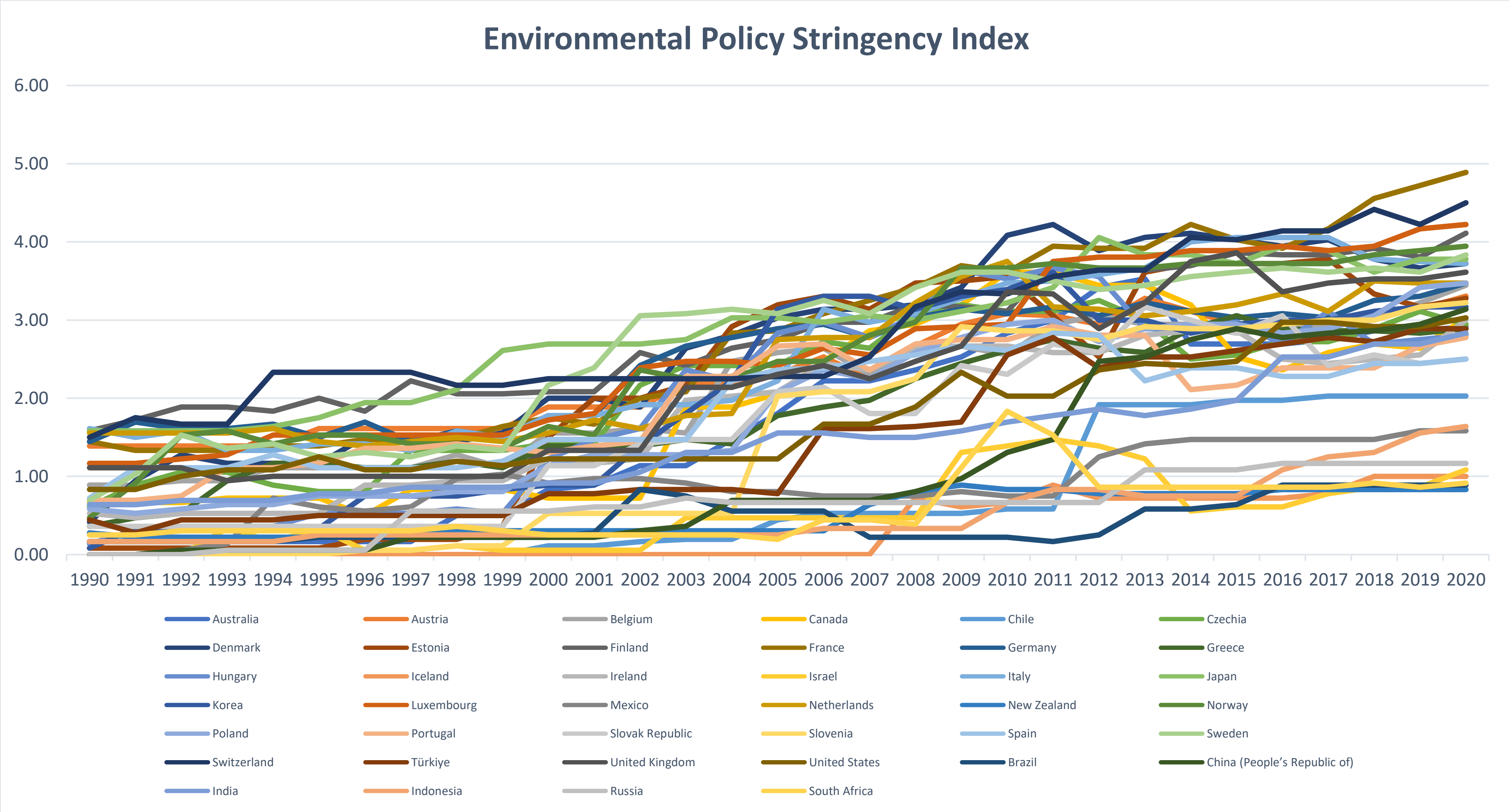

Figure 9: Environmental Policy Stringency Indexes of all the OECD and non-OECD countries. Source: Author's work using data from OECD statistics[13].

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[13] OECD Data Explorer • OECD Environmental Policy Stringency Index, extracted as of 2026-06-04.

Table 3: Propensity Scores Matching (PSM)

VARIABLES	(1) Full Sample	(2) Matched-Sample
Treated	0.0549***	0.0528***
	(0.0048)	(0.0058)
Firm size	0.0293***	0.0292***
	(0.0044)	(0.0045)
Profitability	-0.0011**	-0.0014**
	(0.0005)	(0.0006)
R&D	-0.0232**	-0.0216*
	(0.0101)	(0.0111)
Tangibility	0.1267***	0.1241***
	(0.0434)	(0.0460)
Dividend yield	-0.0071***	-0.0063***
	(0.0016)	(0.0017)
OCF	-0.2794***	-0.2835***
	(0.0537)	(0.0610)
Quick ratio	-0.0150***	-0.0153***
	(0.0026)	(0.0032)
GDP growth	0.0002	-0.0003
	(0.0014)	(0.0015)
Inflation rate	0.0040**	0.0036*
	(0.0018)	(0.0021)
Constant	-0.2205***	-0.2136***
	(0.0708)	(0.0745)
Observations	3,053	2,552
R-squared	0.6409	0.6256
Year FE	Yes	Yes
Industry FE	Yes	Yes
Country FE	Yes	Yes

VCE Clustered Firm	Yes	Yes

The table reports the regression of corporate leverage on the treatment (Treat) dummy. Treat is a dummy variable that is equal to one for firms with an observed positive change in corporate leverage (ΔTDA) and positive temperature change; otherwise, it is set equal to zero. Column 1 reports the OLS estimate using the full sample, while Column 2 reports the OLS estimate based on the matched sample with PSM. The estimates are based on the OLS linear regressions and cluster-robust standard errors for firms with fixed effects for time, industry, and headquarter country codes. Robust standard errors are reported in parentheses with the statistically significant 1%, 5%, and 10% levels, respectively, labeled as *** p<0.01, ** p<0.05, and * p<0.1.

Table 4: Channel tests for mechanisms.			
VARIABLES	(1)	(2)	(3)
Treated	**-0.0783**** (0.0342)	**0.0326**** (0.0127)	**0.0744***** (0.0101)
FD	**-0.5692***** (0.1368)		
Treated x FD	**0.2492***** (0.0646)		
Firm size	0.0319*** (0.0046)	0.0312*** (0.0045)	0.0276*** (0.0045)
Profitability	-0.0012** (0.0005)	-0.0012** (0.0006)	-0.0012** (0.0005)
R&D	-0.0273** (0.0110)	-0.0270** (0.0111)	-0.0260** (0.0112)
Tangibility	0.1385*** (0.0405)	0.1380*** (0.0408)	0.1161*** (0.0410)
Dividend yield	-0.0067*** (0.0017)	-0.0064*** (0.0017)	-0.0064*** (0.0016)
OCF	-0.2982*** (0.0574)	-0.2945*** (0.0580)	-0.2619*** (0.0573)
Quick ratio	-0.0166*** (0.0031)	-0.0172*** (0.0031)	-0.0188*** (0.0032)
GDP growth	-0.0012 (0.0015)	-0.0011 (0.0015)	-0.0010 (0.0015)
Inflation rate	0.0029 (0.0019)	0.0021 (0.0020)	0.0026 (0.0019)
EPSI		**-0.0379**** (0.0150)	
Treated x EPSI		**0.0138**** (0.0060)	
Sales/Assets			**-0.0359****

			(0.0144)
Treated x Sales/Assets			**-0.0219****
			(0.0099)
Constant	0.0221	-0.2131***	-0.2112***
	(0.0957)	(0.0752)	(0.0726)
Observations	2,537	2,537	2,537
R-squared	0.6426	0.6407	0.6452
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
VCE Clustered Firm	Yes	Yes	Yes

The table reports the linear regressions of corporate leverage on treatment dummy and tested mechanisms. Treatment dummy (Treated) is a dummy variable that is set equal to one for treated firms that are exposed to climate change exposure risks (CC-Risk and temperature change); otherwise, the treatment dummy is set equal to zero. The ordinary least-squares (OLS) linear regressions include the fixed effects (FE) for time (Year FE), industry (Industry FE), and country (Country FE) levels Robust standard errors are reported in parentheses. The characters *** p<0.01, ** p<0.05, * p<0.1 present the statistically significant levels at the 1%, 5%, and 10%, respectively.

Table 5: The Mediation test of corporate dividend payout policy.

VARIABLES	(1) Corporate Leverage	(2) Dividends Cash/Assets	(3) Corporate Leverage
Treated	**0.0549*****	**0.0030****	**0.0530*****
	(0.0048)	(0.0012)	(0.0048)
Dividends Cash/Assets			**-0.6507*****
			(0.1322)
Firm size	0.0293***	-0.0009	0.0266***
	(0.0044)	(0.0009)	(0.0043)
Profitability	-0.0011**	0.0004***	-0.0007
	(0.0005)	(0.0001)	(0.0005)
R&D	-0.0232**	-0.0006	-0.0264**
	(0.0101)	(0.0023)	(0.0103)
Tangibility	0.1267***	-0.0084	0.1313***
	(0.0434)	(0.0064)	(0.0445)
Dividend yield	-0.0071***	0.0053***	-0.0043**
	(0.0016)	(0.0006)	(0.0017)
OCF	-0.2794***	0.0837***	-0.2377***
	(0.0537)	(0.0141)	(0.0532)
Quick ratio	-0.0150***	-0.0004	-0.0161***
	(0.0026)	(0.0005)	(0.0026)
GDP growth	0.0002	-0.0000	0.0002
	(0.0014)	(0.0003)	(0.0014)
Inflation rate	0.0040**	-0.0003	0.0046**
	(0.0018)	(0.0003)	(0.0018)
Constant	-0.2205***	0.0136	-0.1859***
	(0.0708)	(0.0196)	(0.0694)

Observations	3,053	2,954	2,945
R-squared	0.6409	0.5196	0.6514
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
VCE Clustered Firm	Yes	Yes	Yes
Controls Included	Yes	Yes	Yes
Sobel-Goodman Mediation Tests	Yes	Yes	Yes

Indirect, Direct, and Total Effects	Sobel	Aroian	Goodman
	-0.002** (0.001)	-0.002**	-0.002**
		(0.001)	(0.001)

A - coefficient	B – coefficient	Indirect effect - A x B	Direct effect – C’
0.003***	-0.651***	-0.002**	0.053***
(0.001)	(0.132)	(0.001)	(0.005)

Total effect C		
0.051***	Proportion of total effect that is mediated:	-0.040
	Ratio of indirect to direct effect:	-0.039
(0.005)	Ratio of total to direct effect:	0.961

The table reports the mediation of common dividends cash in the association between climate risk and corporate leverage. Treatment dummy (Treated) is a dummy variable that is set equal to one for treated firms that are exposed to climate change exposure risks (CC-Risk and temperature change); otherwise, the treatment dummy is set equal to zero The mediation tests are based on linear estimators and cluster-robust standard errors for firms with fixed effects for time, industry, and headquarters country codes. The mediator is only selected based on the statistically significant Sobel-Goodman tests. Robust standard errors are reported in parentheses with the statistically significant 1%, 5%, and 10% levels, respectively, labelled as *** p<0.01, ** p<0.05, and * p<0.1.

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Table 6: Difference-in-differences (DID) regressions and the roles of national broad-based financial development (FD).		
VARIABLES	(1)	(2)
Treated	-0.0124	-0.0639
	(0.0502)	(0.0450)
FD	-0.0615	-0.5314***
	(0.1337)	(0.1392)
Treated x FD	0.1341	0.2061**
	(0.0947)	(0.0868)
COP21	-0.0324	0.0604
	(0.0924)	(0.0757)
Treated x COP21	-0.0059	-0.0051
	(0.0653)	(0.0571)
COP21 x FD	0.1234	0.0665
	(0.1095)	(0.1024)
Treated x FD x COP21	0.0085	0.0282
	(0.1215)	(0.1082)
Firm size		0.0306***
		(0.0044)
Profitability		-0.0010**
		(0.0005)
R&D		-0.0239**
		(0.0101)
Tangibility		0.1285***
		(0.0424)
Dividend yield		-0.0071***
		(0.0016)
OCF		-0.2859***
		(0.0529)
Quick ratio		-0.0158***
		(0.0026)
GDP growth		-0.0002

		(0.0014)
Inflation rate		0.0046***
		(0.0018)
Constant	0.1200	0.0251
	(0.0764)	(0.0940)
Observations	3,424	3,053
R-squared	0.5507	0.6451
Year FE	Yes	Yes
Industry FE	Yes	Yes
Country FE	Yes	Yes
VCE Clustered Firm	Yes	Yes

The table reports the Difference-in-differences (DID) regressions and the roles of national broad-based financial development (FD). Treatment dummy (Treated) is a dummy variable that is set equal to one for treated firms that are exposed to climate change exposure risks (CC-Risk and temperature change); otherwise, the treatment dummy is set equal to zero. The ordinary least-squares (OLS) linear regressions include the fixed effects (FE) for time (Year FE), industry (Industry FE), and country (Country FE) levels Robust standard errors are reported in parentheses. The characters *** p<0.01, ** p<0.05, * p<0.1 present the statistically significant levels at the 1%, 5%, and 10%, respectively.

Table 7: Difference-in-differences (DID) regressions and environmental policy stringency indexes (EPSI)

VARIABLES	(1)	(2)
Treated	0.0370***	0.0260*
	(0.0128)	(0.0136)
EPSI	0.0067	-0.0272*
	(0.0146)	(0.0149)
Treated x EPSI	0.0168**	0.0149*
	(0.0084)	(0.0083)
COP21	0.0323	0.0499
	(0.0495)	(0.0558)
Treated x COP21	0.0403*	0.0486**
	(0.0229)	(0.0215)
EPSI x COP21	0.0041	-0.0090
	(0.0097)	(0.0105)
Treated x EPSI x COP21	-0.0231**	-0.0206*
	(0.0114)	(0.0107)
Firm size		0.0307***
		(0.0044)
Profitability		-0.0011**
		(0.0005)
R&D		-0.0241**
		(0.0101)
Tangibility		0.1281***
		(0.0426)
Dividend yield		-0.0066***
		(0.0016)
OCF		-0.2851***
		(0.0529)

Quick ratio		-0.0162***
		(0.0025)
GDP growth		-0.0002
		(0.0014)
Inflation rate		0.0052***
		(0.0019)
Constant	0.0949**	-0.2308***
	(0.0451)	(0.0740)
Observations	3,424	3,053
R-squared	0.5508	0.6448
Year FE	Yes	Yes
Industry FE	Yes	Yes
Country FE	Yes	Yes
VCE Clustered Firm	Yes	Yes

The table reports Difference-in-differences (DID) regressions and environmental policy stringency indexes (EPSI). Treatment dummy (Treated) is a dummy variable that is set equal to one for treated firms that are exposed to climate change exposure risks (CC-Risk and temperature change); otherwise, the treatment dummy is set equal to zero. The ordinary least-squares (OLS) linear regressions include the fixed effects (FE) for time (Year FE), industry (Industry FE), and country (Country FE) levels Robust standard errors are reported in parentheses. The characters *** p<0.01, ** p<0.05, * p<0.1 present the statistically significant levels at the 1%, 5%, and 10%, respectively.

Table 8: Difference-in-differences (DID) regressions and the joint effect of sales growth.		
VARIABLES	(1)	(2)
Treated	0.0607***	0.0607***
	(0.0124)	(0.0124)
Sales/Assets	-0.0333**	-0.0333**
	(0.0150)	(0.0150)
Treated x Sales/Assets	-0.0216*	-0.0216*
	(0.0111)	(0.0111)
COP21	0.0198	0.0198
	(0.0475)	(0.0475)
Treated x COP21	0.0146	0.0146
	(0.0160)	(0.0160)
Sales/Assets x COP21	-0.0052	-0.0052
	(0.0150)	(0.0150)
Treated x Sales/Assets x COP21	0.0062	0.0062
	(0.0144)	(0.0144)
Firm size	0.0266***	0.0266***
	(0.0044)	(0.0044)
Profitability	-0.0010**	-0.0010**
	(0.0005)	(0.0005)
R&D	-0.0223**	-0.0223**
	(0.0103)	(0.0103)
Tangibility	0.1094**	0.1094**
	(0.0433)	(0.0433)
Dividend yield	-0.0068***	-0.0068***

	(0.0016)	(0.0016)
OCF	-0.2496***	-0.2496***
	(0.0521)	(0.0521)
Quick ratio	-0.0174***	-0.0174***
	(0.0027)	(0.0027)
GDP growth	0.0002	0.0002
	(0.0014)	(0.0014)
Inflation rate	0.0042**	0.0042**
	(0.0018)	(0.0018)
Constant	-0.1849***	-0.1849***
	(0.0707)	(0.0707)
Observations	3,053	3,053
R-squared	0.6468	0.6468
Year FE	Yes	Yes
Industry FE	Yes	Yes
Country FE	Yes	Yes
VCE Clustered Firm	Yes	Yes

The table reports the Difference-in-differences (DID) regressions and the joint effect of sales growth. Treatment dummy (Treated) is a dummy variable that is set equal to one for treated firms that are exposed to climate change exposure risks (CC-Risk and temperature change); otherwise, the treatment dummy is set equal to zero. The ordinary least-squares (OLS) linear regressions include the fixed effects (FE) for time (Year FE), industry (Industry FE), and country (Country FE) levels Robust standard errors are reported in parentheses. The characters *** p<0.01, ** p<0.05, * p<0.1 present the statistically significant levels at the 1%, 5%, and 10%, respectively.

Table 9: Difference-in-differences (DID) regressions and the joint effects of endogenous and exogenous mechanisms.

VARIABLES	(1)	(2)
Treated	-0.3042***	-0.7381***
	(0.1117)	(0.1789)
FD	-1.0101***	-2.1194***
	(0.3353)	(0.4730)
Treated x FD	0.5772***	1.3305***
	(0.2014)	(0.3184)
COP21	-1.3011**	-2.5431**
	(0.6395)	(1.0608)
Treated x COP21	0.1501	1.4185
	(0.6088)	(1.1493)
FD x COP21	2.2317**	4.1976**
	(0.9962)	(1.6660)
Treated x FD x COP21	-0.2339	-2.1718
	(0.9569)	(1.8008)
EPSI	-0.2907**	-0.6284***
	(0.1164)	(0.1618)
Treated x EPSI	0.1433**	0.3844***
	(0.0684)	(0.1076)
FD x EPSI	0.4579**	1.0632***
	(0.1970)	(0.2770)
Treated x FD x EPSI	-0.2140*	-0.6087***
	(0.1216)	(0.1884)
COP21 x EPSI	0.6348**	1.2540***
	(0.2533)	(0.4192)
Treated x COP21 x EPSI	-0.1103	-0.6518
	(0.2380)	(0.4474)
FD x COP21 x EPSI	-1.0402***	-2.0258***
	(0.3996)	(0.6634)
Treated x FD x COP21 x EPSI	0.1705	0.9847

	(0.3777)	(0.7046)
Sales/Assets		-1.0185***
		(0.2982)
Treated x Sales/Assets		0.6933***
		(0.2218)
FD x Sales/Assets		1.7500***
		(0.5118)
Treated x FD x Sales/Assets		-1.1959***
		(0.3771)
COP21 x Sales/Assets		1.8813*
		(1.1238)
Treated x COP21 x Sales/Assets		-1.6699
		(1.2270)
FD x COP21 x Sales/Assets		-2.9257*
		(1.7651)
Treated x FD x COP21 x Sales/Assets		2.5243
		(1.9142)
EPSI x Sales/Assets		0.5211***
		(0.1742)
Treated x EPSI x Sales/Assets		-0.3498***
		(0.1194)
FD x EPSI x Sales/Assets		-0.9195***
		(0.2939)
Treated x FD x EPSI x Sales/Assets		0.5583***
		(0.1999)
COP21 x EPSI x Sales/Assets		-0.9089**
		(0.4462)
Treated x COP21 x EPSI x Sales/Assets		0.6966
		(0.4721)
FD x COP21 x EPSI x Sales/Assets		1.4374**
		(0.7054)
Treated x FD x COP21 x EPSI x Sales/Assets		-1.0160

		(0.7369)
Firm size	0.0315***	0.0276***
	(0.0044)	(0.0044)
Profitability	-0.0011**	-0.0010**
	(0.0005)	(0.0005)
R&D	-0.0251**	-0.0235**
	(0.0102)	(0.0102)
Tangibility	0.1292***	0.1126***
	(0.0415)	(0.0399)
Dividend yield	-0.0068***	-0.0062***
	(0.0016)	(0.0016)
OCF	-0.2903***	-0.2585***
	(0.0525)	(0.0514)
Quick ratio	-0.0166***	-0.0192***
	(0.0025)	(0.0026)
GDP growth	-0.0002	0.0002
	(0.0014)	(0.0013)
Inflation rate	0.0049**	0.0048**
	(0.0019)	(0.0019)
Constant	0.3144	0.9894***
	(0.1928)	(0.2711)
Observations	3,053	3,053
R-squared	0.6492	0.6599
Year FE	Yes	Yes
Industry FE	Yes	Yes
Country FE	Yes	Yes
VCE Clustered Firm	Yes	Yes

Table reports the difference-in-differences (DID) regressions and the joint effects of endogenous and exogenous mechanisms. Treatment dummy (Treated) is a dummy variable that is set equal to one for treated firms that are exposed to climate change exposure risks (CC-Risk and temperature change); otherwise, the treatment dummy is set equal to zero. The ordinary least-squares (OLS) linear regressions include the fixed effects (FE) for time (Year FE), industry (Industry FE), and country (Country FE) levels Robust standard errors are reported in parentheses. The characters *** p<0.01, ** p<0.05, * p<0.1 present the statistically significant levels at the 1%, 5%, and 10%, respectively.

Appendix A1: Variables, detailed descriptions, and data vendors		
Variable	**Description**	**Data vendor**
Corporate leverage	Corporate debt to assets total [TDA] to capture book leverage ratio [LEV].	LSEG - Thomson Reuters DataStream
Temperature change	National Annual Surface Temperature Change (Degree Celsius). Estimates of the annual change in mean surface temperature calculated relative to a baseline climatology covering the years 1951–1980 (also known as temperature anomalies). Positive values indicate the temperature is warmer than normal, while negative values indicate the temperature is cooler than normal.	(IMF-Climate, 2024)
EPSI	Environmental policy stringency indexes.	OECD statistics
CC-Risk	Firm-level climate change risk multiplied by 100.	(SAUTNER et al., 2023)
Firm size	The natural logarithm of the total corporate assets.	LSEG - Thomson Reuters DataStream
Profitability	Corporate return on assets.	LSEG - Thomson Reuters DataStream
R&D	A corporate R&D dummy that is set equal to 1 for firms having Research & Development expenditure, it is set equal to zero.	LSEG - Thomson Reuters DataStream
Tangibility	Corporate property, plant, and equipment value to asset total	LSEG - Thomson Reuters DataStream
Dividend yield	Corporate dividend yield is the fraction of annual dividends per share to price per share	LSEG - Thomson Reuters DataStream
OCF	Operating cash flow to assets total.	LSEG - Thomson Reuters DataStream
Quick ratio	Corporate quick ratio. Quick Ratio = [Cash & equivalents + marketable securities + accounts receivable] / Current liabilities	LSEG - Thomson Reuters DataStream
GDP growth	GDP growth (annual %)	(WB, 2024)
Inflation rate	Inflation, GDP deflator: linked series (annual %)	(WB, 2024)
Sales/Assets	Corporate sales to asset total	LSEG - Thomson Reuters DataStream
Dividends Cash/Assets	Common cash dividends to assets total.	LSEG - Thomson Reuters DataStream

ESG	Corporate environmental, social, and governance (ESG) score. Missing values are replaced with zero.	LSEG - Refinitiv Eikon
Environment score	Corporate environmental (E) pillar score. Missing values are replaced with zero.	LSEG - Refinitiv Eikon
Social score	Corporate social (S) pillar score. Missing values are replaced with zero.	LSEG - Refinitiv Eikon
Governance score	Corporate governance (G) pillar score. Missing values are replaced with zero.	LSEG - Refinitiv Eikon
FD	Multidimensional financial development (FD) index. The index captures the development of financial institutions (FI) and markets (FM), including access, depth, and efficiency sub-indices.	(IMF-FD, 2024)

Note: except macroeconomic factors, firm-level climate risk, and national temperature change, all the continuous variables are winsorized at the 1st and 99th percentile to mitigate the potential effects of outliers. LSEG workspace LSEG Data & Analytics | Financial Technology & Data | Data Analytics (formerly Thomson Reuters DataStream, World Scope, Refinitiv Eikon vendors) is accessed using a licensed account. The OECD data on the EPSI database can be accessed at OECD Data Explorer • OECD Environmental Policy Stringency Index. Corporate climate change exposure risk data can be accessed at OSF | Firm-level Climate Change Exposure. The financial development index can be accessed at FDI Datasets of the IMF.

Appendix A2: Robust panel treatment regressions.

VARIABLES	(1)	(2)
Treated	0.0598***	0.0580***
	(0.0056)	(0.0055)
FD	-0.4128***	
	(0.1315)	
Treated * FD	0.2492***	
	(0.0646)	
Firm size	0.0319***	0.0276***
	(0.0046)	(0.0045)
Profitability	-0.0012**	-0.0012**
	(0.0005)	(0.0005)
R&D	-0.0273**	-0.0260**
	(0.0110)	(0.0112)
Tangibility	0.1385***	0.1161***
	(0.0405)	(0.0410)
Dividend yield	-0.0067***	-0.0064***
	(0.0017)	(0.0016)
OCF	-0.2982***	-0.2619***
	(0.0574)	(0.0573)
Quick ratio	-0.0166***	-0.0188***
	(0.0031)	(0.0032)
GDP growth	-0.0012	-0.0010
	(0.0015)	(0.0015)
Inflation rate	0.0029	0.0026
	(0.0019)	(0.0019)
Sales/Assets		-0.0496***
		(0.0129)
Treated * Sale/Assets		-0.0219**
		(0.0099)
Constant	-0.2559***	-0.2016***
	(0.0753)	(0.0714)
Observations	2,537	2,537
R-squared	0.6426	0.6452
Year FE	Yes	Yes
Industry FE	Yes	Yes
Country FE	Yes	Yes
VCE Clustered Firm	Yes	Yes

The table reports robust panel treatment regressions using the centered values of multidimensional financial development (Column 1) and corporate sales to assets total (Column 2). The centered predictors are calculated by subtracting their standard deviations from the real observations in the sample. The DID regressions are based on the OLS linear estimators and cluster-robust standard errors for firms with fixed effects for time, industry, and headquarters country codes using the matched sample. Robust standard errors are reported in parentheses with the statistically significant 1%, 5%, and 10% levels, respectively, labeled as *** $p<0.01$, ** $p<0.05$, and * $p<0.1$.

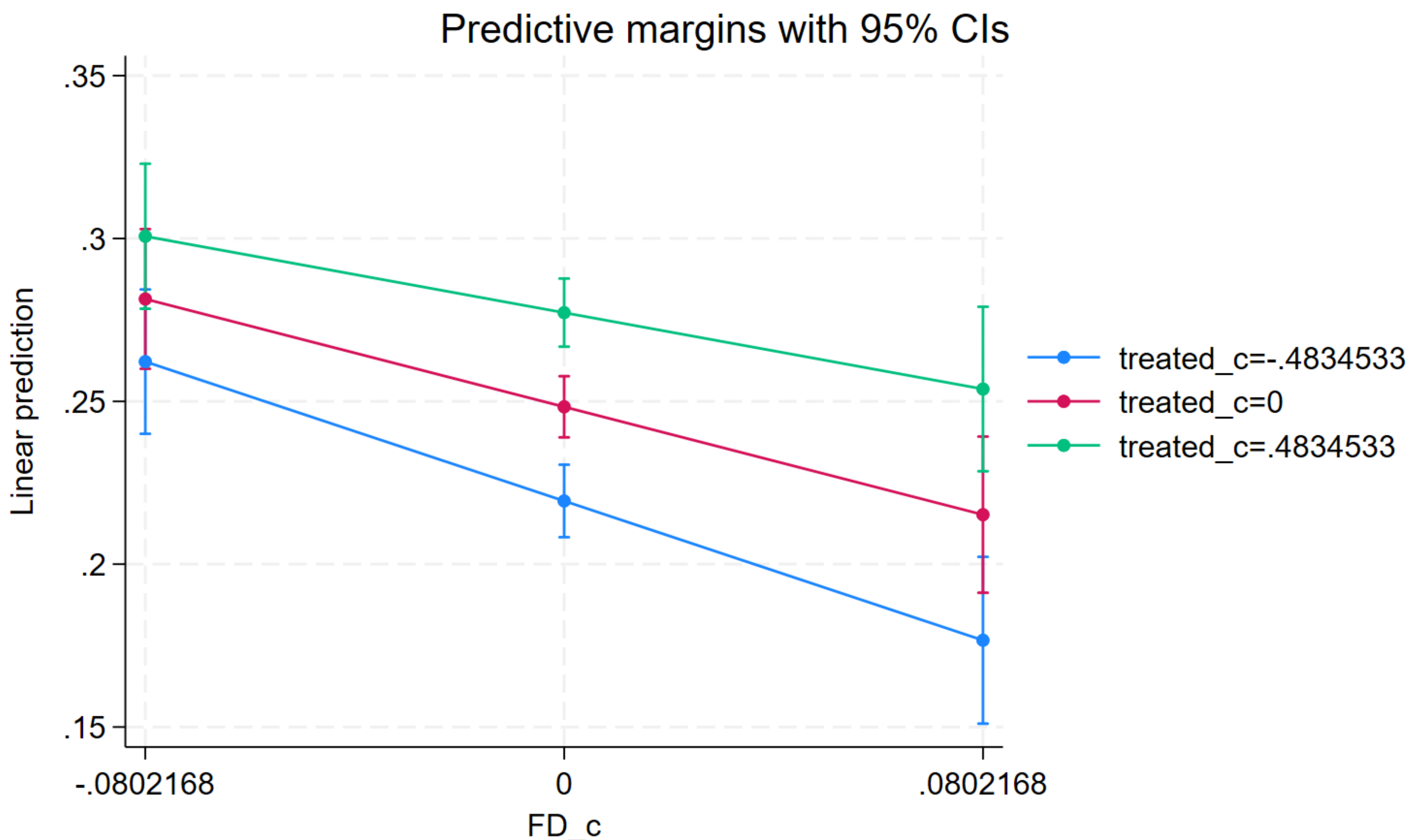

Figure 1A. Predictive margins with 95% Confident Intervals for financial development. Source: Author’s work.

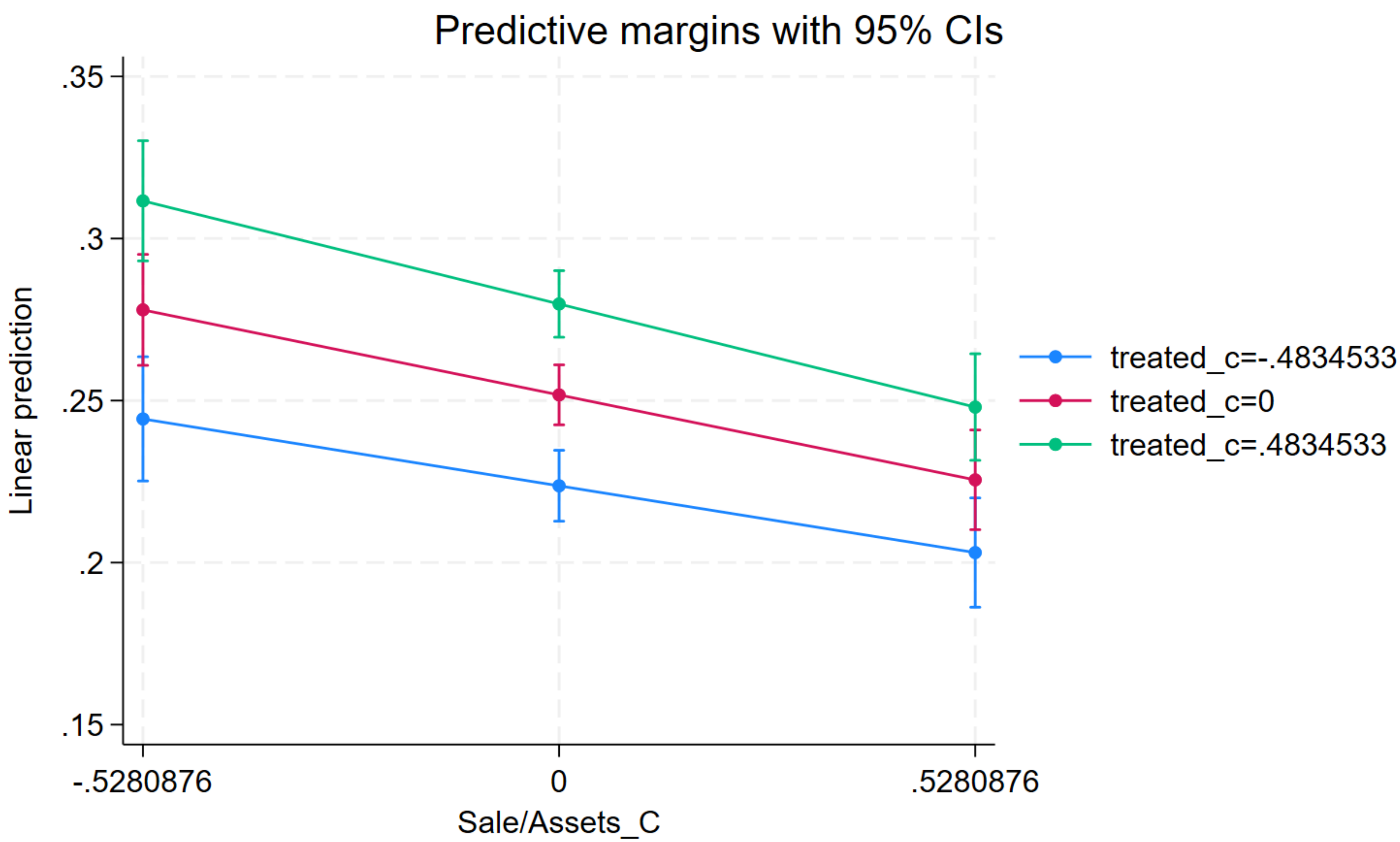

Figure 1B. Predictive margins with 95% Confident Intervals for corporate sales. Source: Author's work.

Appendix A3: OLS estimates carbon risk

VARIABLES	(1)	(2)	(3)	(4)	(5)
Ln (CO2PC)	-0.1363**	-0.1652**	-0.1555**	-0.1720***	-0.1552**
	(0.0642)	(0.0666)	(0.0661)	(0.0660)	(0.0670)
ESG		-0.0005*			
		(0.0003)			
Firm size	0.0264***	0.0317***	0.0304***	0.0317***	0.0295***
	(0.0052)	(0.0062)	(0.0064)	(0.0058)	(0.0061)
Profitability	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
R&D	-0.0116	-0.0082	-0.0081	-0.0085	-0.0103
	(0.0116)	(0.0116)	(0.0114)	(0.0118)	(0.0116)
Tangibility	0.0723	0.0683	0.0685	0.0686	0.0704
	(0.0537)	(0.0537)	(0.0536)	(0.0536)	(0.0541)
Dividend yield	-0.0064***	-0.0062***	-0.0061***	-0.0059***	-0.0065***
	(0.0021)	(0.0021)	(0.0021)	(0.0021)	(0.0021)
OCF	-0.3085***	-0.3044***	-0.3052***	-0.3058***	-0.3049***
	(0.0684)	(0.0684)	(0.0687)	(0.0679)	(0.0684)
Quick ratio	-0.0156***	-0.0147***	-0.0149***	-0.0145***	-0.0152***
	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)
GDP growth	0.0016	0.0013	0.0013	0.0012	0.0015
	(0.0019)	(0.0019)	(0.0019)	(0.0019)	(0.0019)
Inflation rate	0.0019	0.0023	0.0022	0.0022	0.0021
	(0.0019)	(0.0019)	(0.0019)	(0.0019)	(0.0019)
ESG ratings			-0.0004		
			(0.0003)		
Social score				-0.0006**	
				(0.0003)	
Environment score					-0.0003
					(0.0003)
Governance score	-0.0481	-0.1257	-0.1084	-0.1240	-0.0919
	(0.0779)	(0.0889)	(0.0913)	(0.0836)	(0.0869)
Observations	2,367	2,367	2,367	2,367	2,367
R-squared	0.6213	0.6232	0.6225	0.6239	0.6222
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
VCE Clustered Firm	Yes	Yes	Yes	Yes	Yes

The table reports the ordinary least-squares linear (OLS) regressions of corporate leverage on the logarithm value of carbon emissions per capita and ESG ratings. The OLS regressions compute cluster-robust standard errors for firms including the year, industry, and country fixed effects (FE). Robust standard errors are reported in parentheses with the statistically significant 1%, 5%, and 10% levels, respectively, labeled as *** p<0.01, ** p<0.05, and * p<0.1.

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