



The influence of carbon risk on debt structure^{☆,☆☆}

Hamdi Ben-Nasr^a, Shabeen Afsar Basha^a, Syed Shams^{b,*}

^a College of Business and Economics, Qatar University, Doha, Qatar

^b School of Business, University of Southern Queensland, Australia

ARTICLE INFO

JEL classifications:

G31
G32
Q51
Q54

Keywords:

Climate change
Carbon emissions
Bank debt
Regulations

ABSTRACT

We add to the literature on the effect of carbon risk on the availability and cost of bank loans, by focusing on the impact of carbon risk on the proportion of bank debt relative to total debt. Using a global sample of 58 countries covering the period 2007–2020, we find that carbon risk is negatively associated with bank debt ratio, indicating that high emitter firms are less able to secure bank debt. The findings support our hypothesis that high-emitter firms reduce bank debt to avoid bank scrutiny and it is likely banks avoid lending to high-emitter firms for reputational concerns. Our results are robust to a battery of sensitivity tests and addressing endogeneity concerns using several approaches. We add to this literature by distinguishing between the demand-side vs. supply-side. Our channel tests are in line with the demand-side perspective. Indeed, we show that the negative relationship between carbon risk and bank debt is more (less) pronounced in firms with severe agency (information asymmetry) problems. We also provide support for the supply-side perspective. We show that the negative association between carbon risk and bank debt is stronger in financially developed countries and in countries with stringent environmental regulations. We offer many practical and policy implications based on our results. Our study highlights the potential role of banks in aiding climate policy implementation. Furthermore, firms can adopt carbon risk mitigating strategies to amplify their capital sources.

“.. facilitated emissions has gained prominence over the past year following a growing body of evidence showing carbon-intensive companies are more reliant on bank services to arrange financing from investors, than they are on loans from bank themselves”¹

1. Introduction

Over five decades ago, the First Earth Summit by the United Nations in Stockholm awakened governments, practitioners, and academia towards climate change, accentuating the need to understand the magnitude and likelihood of climate change. The summit recommended identifying and controlling pollutants that aggravate climate change. Many Earth summits that followed culminated in the adoption of the first global emissions reduction agreement in 1997, which came to be known as the Kyoto Protocol (Jackson, 2007). The agreement that came

into force in 2005 by thirty-five participating developed countries provided for market mechanisms. It allowed emissions trading by the participating countries with other nations, making emission reduction a global concern. The protocol finally led to the Paris agreement in 2015 that brought together 194 countries with an aim to reduce emissions to control climate change (UN report²; Jackson, 2007). The Kyoto agreement's market mechanisms and amendments during the following climate conferences generated an interest in examining the effect of carbon risk on corporate outcomes and policies. Studies such as, Jung et al. (2018), Bolton and Kacperczyk (2021), Bose et al. (2021), and Ehlers et al. (2022) use firm carbon emissions as a proxy of carbon risk. Carbon emissions comprise the emissions attributed to the firm's activities directly (known as Scope 1) and indirect emissions attributed to the energy purchases of the firm (known as Scope 2). Numerous studies document the relationship between carbon risk and financial policies,

[☆] This article is part of a Special issue entitled: ‘Corporate Debt Choices’ published in International Review of Financial Analysis.

^{☆☆} Hamdi Bennisar acknowledges financial support from Qatar University through the internal grant “IRCC-2024-005” and an RRC award [ESC01-0429-240006] from the Qatar National Research Fund (a member of The Qatar Foundation). The statements made herein are solely the responsibility of the author[s].

^{*} Corresponding author.

E-mail addresses: hbennasr@qu.edu.qa (H. Ben-Nasr), sa1705541@qu.edu.qa (S.A. Basha), Syed.Shams@unisq.edu.au (S. Shams).

¹ <https://www.responsible-investor.com/european-and-global-banks-split-on-the-need-to-disclose-financed-emissions/>

² <https://www.un.org/en/climatechange/markings-kyoto-protocol%E2%80%99s-25th-anniversary>

such as firm performance (Matsumura et al., 2014; Perdichizzi et al., 2024), acquisitions (Bose et al., 2021), cost of equity (Cepni et al., 2024), default risk (Kabir et al., 2021; Wang et al., 2023; Wang et al., 2024), credit risk (Capasso et al., 2020; Umar et al., 2021), idiosyncratic volatility (Perera et al., 2023), cost of debt (Caragnano et al., 2020; Jung et al., 2018), and accounting conservatism (Ferdous et al., 2024). This growing body of research highlights the far-reaching implications of climate policies on the financial policies. Our study contributes to this line of literature by examining the influence of carbon risk on the proportion of bank debt relative to total debt using a global sample.

Several studies confirm the cost of debt increasing tendency of carbon risk. For instance, Jung et al. (2018) show that carbon emissions are associated with a higher cost of debt (i.e., the ratio of interest expenses over the amount of debt that bears interest) of Australian firms. Painter (2020) examines the impact of climate change risk stemming from the increase in sea level, on the cost of US municipal bonds and shows that counties that are exposed to high climate risk are penalized with a higher cost of municipal bonds. Javadi and Masum (2021) examine the impact of climate change, as measured by a drought index, on the cost of bank loans of US firms. They show that high climate risk is associated with higher bank loans spread. Caragnano et al. (2020) examine the impact of CO₂ emissions on the cost of debt of European firms and show that the cost of debt is positively related to carbon emissions. Safiullah et al. (2021) examine the effect of carbon emissions on corporate debt rating in the US. They show that debt ratings are negatively related to carbon emissions. In other studies, Ilhan et al. (2021) show that high emitter firms are risky and have a low reputation due to the negative news in the media (e.g., Velte et al., 2020), which leads to a higher cost of bank loans (e.g., Javadi & Masum, 2021). Similarly, Degryse et al. (2023) show that firms considered as green (measured by the firm's voluntary participation in the Carbon Disclosure Project (CDP)) enjoy low bank loan spreads. We add to this literature by examining the impact of carbon risk on the proportion of bank debt relative to total debt rather than on the cost or availability of bank loans per se. This contribution is important since although the level of debt may not change its composition (i.e., bank debt vs. public debt reliance) may change (Rauh & Sufi, 2010). We define bank debt reliance as the ratio of bank debt to total debt.

Carbon risk may be negatively related to bank debt for two main reasons. First, to avoid bank scrutiny (i.e., the demand point of view), firms facing higher carbon risks borrow less bank debt. In fact, banks enjoy lower monitoring efforts and costs and have the flexibility and ability to monitor borrowers, intensifying banks' monitoring incentives (e.g., Chava et al., 2009; Diamond, 1984; Houston & James, 1996). Additionally, banks may discipline high emitter firms by reinitiating the contract loan terms or terminating the contract. However, bond debt holders having a diffuse relationship with the firm, may experience more free-rider monitoring problems and may refrain from engaging in costly monitoring. Therefore, we expect that high emitter firms to avoid close monitoring from banks and opt to issue bonds.

Second, from a supply-side perspective, banks may supply less credit to high-emitter firms or request higher rates for reputational reasons. Indeed, prior research shows that banks that lend to high emitting firms experience withdrawals of deposits (Homanen, 2018) as well as increased volatility in depositor bases (Houston et al., 2021). To mitigate the negative impact, banks may offer better lending terms to firms with high environmental performance (Nandy & Lodh, 2012) and may charge higher rates to high emitter firms (Altavilla et al., 2024). Additionally, high emitter firms tend to have lower quality of accounting information (e.g., Wedari et al., 2021) to hide their ethical misbehavior, which increase banks' monitoring cost. Indeed, prior studies show that carbon risk is associated with a low bond debt rating (e.g., Safiullah et al., 2021). Banks as sophisticated and informed lenders may use non-price mechanisms to address borrowers' carbon risks (e.g., Chen et al., 2021; Lemma et al., 2020). These mechanisms will include tighter debt covenants and shorter maturities, as well as increased collateral. Given

that, the positive association between carbon risk and cost of borrowing should be higher for bank loans when compared to corporate bonds. Consistent with this view Glingler and Moreau (2019) show that a one standard deviation increase in carbon risk increases the cost of bank loans (corporate debt) by 23.37 (6.02) basis points after 2015. Based on supply side effect, we expect that bank loans are less attractive to high emitter firms than corporate debt.

Using a global sample of 14,307 firm-year observations from 58 countries over the period from 2007 to 2020, we conduct a number of estimations that produce robust results confirming the effect of carbon risk on bank debt. We find that carbon risk measured by both natural logarithm of carbon emissions and carbon intensity (carbon emission scaled by net sales) are negatively associated with bank debt³ after controlling for year, industry, firm and country fixed effects indicating that high-emitter firms are less able to secure bank debt, which is consistent with the demand side argument suggesting that high emitter firms tend to substitute away from bank debt to avoid bank scrutiny. We find a stronger (weaker) negative relationship between carbon risk and bank debt in firms suffering from severe agency (information asymmetry) problems. Our results are also consistent with the supply side argument suggesting that banks may supply less credit to high emitter firms since high carbon emissions are associated with negative news in the media hindering their reputation. We also show that bank debt of firms in countries that are more financially developed countries and countries with stringent environmental regulations have a stronger negative association with carbon risk.

Our results are robust to addressing endogeneity concerns using several approaches. We address endogeneity concerns using the instrumental variable approach, a two-step system generalized methods of moment (GMM2S), propensity score matching (PSM), entropy balancing and Heckman two-stage selection approaches. Furthermore, we plot an exogenous shock to carbon emissions to further address endogeneity issues. Specifically, we use the Paris agreement as an exogenous shock to climate risk. We show that the negative association between carbon emission and bank debt had become more severe after the Paris agreement (i.e., COP 21). Our results are also robust to additional corporate governance control variables, alternative measures of debt financing and excluding countries with highest number of firm year observations.

Our study makes several contributions to the literature. First, our research question is different from previous studies examining the effect of carbon risk on the cost and availability of bank loans (e.g., Javadi & Masum, 2021; Nguyen & Phan, 2020). Indeed, we examine the effect of climate risk on debt composition (i.e., the firm's degree of reliance on bank debt versus public debt). Second, we add to this literature by using a sample of 58 countries over the period 2007–2020—which represents a major advantage over most existing research based on single-country or regional data. Third, we use a dual-perspective framework (demand-side vs. supply-side). The demand-side perspective suggests that carbon risk is associated with a lower degree of reliance on bank debt ratio since firms with high agency and information asymmetry costs tend to avoid strict bank debt monitoring (e.g., Diamond, 1984; Houston & James, 1996). Our results provide support for this perspective. Indeed, we show that the negative association between carbon risk and bank debt ratio is more (less) pronounced in firms with high agency costs and severe informational asymmetry (in the presence of large shareholders such as sovereign wealth funds (SWFs), insiders, strategic shareholders, strong internal governance and high environmental responsibility). The supply side perspective suggests that banks may supply less credit to high-emitter firms or request higher rates for reputational reasons. Our results provide support for this perspective by showing that the negative association between carbon risk and bank debt ratio is more pronounced in countries that implemented an emission trading system (ETS) and countries with high climate risk performance. Fourth, our paper adds to

³ Measured as the ratio of bank debt to total debt.

the literature on the impact of carbon risk on capital structure (e.g., Cumming et al., 2024; Ginglinger & Moreau, 2019; Zhou & Wu, 2023) by focusing on debt composition, which may change even when the level of firm debt remains constant (e.g., Rauh & Sufi, 2010). Finally, our study contributes to the growing body of debt mix literature that examines the key determinants of debt choice (Boubaker et al., 2018 (product market competition); Li et al., 2019 (changes in the information environment); Cline et al., 2019 (institutional investors' horizon); Ben-Nasr, 2019 (unemployment insurance benefits); Ben-Nasr et al., 2020 and Huang et al., 2023 (political risk uncertainty); Ben-Nasr et al., 2021 (board reforms); Chen et al., 2021 (the sensitivity of executive compensation to stock return volatility) and Chen et al., 2023 (credit default swaps); Li et al., 2024 (International Financial Reporting Standard 9)), Kabir et al., 2024 (managerial ability) by focusing on an important topic namely, carbon risk.

The rest of the paper reads as follows. Section 2 reviews the literature and develops our hypotheses. Section 3 presents our empirical design. Section 4 discusses our results. Section 5 concludes our paper.

2. Literature review and hypotheses development

2.1. Literature review

Several studies examine the economic outcomes of environmental concerns, climate change risk in general and carbon risk in particular. Early studies document the cost of capital increasing tendencies of environmental risks (Chava, 2014⁴; El Ghouli et al., 2016⁵; Bolton & Kacperczyk, 2021; Bolton & Kacperczyk, 2023a⁶; Trinks et al., 2022⁷; Ilhan et al. (2021) show that the cost of protection against tail risk in option markets is higher for firms with high carbon risk. Bose et al. (2025) examine the effect of carbon emissions on stock price crash risk. They show that carbon risk is associated with the hiding of bad news by opportunistic managers, which increases the likelihood of stock price crash risk. Pankratz et al. (2023) show that high temperature is associated with low firm financial performance. Bua et al. (2024) show that equity investors require higher compensation for both of physical and transition climate risk. Contrary to these studies, Aswani et al. (2024) show that the carbon emissions- stock returns relationship is sensitive to the measure of emissions used. In fact, they find that while emissions levels are associated with stock returns, the effect disappears for the carbon intensity measure, which they argue is possibly due to either the correlation between the emission levels and firm characteristics such as, firm size or the estimation method of emissions. Phan et al. (2022) show that carbon risk negatively impacts corporate investment and the effect is more profound for carbon intensive firms, while Naem and Li (2019) show that carbon risk is negatively associated with access to finance. Furthermore, Safiullah et al. (2021) show that the presence of institutional investors mitigates carbon risk. Based on this discussion, most studies confirm that climate risk is associated with higher equity risk premium, low firm performance, low investment efficiency and

increased financial constraints. We add to this literature by examining the effect of carbon risk on the share of bank debt in firms' total debt structure.

Several studies examine the effect of environmental performance on capital structure, further bifurcated in to overall leverage studies, bank debt (including syndicated bank debt and non-syndicated debt)⁸ and corporate debt. For instance, Francis et al. (2022) show that environmental corporate social responsibility is associated with lessor debt specialization for firms with higher regulatory and transitional climate risk. Among the overall debt studies, Du et al. (2015) report a lower cost of debt for firms with higher corporate environmental performance. Jung et al. (2018) show that carbon risk increases the cost of debt. Nguyen and Phan (2020) show that carbon risk increases the financial constraints of polluters, negatively impacting the financial leverage of Australian firms. This is explained by the tendency of large banks to restrict their lending to polluting firms with potential risk of litigation or compliance cost. Nguyen et al. (2025) report that post the Kyoto protocol, emitter firms are less likely to obtain debt from major banks and resort to new lenders instead. Safiullah et al. (2021) report a negative association between carbon emissions and debt rating. Lemma et al. (2021) show that firms with commitment to climate change enjoy improved corporate reputation, credit rating and reduced default risk. Goodell et al. (2025) examine the impact of firm-level climate change on capital structure. They show that climate risk is associated with shorter debt maturity. This finding suggests that debtholders reduce debt maturity to mitigate firms' financial uncertainty due to climate risk. Indeed, short-term debt is associated with higher flexibility and lower risk of refinancing. Ginglinger and Moreau (2019) examine the effect of climate risk based on the leverage of US firms after the Paris Agreement. They show that leverage is negatively related to carbon risk after 2015. They also show that firms with high carbon risk increase their equity issuance after 2015, consistent with the demand effect of leverage. Additionally, they show that carbon risk is positively associated with the cost of corporate and bank debt after 2015 for high climate risk firms, suggesting that supply effect also explains their results. Zhou and Wu (2023) show that climate risk exposure is positively associated with the speed of leverage adjustments (SOA) for a sample of firms from 35 countries. Cumming et al. (2024) focus on the energy sector and examine the effect of physical carbon risk along with the cost of debt on SOA for a sample of firms from 18 countries. They show a positive relation between carbon risk and the SOA for firms with a low cost of debt. Painter (2020) show that the cost of municipal bonds is higher in counties that are more subject to climate change. Palea and Drogo (2020) report a similar effect for European firms and show that while more polluting firms faced a high cost of debt prior to the Paris agreement, the adverse impact of emissions on the cost of debt extended to even low polluting after the Paris agreement.

As for bank loans, a majority of studies examine environmental risks/concerns (including carbon risk) - cost of debt nexus for syndicated loans.⁹ In early studies, Nandy and Lodh (2012) show that eco-friendly firms enjoy favorable loan contracts and Chava (2014) show that the cost of debt is higher for firms facing environmental concerns. Javadi and Masum (2021) report a positive relationship between climate risk and the cost of bank loans. Hrazdil et al. (2024) show that adverse climate related incidents are associated with higher cost of debt, shorter maturity and more collateral requirements. Similarly, Caragnano et al. (2020) show that carbon emissions increase the cost of debt for European firms. Furthermore, D'Arcangelo et al. (2023) show that stringent

⁴ Chava (2014) document that investors and lenders demand a higher cost of capital from firms facing more environmental concerns.

⁵ El Ghouli et al. (2016) report a lower cost of equity for firms with higher corporate environmental responsibility in their sample of manufacturing firms. Corporate Environmental responsibility is based on direct and indirect emissions related to greenhouse gases (GHGs), water, waste, land and water pollutants, air pollutants, and natural resource use.

⁶ Bolton and Kacperczyk (2021) report evidence suggesting that US investors require a compensation for bearing carbon risk and Bolton and Kacperczyk (2023a) show that carbon risk is associated with a risk premium in global markets.

⁷ Trinks et al. (2022) document a similar increased cost of equity for high emitting firms in their sample of global firms with a more profound impact for European firms, firms facing carbon regulations and firms in the high-emission sectors

⁸ Please refer to the line of literature examining debt specialization that discuss the types of debt in detail (For e.g., Colla et al., 2013; Francis et al., 2022; Berger et al., 2021)

⁹ Syndicated loans are highly monitored by banks resulting in lower loan spreads but lessor loan maturities and firms with higher monitoring facing higher covenant violations and loan renegotiations (Gustafson et al., 2021).

environmental regulation further decreases the cost of debt for low emitting firms. Ehlers et al. (2022) and Kacperczyk and Peydro (2022) show that lenders demand a higher carbon premium and the effect is more profound after the Paris agreement. Basu et al. (2022) show that high ESG banks are less likely to offer mortgage loans in localities that are more subject to climate risk. Houston and Shan (2022) report a positive relationship between banks' ESG rating and their likelihood to offer loans to highly rated ESG borrowers. Kacperczyk and Peydro (2022) show that banks committed to decarbonization are less likely to lend to firms with high carbon risk. Degryse et al. (2023) show that banks with high environmental responsibility (i.e., green banks) are more likely to offer cheap loans to green firms after the Paris agreement. Giannetti et al. (2023) show that banks with high environmental disclosure are more likely to lend firms with high carbon emissions (i.e., brown firms) without higher interest rates or shorter maturity. Ding et al. (2023) show that carbon risk in China is negatively related to the number of loans offered by banks. In conclusion, the findings of Haas and Kempa (2023) argue that where carbon pricing is not feasible, credit market interventions can be effective in promoting 'low-carbon development'. Asimakopoulou et al. (2023) show that ESG rated, specifically low-growth, financially constrained firms prefer bank debt to bond debt as they reduce information asymmetry with their ESG rating. Furthermore, studies such as, Massa and Zhang (2021)¹⁰ and Berger et al. (2021) show a shift from corporate debt to bank debt over time necessitating the bifurcation in the study of debt financing. In addition, while a few studies examine rationale of firms' debt choice. Studies examining the effect of climate risk on overall bank debt are non-existent^{11, 12}. We add to this literature by examining the impact of a firm's carbon risk on the share of bank debt in firms' total debt structure.

2.2. Hypotheses development

Based on previous studies on environmental performance and financial contracting research, carbon emissions are likely to decrease both the demand for and the supply of bank debt financing. From the demand-side perspective, firms facing higher carbon risk tend to borrow less from banks to avoid bank scrutiny. In fact, by virtue of their close relationships with borrowers and their superior monitoring capacity, banks may exert pressure on borrowers facing a higher carbon risk by reneging their lending arrangements. Conversely, given the diffuse ownership of their debt claims and the resulting free-rider problems, corporate bondholders have much weaker monitoring incentives (Diamond, 1984, 1991; Houston & James, 1996), thus making it less likely for them to terminate funding. As the public awareness of environmental issues have grown significantly in recent years, carbon-emitting firms are confronted with heightened uncertainty surrounding their earnings, and are therefore, more inclined towards risk-averse decision-making and the adoption of conservative financial policies. For example, firms with a higher carbon risk have been shown to pay less dividends (Balachandran & Nguyen, 2018), reduce investments (Phan et al., 2022), decrease financial leverage (Nguyen & Phan, 2020), acquire firms in countries with weaker environmental standards, where sanctions are less likely to be imposed (Bose et al., 2021). From this perspective, we expect firms with a higher carbon risk to avoid strict bank-monitoring and rely less on bank debt.

¹⁰ Massa and Zhang (2021) show that firms shifted from bond debt to bank debt financing post the Hurricane Katrina.

¹¹ For example, Huang et al. (2023) examine debt choice for firms exposed to political risk and find that firms with higher political risk prefer private debt to public debt while Kabir et al. (2025) show that firms with higher managerial ability prefer public debt over private debt.

¹² The plethora of studies examines the impact of climate risk on syndicated bank debt and a few studies on corporate debt (for e.g., Pohl et al., 2023; Florilla et al., 2025)

From the supply-side perspective, banks may reduce their loan supply to firms with higher carbon emissions as a way to avoid any potential reputational harm associated with their borrower's emissions.¹³ This argument is based on the idea that environmental issues have garnered heightened attention within the finance community, propelled by corporate disclosure mandates (EPA, 2009; ICAEW, 1992) and widespread media coverage (Gallego-Álvarez et al., 2015; Velte et al., 2020). As a result of this increased attention to environmental footprint, investors and other market participants have instituted multifaceted mechanisms to incentivize environmentally sustainable conduct and censure entities that demonstrate a lax approach to their environmental obligations. For instance, investors are likely to charge higher spreads or demand higher interest rates for companies with a poor carbon footprint, reflecting the higher perceived risk attributed to environmental non-compliance (e.g., Jung et al., 2018). Moreover, credit rating agencies are likely to lower credit ratings for such non-compliant firms, making it more difficult and expensive for them to access capital markets (Safiullah et al., 2021). In the same vein, lenders are likely to use non-price mechanisms through which they address borrowers' carbon risk, by offering tighter debt covenants such as shorter maturities and greater collateral requirements (e.g., Chen et al., 2021; Lemma et al., 2020). Along these lines, we expect that bank lenders are less willing to extend credit to carbon-emitting firms, reflecting their commitment to penalizing carbon-intensive practices and directing their financial resources towards environmentally responsible initiatives (e.g., Altavilla et al., 2024).

H1. Bank debt reliance is negatively related to carbon risk.

3. Empirical design

3.1. Sample construction

We obtain bank and corporate lending information as well as financial data used to calculate our control variables from Standard and Poor's Capital IQ database. We gather the emissions and other carbon risk proxies from the Climate Disclosure Project (CDP) database and Refinitiv Datastream. We collect macroeconomic and institutional data from the World Bank and International Country Risk Guide (ICRG). We, then match the CDP data with bank and corporate debt, financial, and macroeconomic, and institutional data. We exclude financial firms from our sample due to their specific financial structure (e.g., firms with a four-digit code between 6000 and 6999). We winsorize our data at the 1 % and 99 % to control for the effects of outliers.

We start with 36,305 observations for the period 2005–2020 by matching the CDP data and Capital IQ firm data. We drop observations for missing bank debt variable (13,733 observations), financial firms (2224 observations) and after dropping missing controls and winsorizing (6027 observations) we obtain 14,321 observations for the period 2005–2020. We further drop the observations for years 2005 and 2006 due to low number of observations resulting in a global sample of 14,307 observations from 58 countries for the study period 2007–2020. Table 1, Panel A reports our sample distribution by country, industry and year. As can be seen, USA accounts for 25.68 % of our firm-year observations, followed by Japan (14.86 %) and United Kingdom (10.47 %). The highest number of our firm-year observations belongs to Basic industry (i.e., 18.1 %) and followed by Consumer Durables industry (i.e., 17.6 %). Campbell's (12 industries) classification is used to define industries. Year distribution shows that the highest number of firm year observation is reported in the year 2020 (i.e., 11 %) followed by 2019 (i.e., 10.5 %).

¹³ Prior research provides evidence that the adverse impact on the reputation of banks' lending to high emitting firms is manifested through deposit outflows (Homanen, 2018) and increased depositor base volatility (Houston et al., 2021).

Table 1
Country, year and industry distribution.

Panel A Observations by Country, Industry and year								
Country	Obs.	Percent	Country	Obs.	Percent	Industry	Obs.	Percent
Argentina	3	0.02	Luxembourg	30	0.21	Basic	2582	18.1
Australia	399	2.79	Malaysia	25	0.17	Capital Goods	1633	11.4
Austria	81	0.57	Malta	3	0.02	Construction	951	6.7
Belgium	80	0.56	Mexico	84	0.59	Consumer Durables	2515	17.6
Brazil	345	2.41	Mongolia	1	0.01	Food/Tobacco	1004	7.0
Canada	11	0.08	Morocco	1	0.01	Leisure	442	3.1
Chile	35	0.24	Netherlands	220	1.54	Other	548	3.8
China	271	1.89	New Zealand	63	0.44	Petroleum	516	3.6
Colombia	44	0.31	Nigeria	4	0.03	Service	1027	7.2
Cyprus	1	0.01	Norway	263	1.84	Textiles/trade	748	5.2
Czechia	5	0.03	Panama	1	0.01	Transportation	765	5.4
Denmark	154	1.08	Philippines	27	0.19	Utilities	1576	11.0
Estonia	1	0.01	Poland	23	0.16	Total	14,307	
Finland	326	2.28	Portugal	70	0.49			
France	651	4.55	Russian Federation	51	0.36	Year	Obs.	Percent
Germany	578	4.04	Singapore	116	0.81	2007	41	0.3
Greece	8	0.06	South Africa	421	2.94	2008	99	0.7
Hong Kong	192	1.34	Spain	316	2.21	2009	719	5.0
Hungary	11	0.08	Sri Lanka	1	0.01	2010	937	6.6
Iceland	2	0.01	Sweden	402	2.81	2011	992	6.9
India	62	0.43	Switzerland	215	1.5	2012	1098	7.7
Indonesia	11	0.08	Thailand	71	0.5	2013	1125	7.9
Ireland	166	1.16	Turkey	173	1.21	2014	1193	8.3
Israel	39	0.27	Ukraine	4	0.03	2015	1243	8.7
Italy	277	1.94	United Arab Emirates	6	0.04	2016	1312	9.2
Japan	2126	14.86	United Kingdom	1498	10.47	2017	1188	8.3
Republic of Korea	659	4.61	United States	3674	25.68	2018	1288	9.0
Kuwait	3	0.02	Uruguay	1	0.01	2019	1501	10.5
Lithuania	1	0.01	Vietnam	1	0.01	2020	1571	11.0
			Total	14,307		Total	14,307	

Panel B Summary Statistics								
Variables	High emissions			Low emissions			Difference	
	MEAN	MEDIAN	SD	MEAN	MEDIAN	SD	Mean	Median
BD	0.333	0.218	0.340	0.453	0.406	0.389	***	***
LNEMISSIONS	14.122	14.051	1.811	10.098	11.174	4.335	***	***
LEV	0.288	0.274	0.144	0.262	0.250	0.159	***	***
FSIZE	9.547	9.596	1.381	8.140	8.156	1.423	***	***
PROFITAB	0.073	0.065	0.057	0.079	0.070	0.062	***	***
TANG	0.330	0.292	0.211	0.274	0.222	0.211	***	***
Q	1.209	0.957	0.776	1.365	1.084	0.906	***	***
RATING	0.514	1.000	0.500	0.288	0.000	0.453	***	***
MEANBD	0.410	0.419	0.095	0.408	0.420	0.095		
ZSCOREDUMMY	0.731	1.000	0.443	0.665	1.000	0.472	***	***
LGPPC	10.595	10.724	0.580	10.514	10.689	0.679	***	***
LAWORDER	4.863	5.000	0.839	4.811	5.000	0.938	***	*
PVTCREDIT	1.482	1.613	0.413	1.412	1.494	0.446	***	***

Notes: Panel A reports the distribution of our sample by country. Panel B shows the descriptive statistics for our variables separately for the sub-sample of high and low emitting firms. We present the results of the mean and median difference tests between high and low emitting firms. The full sample includes 14,307 observations from 58 countries during the 2007 and 2020 period. [Appendix 1](#) presents the description of the variables.

3.2. Variables

3.2.1. Dependent variable

We follow prior studies such as, [Ben-Nasr et al. \(2021\)](#), [Boubaker et al. \(2018\)](#) and [Kabir et al. \(2024\)](#) and use the ratio of bank debt over total debt as our proxy of bank debt. Bank debt comprises of outstanding balance of revolving credit and term loans obtained from Capital IQ. [Appendix 1](#) provides the definition and the data sources of our variables.

3.2.2. Main independent variable (carbon risk)

We obtain the firms' Scope 1 and Scope 2 emission from CDP. Scope 1 emissions are the direct emissions from the sources or activities a firm owns or controls ([Bolton & Kacperczyk, 2021](#); [Bose et al., 2021](#); [Jung et al., 2018](#)). Scope 2 emissions are indirect emissions attributable to the firm's use of energy (e.g., electricity purchased). In line with [Bose et al.](#)

(2021) we use the natural logarithm of one plus sum of Scope 1 and Scope 2 emissions as our proxy for carbon risk. Our alternate proxy of carbon risk is carbon intensity (Total emissions scaled by revenue), following [Ehlers et al. \(2022\)](#).

3.2.3. Control variables

In line with [Ben-Nasr et al. \(2021\)](#), [Chen et al. \(2023\)](#) and [Li et al. \(2024\)](#), we control for the following variables: (i) LEV calculated as total debt over total assets to control for financial leverage. Firms with high leverage have higher default risk, hence are less able to raise corporate debt. (ii) FSIZE calculated as the natural logarithm of total assets in US\$. Larger firms tend to have higher information quality, hence are more likely to raise highly information sensitive debt namely corporate debt. (iii) PROFITAB calculated as operating income over total assets to control for firm profitability. High profitability is associated with good

reputation, hence a high likelihood to raise bond debt. (iv) TANG calculated as the ratio of net property plant and equipment over total assets to control for tangible assets. High asset tangibility increases the likelihood to raise funds from the bond markets. (v) Q is the ratio of market value of equity and the book value of debt over total assets to control growth opportunities. High Tobin's Q indicate high growth opportunities, which decreases the likelihood to borrow from banks. Due to the ability of banks to strictly monitor borrowers, firms with high growth potential are more likely to avoid bank debt. (vi) ZSCOREDUMMY a dummy variable that equals one if the Altman's, 1968 z-score is lower than 1.81 and zero otherwise. A ZSCOREDUMMY of one indicates high financial constraints, which is associated with a higher likelihood to use bank debt. Constrained firms may prefer the financial flexibility offered by banks in the event of distress (Chemmanur & Fulghieri, 1994). Furthermore, the relative ease of restructuring by private debtholders in the event of financial distress is confirmed by some studies (e. g, Houston & James, 2001). Therefore, it is likely banks are better able to deal with firms with bankruptcy risk since they can renegotiate the contract afterward. (vii) RATING is a dummy variable equals one if the firm has a long-term debt rating on S&P rating above BBB- and zero.no long-term debt S&P rating and zero otherwise. Firms with lower rating are less likely to raise corporate debt. (viii) MEANBD is the industry year average of bank debt ratio. Firms located in industries relying heavily on bank debt are more likely to opt for bank debt. (ix) LGDPPC is the natural logarithm of the gross domestic product per capita in US\$, (x) LAWORDER is the ICRG's law and order index used to control for macroeconomic determinants of the bank debt ratio. (xi) PVT CREDIT is the domestic credit to private sector (percent of GDP) to control for loan supply. Firms located in countries with high credit to the private sector are more likely to borrow from banks. The intuition behind this is that more credit supply in the country is associated with more bank debt availability.

3.3. Empirical model

To examine the impact of carbon risk on bank debt, we estimate the following model:

$$BD_{itjc} = \beta_0 + \beta_1 LNEMISSIONS_{itjc} + \beta_2 CONTROLS_{itjc} + \gamma_t + T_j + U_c + \xi_{itjc} \quad (1)$$

where BD is the ratio of bank debt to total debt, LNEMISSIONS is the natural logarithm of one plus total emissions (Scope 1 and Scope 2) from CDP, in line with Bose et al. (2021). Control variables: In line with Ben-Nasr et al. (2021), Chen et al. (2023) and Li et al. (2024), we control for the following variables: (i) LEV (total debt over total assets), (ii) FSIZE (the natural logarithm of total assets in US\$), (iii) PROFITAB (operating income over total assets), (iv) TANG (the ratio of net property plant and equipment over total assets), (v) Q (the ratio of market value of equity and the book value of debt over total assets), (vi) ZSCOREDUMMY (a dummy variable that equals one if the Altman's (1968) z-score is lower than 1.81 and zero otherwise), (vii) RATING (a dummy variable equals one if the firm has a long-term debt rating on S&P rating above BBB- and zero.no long-term debt S&P rating and zero otherwise), (viii) MEANBD (the industry year average of bank debt ratio), (ix) LGDPPC (the natural logarithm of the gross domestic product per capita in US), (x) LAWORDER (ICRG's law and order index) and (xi) PVT CREDIT (the domestic credit to private sector (percent of GDP)). γ_t are year dummies to control for year fixed effects. T_j are industry dummies to control for industry fixed effects. U_c are country dummies to control for country fixed effects. ξ_{itjc} is the error term. We estimate Eq. (1) using ordinary least squares (OLS), in and cluster the standard errors at the firm level because our proxy for carbon risk LNEMISSIONS is defined at the firm-level. Table 1, Panel B reports descriptive statistics for our variables for sample segmented by country-year median of LNEMISSIONS into high and low emissions. The mean (median) bank for the low emission sample is 0.453

(0.406) and the high emission sample is 0.333 (0.218) indicating the lower bank debt use by high emitting firms. In unreported results, the sample average (median) of BD is 0.400 (0.305) and the average (median) of LNEMISSIONS is 11.878 (12.563). As for the control variables, the coefficients are comparable to those in related studies (e.g., Ben-Nasr et al., 2021).

3.4. Correlation matrix

Table 2 presents the correlations between key independent variables. As we can see, LNEMISSIONS is negatively associated with BD at the 1 % level, suggesting that firms with higher carbon risk tend to use less bank debt, providing a preliminary support for H1. The correlation matrix does not display high correlations between our variables ruling out multicollinearity issues.¹⁴ As for the correlations between BD and the control variables, we report several expected significant negative correlations for FSIZE, PROFITAB, TANG, LGDPPC and LAWORDER suggesting that larger, more profitable, highly tangible firms and firms from high income and high law and order countries tend to use less bank debt. We also report positive and significant correlation coefficients for ZSCOREDUMMY and MEANBD, suggesting that firms with low Z-Score (i.e., with high bankruptcy risk) and from industries with low bank debt ratio are more likely to use bank debt. These results are consistent with the findings of prior literature (e.g., Ben-Nasr et al., 2021).

4. Results discussion

4.1. Baseline results

Table 3 reports the results of estimating regression (1) for our global sample. Model (1) reports the results of regressing BD on LNEMISSIONS and CONTROLS after controlling for firm and year fixed effects to control for potential missing firm-specific unobservable variables. As expected, the results show the coefficient of LNEMISSIONS is negative and significant at 1 % level consistent with our hypothesis, suggesting that firms with high carbon emissions are more likely to decrease their reliance on bank debt to avoid the high scrutiny. The variable LNEMISSIONS is also economically highly significant. Indeed, a one standard deviation increase in LNEMISSIONS decreases BD by 5.23 %.¹⁵ The negative carbon emissions-bank debt relationship is consistent with previous studies such as, Degryse et al. (2023) and Nguyen et al. (2025). Furthermore, many other studies such as, Painter, 2020; Javadi & Masum, 2021; Caragnano et al., 2020; Ehlers et al., 2022; Al Rabab'a et al., 2023; Kacperczyk & Peydro, 2022; and Javadi and Masum (2021) also establish a negative relationship between carbon risk and debt. While these studies examine syndicated loans (For., e.g., Degryse et al., 2023; Ehlers et al., 2022; Kacperczyk & Peydro, 2022) or examine a few countries (For e.g., Nguyen et al. (2025) examine Australian firms, Javadi and Masum (2021) examine syndicated loans in the United States' firms, Caragnano et al. (2020) examine the relationship between carbon risk and cost of debt in European firms, Al Rabab'a et al. (2023) examine firms in Asia pacific countries) this is the first study to confirm the negative impact of carbon risk on overall bank debt in an international sample. As for the control variables, we find that several control variables are consistent with the findings of prior literature on debt choice (e.g., Ben-Nasr et al., 2021). For instance, we report negative and significant coefficients for FSIZE, Q and RATING, suggesting that larger firms, firms with high growth opportunities and that have a debt rating

¹⁴ We also run variance inflation factor (VIF) tests to address potential multicollinearity issues and the mean VIF is 1.8 and all variables have a VIF of less than 10.

¹⁵ The coefficient for LNEMISSIONS is -0.004 . The standard deviation of LNEMISSIONS is 3.991 and the median of BD is 0.305. A one standard deviation increase in LNEMISSIONS decreases BD by 5.23 % ($(-0.004 \times 3.991) / 0.305$).

Table 2
Pearson correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) BD												
(2) LNEMISSIONS	−0.240***											
(3) LEV	−0.122***	0.134***										
(4) FSIZE	−0.384***	0.519***	0.182***									
(5) PROFITAB	−0.022***	−0.108***	−0.108***	−0.040***								
(6) TANG	−0.013	0.272***	0.239***	0.094***	−0.092***							
(7) Q	−0.118***	−0.106***	−0.025***	−0.123***	0.607***	−0.147***						
(8) RATING	0.078***	0.099***	0.253***	0.088***	−0.553***	0.174***	−0.636***					
(9) MEANBD	−0.397***	0.291***	0.185***	0.521***	0.132***	0.043***	0.094***	−0.057***				
(10) ZSCOREDDUMMY	0.223***	−0.162***	−0.226***	−0.193***	−0.029***	−0.298***	−0.005	−0.082***	−0.161***			
(11) LGDPPC	−0.178***	0.043***	0.015*	0.153***	−0.004	−0.124***	0.051***	−0.036***	0.186***	0.009		
(12) LAWORDER	−0.061***	0.002	−0.067***	0.065***	−0.024***	−0.107***	0.003	−0.011	0.056***	0.052***	0.806***	
(13) PVT-CREDIT	−0.079***	0.021**	−0.012	0.092***	0.01	−0.015*	0.102***	−0.130***	0.133***	0.042***	0.446***	0.284***

Notes: Table 2 presents the pair-wise correlations between the regression variables. Symbols ***, **, and * denote significance at 1 %, 5 % and 10 % levels, respectively. The full sample includes 14,307 observations from 58 countries during the 2005 and 2020 period. Appendix 1 presents the description of the variables.

Table 3

Baseline results: carbon emissions and bank debt financing.

VARIABLES	(1) BD	(2) BD	(3) BD
LNEMISSIONS	−0.003** (0.001)	−0.004*** (0.001)	
CO2INTENSITY			−0.015** (0.006)
LEV	−0.112** (0.047)	−0.024 (0.036)	−0.102** (0.048)
FSIZE	0.001 (0.013)	−0.062*** (0.005)	−0.053*** (0.006)
PROFITAB	−0.016 (0.081)	−0.054 (0.094)	−0.189 (0.125)
TANG	−0.054 (0.070)	0.019 (0.033)	0.075* (0.043)
Q	−0.007 (0.008)	−0.020** (0.008)	−0.016 (0.010)
ZSCOREDDUMMY	0.005 (0.011)	0.024* (0.013)	0.007 (0.016)
RATING	−0.382*** (0.046)	−0.089*** (0.014)	−0.084*** (0.017)
MEANBD	0.568*** (0.075)	0.334*** (0.070)	0.355*** (0.092)
LGDPPC	0.107*** (0.034)	0.204*** (0.033)	0.164*** (0.040)
LAWORDER	−0.002 (0.020)	−0.014 (0.021)	0.031 (0.026)
PVTCREDIT	0.085*** (0.030)	0.047 (0.030)	0.069* (0.037)
Constant	−0.415 (0.387)	−1.097*** (0.350)	−1.375*** (0.483)
Observations	14,307	14,307	8965
R-squared	0.816	0.375	0.370
Cluster	Firm	Firm	Firm
Year FE	Yes	Yes	Yes
Firm FE	Yes	No	No
Indus FE	No	Yes	Yes
Country FE	No	Yes	Yes

Notes: Table 3 presents the regressions results of the impact of emissions on bank debt. Symbols ***, **, and * denote significance at 1 %, 5 % and 10 % levels, respectively. The full sample includes 14,307 observations from 58 countries during the 2006\7 and 2020 period. Appendix 1 presents the description of the variables.

tend to use less bank debt. We also report positive and significant coefficients for MEANBD, ZSCOREDDUMMY, and LGDPPC, suggesting that firms from industries with high bank debt ratio, with high bankruptcy risk, and from high-income countries tend to use more bank debt. In Model (2) we augment Model (1) with year-, country- and industry- fixed effects to control for potential missing country-, year- and industry-specific unobservable variables. The results show that the coefficient for LNEMISSIONS remains negative and significant at the 1 % level. Model (3) reports our results when we use an alternative proxy for carbon risk namely co2 intensity calculated as total co2 emission over net sales (CO2INTENSITY) to account for the fact that the firm's emissions vary with its production volume. The results show that CO2INTENSITY loads negative and highly significant, further corroborating our earlier finding. In line with our earlier results, CO2INTENSITY is economically significant, a one standard deviation increase in CO2INTENSITY leads to a decrease of 4.89 % in bank debt.¹⁶

4.2. Addressing endogeneity issues

So far, we document a negative impact of carbon emission on

¹⁶ The coefficient for CO2INTENSITY is −0.015. The standard deviation of CO2INTENSITY is 0.995 and the median of BD is 0.305. A one standard deviation increase in CO2INTENSITY decreases BD by 4.89 % ((−0.015 * 0.995 / 0.305)

borrowings from bank, suggesting that firms' exposure to carbon risk inhibits its propensity to borrow from banks. We conduct additional tests to address endogeneity concerns that can be due to potential unobservable omitted variables, reverse causality, and measurement error. First, we use an instrumental variable approach. In the first stage, we regress *LNEMISSIONS* on exogenous variables (i.e., variables that are related to *LNEMISSIONS*, but not related to *BD*) and our controls. Our instruments include the country-year adjusted median of *LNEMISSIONS* (*MEDEMISSIONS*) while excluding the firm being considered and the *CO2* per capita (*CO2PERCAPITA*) that measures the average annual emissions per person in a country. Following Phan et al. (2022), we use lagged values of these instruments. The results of the first stage are reported in Model (1) of Panel A of Table 4. The coefficients for the lagged values of *MEDEMISSIONS* and *CO2PERCAPITA* are positive and highly significant, as expected. The Anderson-Rubin Wald test statistic, is significant at the 1 % level, suggesting that *LNEMISSIONS* is endogenous, confirming the suitability of our instrumental-variable approach. The Kleibergen-Paap test (Kleibergen & Paap, 2006) rejects the null the 1 % level.¹⁷ Hansen J test¹⁸ fails to reject the null hypothesis, ruling out the under-identification and over-identification of our instrumental variable estimation. The results of the second stage are reported in Model (2) of Panel A which show that the coefficient for *LNEMISSIONS* is negative and highly significant, suggesting that our findings are not affected by endogeneity issues.

Our findings may be driven by the fact that firms with high *LNEMISSIONS* may differ from firms with low *LNEMISSIONS*. In our second set of tests, we use a propensity matching score approach (PSM) and entropy balanced matching to address the issue of our results being driven by the difference in characteristics of high-emission and low-emission firms. To implement the PSM approach, we divide our sample into firms with high *LNEMISSIONS* (*LNEMISSIONS_HIGH* = 1) (i.e., firms with *LNEMISSIONS* that is higher than the sample median for *LNEMISSIONS*) and firms with low *LNEMISSIONS* (*LNEMISSIONS_HIGH* = 0) (i.e., firms with *LNEMISSIONS* that is lower than the sample median for *LNEMISSIONS*). We use a probit model to regress *LNEMISSIONS_HIGH* on our control variables. We calculate the probability of the firm belonging to the treated group (i.e., the sub-sample of firms with *LNEMISSIONS_HIGH* = 1), called the propensity score. We use it to match firms from the treatment group with firms from the control group without replacement and a caliper of 0.06.¹⁹ We obtain 3651 observations in the treatment group and 3651 observations in the control group. The descriptive statistics for our control and treatment groups, presented in Appendix 2, show that the difference between the control variables between the two groups are not statistically significant. The results of estimating Eq. (1) for the propensity matching sample are reported in Model (1) of Panel B of Table 4. The results show that the coefficient for *LNEMISSIONS* remains negative and significant at the 1 % level, further corroborating our earlier finding. We also use the entropy balancing approach to correct for the differences in characteristics between the treatment and control group. Specifically, the entropy balancing approach equalizes the moments of the control variables for the treatment and control groups. The unreported results for the sake of brevity show that the average, standard deviation, and skewness of the control variables of the treatment and control group are equal after balancing. Our results for the entropy balanced sample are reported in Model (2) of Panel B, that show that the coefficient of *LNEMISSIONS* is negative and highly significant, further supporting our earlier findings.

Third, we use the Heckman two-stage approach to address selection bias issue, in line with Bose et al. (2021). The intuition behind using this test is that our findings may be driven by the fact that only firms that respond to the CDP questionnaire are included into our sample. In the first stage, we estimate a probit regression to obtain the likelihood of reporting their emissions to CDP. For the construction of the sample for Heckman two-stage estimation we first obtain the sample with non-missing bank debt and control variables from the S&P Capital IQ database. We then match the data with firms with CDP data on carbon emissions. We regress a dummy variable equal to one if the firm is among our matched firms with CDP data and zero otherwise (*CDPREPORTINGD*) on an exogenous variable, Proportional representation (*PROPREP*) that is not included in Eq. (1) and our control variables. *PROPREP* is a dummy variable equal to one if candidates are elected in a country based on the percent of votes received by them and zero otherwise. This is in line with Agoraki et al. (2024) that use variables related to the firm's location as an exogenous variable to satisfy the exclusion restriction. Furthermore, Lockwood and Lockwood (2022) report that the proportional representation electoral systems mitigate the effect of the hostility of the right-wing populist parties towards climate policies. *PROPREP* is expected to influence the climate issues of a country but not the use of bank debt. The results of the first stage are reported in Model (3) of Panel B of Table 4. The coefficient of *PROPREP* is positive and significant at the 1 % level, suggesting that firms located in countries with proportional representation are more likely to report carbon emissions. We obtain the inverse Mills ratio from the first-stage regression (*MILLS_RATIO*). We add *MILLS_RATIO* to Eq. (1) in the second stage of the Heckman approach. The results reported in Model (4) of Panel B of Table 4 show that coefficient of *LNEMISSIONS* is negative and significant at the 1 % level. However, the coefficient for *MILLS_RATIO* is not significant, suggesting that our findings are not affected by the selection bias. In our final approach, we estimate a two-step dynamic GMM model to account for the dynamic relationship between bank debt and carbon risk. The results presented in Model (5) show that the coefficient for *LNEMISSIONS* remains negative and highly significant, suggesting that our results are not affected by endogeneity concerns.²⁰

Fifth, to further address endogeneity concerns, we use the Paris agreement of 2015 as an exogenous shock to climate risk. Years after the initial Kyoto agreement, a legally binding climate change agreement was adopted during the United Nations Climate Change Conference held in Paris in 2015. We conduct a difference-in-difference analysis using the Paris agreement as an exogenous shock. We create *PARIS*, a dummy variable that equals one for four years after the Paris agreement in 2015 and zero for four years before the agreement. We compute the variable *TREAT* that equals to one if the country-adjusted median emission during the four years after the Paris agreement is greater than the country-adjusted median emission during the four years before the Paris agreement. We include an interaction term between *TREAT* and *PARIS*. The results reported in Table 5 show that the coefficient for *TREAT*PARIS* is significantly negative, suggesting that the adverse effect of *LNEMISSIONS* on bank debt had become more severe after the Paris climate conference (i.e., COP 21). This can be explained by the tendency of brown firms to avoid bank debt due to the increasing environmental scrutiny by the banks in response to the implementation of carbon regulations post the Paris agreement. These results are consistent with previous studies such as, Nguyen et al. (2025), Degryse et al. (2023) and Cumming et al. (2024) which confirm the increasing adverse effect of climate risk on debt post the Paris agreement. With this we conclude our identification tests that confirm our main results.

¹⁷ The null hypothesis of the Kleibergen-Paap test is that the first stage model is under identified

¹⁸ The Hansen J-statistic tests the joint-validity of the instruments; a rejection of the test indicates that the instruments are not valid.

¹⁹ In line with the suggestions of Stuart and Rubin (2008) and Nguyen et al. (2025), we use a caliper size that is approximately 25 % standard deviation of the propensity score.

²⁰ We further run a lead-lag model to rule out endogeneity issues due to reverse causality and find (not reported for the sake of brevity) the results remain unchanged.

Table 4

Sample selection bias and endogeneity tests.

Panel A Instrumental variable estimation					
VARIABLES				Instrumental Variable	
				(1)	(2)
				LEMISSION	BD
LNEMISSIONS					−0.018** (0.007)
L. MEDEMISSIONS				0.326*** (0.039)	
L.CO2PERCAPITA				0.155** (0.069)	
Observations				10,414	10,414
Cluster				Firm	Firm
Year FE				No	No
Indus FE				Yes	Yes
Country FE				Yes	Yes
First stage- Anderson-Rubin Wald test (F)					3.551**
Weak ID test					35.16***
Under Identification test					50.13***
Hansen J (P-value)					0.551
Panel B Other endogeneity tests					
VARIABLES	PSM (1) BD	ENTROPY (2) BD	HECKMAN (3) CDPREPORTING	(4) BD	TWO Step GMM (5) BD
LNEMISSIONS	−0.006*** (0.002)	−0.004*** (0.001)		−0.006*** (0.001)	−0.081** (0.039)
PROPREP			0.038** (0.019)		
L.BD					0.322*** (0.097)
LEV	−0.079* (0.047)	−0.030 (0.038)	−0.083 (0.052)	−0.093*** (0.024)	−0.019 (0.263)
FSIZE	−0.055*** (0.007)	−0.064*** (0.005)	0.250*** (0.005)	−0.095*** (0.021)	−0.084 (0.078)
PROFITAB	−0.409*** (0.144)	−0.067 (0.101)	0.400*** (0.120)	−0.185** (0.082)	0.051 (0.757)
TANG	0.021 (0.045)	0.028 (0.034)	−0.189*** (0.039)	0.060** (0.024)	−0.197 (0.222)
Q	−0.023* (0.012)	−0.019** (0.009)	−0.001 (0.002)	−0.018*** (0.006)	−0.030 (0.042)
MEANBD	0.622*** (0.100)	0.320*** (0.075)	0.600*** (0.041)	−0.020 (0.042)	0.030 (0.296)
RATING	−0.162*** (0.017)	−0.089*** (0.015)	0.104*** (0.018)	−0.067*** (0.011)	0.541 (0.578)
ZSCOREDDUMMY	0.031* (0.018)	0.026* (0.014)	−0.036* (0.024)	0.021** (0.010)	0.070 (0.081)
LGDPPC	−0.138*** (0.024)	0.197*** (0.034)	0.172*** (0.020)	0.130*** (0.039)	0.395 (.)
LAWORDER	0.050*** (0.016)	−0.014 (0.026)	−0.042*** (0.014)	0.020 (0.034)	0.009 (0.051)
PVTCREDIT	0.038** (0.018)	0.046 (0.031)	−0.130*** (0.024)	0.045 (0.033)	0.059 (0.038)
Constant	2.071*** (0.215)	−0.988*** (0.363)	−4.170*** (0.163)	0.370 (0.628)	−3.015*** (0.144)
Observations	7302	14,307	28,619	9859	9817
R-squared	0.258	0.363			
Cluster	Firm	Firm	No	No	No
Year FE	Yes	Yes	Yes	No	Yes
Indus FE	Yes	Yes	Yes	No	Yes
Country FE	No	Yes	Yes	No	Yes
Mills Ratio				−0.131	

Notes: This table presents the results of the endogeneity tests. Panel A presents the results of a two-step generalized methods of moment (GMM2S) instrumental variable estimation to account for heteroscedasticity and serial correlation. Panel B reports the results of the propensity score matching, entropy balanced sample, Heckman selection and System GMM approaches. Symbols ***, **, and * denote significance at 1 %, 5 % and 10 % levels, respectively. The full sample includes 14,307 observations from 58 countries during the 2007 and 2020 period. [Appendix 1](#) presents the description of the variables.

4.3. Channel tests

We next examine the potential mechanisms of the impact of carbon risk on bank debt.

4.3.1. The demand-side perspective

According to the demand-side perspective, firms facing higher carbon risk tend to obtain less bank debt to avoid bank scrutiny as banks enjoy lower monitoring efforts and costs and have the flexibility and ability to monitor borrowers, intensifying banks' monitoring incentives (e.g., [Ben-Nasr, 2019](#); [Ben-Nasr et al., 2021](#); [Chava et al., 2009](#);

Table 5
An exogenous shock.

VARIABLES	(1) BD
TREATPARIS	0.444** (0.200)
PARIS	−0.068*** (0.014)
TREATPARIS X PARIS	−0.058*** (0.019)
LEV	−0.048 (0.040)
FSIZE	−0.067*** (0.004)
PROFITAB	−0.127 (0.113)
TANG	0.005 (0.035)
Q	−0.018* (0.009)
ZSCOREDDUMMY	0.032** (0.014)
RATING	−0.094*** (0.015)
MEANBD	0.296*** (0.079)
LGDPPC	0.230*** (0.038)
LAWORDER	−0.024 (0.037)
PVTCREDIT	0.077** (0.036)
Constant	−1.203*** (0.396)
Observations	10,634
R-squared	0.378
Cluster	Firm
Year FE	Yes
Indus FE	Yes
Country FE	Yes

Notes: This table presents the robustness results of our main results with difference-in-difference analysis using exogenous shocks. Symbols ***, **, and * denote significance at 1 %, 5 % and 10 % levels, respectively. The full sample includes 14,307 observations from 58 countries during the 2007 and 2020 period. [Appendix 1](#) presents the description of the variables.

Chemmanur & Fulghieri, 1994; Diamond, 1984; Houston & James, 1996; Kacperczyk & Peydro, 2022; Lin et al., 2013). In fact, by virtue of their closer touch with borrowers and their superior monitoring capacity, banks may exert pressure on borrowers facing a higher carbon risk by threatening to end the lending arrangements. If this is valid, we expect this negative relation to be stronger in the presence of factors that exacerbate the substitution away from bank debt, such as severe agency problems (both at the firm-level and the country-level). The agency costs framework predicts a negative relationship between agency cost and bank debt (Ben-Nasr et al., 2021). The intuition behind this is that entrenched managers tend to avoid bank scrutiny and opt for corporate debt. To test this point of view, we augment Model (1) of Table 3 with a firm-level proxy for agency costs namely the ratio of free cash flow to total assets (FCFTA) following (Hasan & Uddin, 2022; Javakhadze et al., 2014). Firms with excess free cash flows are more prone to over-investment problems and wastage of free cash flows (Hasan & Uddin, 2022; Javakhadze et al., 2014; Jensen, 1986; Naeem & Li, 2019). The results reported in Model (1) of Panel A in Table 6 show that the coefficient for LNEMISSIONS X FCFTA loads negative and highly significant, suggesting that firms having higher free cash flows and hence facing severe agency problems are less likely to opt for bank debt to avoid bank scrutiny. We also use the number of antitakeover provisions available to the shareholders in excess of two provisions (SHRATO) as a proxy for

Table 6
The role of firm-level moderators.

Panel A Agency problems proxies			
VARIABLES	(1) BD	(2) BD	
LNEMISSIONS	−0.017*** (0.005)	−0.012** (0.005)	
FCFTA	−0.019** (0.008)		
LNEMISSIONS X FCFTA	−0.008** (0.004)		
SHRATO		−0.024*** (0.008)	
LNEMISSIONS X SHRATO		−0.010** (0.004)	
Constant	−1.198*** (0.348)	−1.785*** (0.458)	
Observations	14,036	10,957	
R-squared	0.378	0.348	
Control Variables	Yes	Yes	
Cluster	Firm	Firm	
Year FE	Yes	Yes	
Indus FE	Yes	Yes	
Country FE	Yes	Yes	
Panel B Information asymmetry proxies			
VARIABLES	(1) BD	(2) BD	(3) BD
LNEMISSIONS	−0.007*** (0.002)	−0.009*** (0.003)	−0.010*** (0.003)
ANALYST_FOR_DISP	−0.125 (0.079)		
LNEMISSIONS X ANALYST_FOR_DISP	0.011* (0.006)		
ABPROD		−1.658*** (0.608)	
LNEMISSIONS X ABPROD		0.096** (0.043)	
EARNVOL			−1.768* (0.962)
LNEMISSIONS X EARNVOL			0.155* (0.085)
Constant	−0.887** (0.350)	−0.512 (1.306)	−1.347** (0.610)
Observations	10,534	980	5911
R-squared	0.380	0.357	0.280
Control Variables	Yes	Yes	Yes
Cluster	Firm	Firm	Firm
Year FE	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Panel C Ownership structure			
VARIABLES	(1) BD	(2) BD	(3) BD
SOVOWN	−1.332* (0.721)		
LNEMISSIONS X SOVOWN	0.106** (0.051)		
INSIDEROWN		−0.225** (0.092)	
LNEMISSIONS X INSIDEROWN		0.016* (0.008)	
STRATOWN			−0.001* (0.001)
LNEMISSIONS X STRATOWN			0.000*** (0.000)
Constant	−1.078*** (0.350)	−1.115*** (0.349)	−1.061*** (0.363)
Observations	14,307	14,307	14,307
R-squared	0.376	0.376	0.377
Control Variables	Yes	Yes	Yes
Cluster	Firm	Firm	Firm

(continued on next page)

Table 6 (continued)

Panel A Agency problems proxies			
		(1)	(2)
VARIABLES		BD	BD
Year FE	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Panel D CSR			
		(1)	(2)
VARIABLES		BD	BD
LARGEBOARDSIZE		−0.142*** (0.046)	
LNEMISSIONS X LARGEBOARDSIZE		0.009*** (0.003)	
HIGHENVPILLARSCORE			−0.079** (0.034)
LNEMISSIONS X HIGHENVPILLARSCORE			0.005* (0.002)
Constant		−0.506 (0.553)	−1.083*** (0.351)
Observations		6551	14,307
R-squared		0.366	0.376
Control Variables		Yes	Yes
Cluster		Firm	Firm
Year FE		Yes	Yes
Indus FE		Yes	Yes
Country FE		Yes	Yes

Notes: Table 6 reports cross-sectional tests to validate the demand-side channel. Panel A presents the results of the role of agency problems in moderating the relationship between carbon risk and debt choice. Panel B presents the results of the role of the information asymmetry problems in moderating the relationship between carbon risk and debt choice. Panel C presents the results of the role of ownership structure in moderating the relationship between carbon risk and debt choice. Panel D presents the role of the role of CSR in moderating the relationship between carbon risk and debt choice. Symbols ***, **, and * denote significance at 1 %, 5 % and 10 % levels, respectively. The full sample includes 14,307 observations from 58 countries during the 2007 and 2020 period. Appendix 1 presents the description of the variables.

agency costs, in line with Carline and Gogineni (2021). On one hand, the protection provided by takeover provisions can increase management entrenchment (Gompers et al., 2003), resulting in firms with higher SHRATO avoiding bank debt (Gompers et al., 2003). Therefore, this point of view suggests that anti-takeover provisions aggravate the negative effects of carbon risk on bank debt. On the other hand, fewer takeover provisions lead to higher bank loan spreads as banks price the uncertainty associated with hostile takeovers (Chava et al., 2009), hence reduce the likelihood of offering bank loans to firms. This point view suggests anti-takeover provisions mitigate the negative effect of carbon risk on bank debt. To disentangle between these two views, we add SHRATO and an interaction term between SHRATO and LNEMISSIONS to Model (1) of Table 3. The results reported in Model (2) of Panel A in Table 4 show that the coefficient for LNEMISSIONS X SHRATO loads negative and highly significant, further confirming the stronger negative effect of carbon emissions on bank debt in firms with more takeover provisions, hence again supporting the demand side perspective, suggesting that firms agency issues intensify the negative carbon risk -bank debt association.

Firms with severe informational asymmetry prefer financing sources that are less information-sensitive, such as bank debt (Hasan & Uddin, 2022; Kabir et al., 2024), and thus the substitution away from bank debt as a result of carbon risk would be less pronounced. To test this point view, we employ two information asymmetry proxies. First, we use the dispersion of analyst forecast from I/B/E/S, in line with Li et al. (2024). A higher analyst forecast dispersion (ANALYST_FOR_DISP) indicates higher information asymmetry. We augment our basic model (Model (1) of Table 3) with ANALYST_FOR_DISP and LNEMISSIONS X

ANALYST_FOR_DISP. The results reported in Model (1) of Panel B in Table 6 show that the coefficient for LNEMISSIONS X ANALYST_FOR_DISP loads positive and significant, suggesting that high emitter firms with high analyst forecast dispersion are more likely to opt for bank debt. This finding suggests the effect of carbon risk on bank debt is weaker in firms suffering from high information asymmetry, again supporting the demand-side perspective. Second, we use a measure of real earnings management, abnormal production costs (ABPROD) estimated following Roychowdhury (2006) as a proxy for information asymmetry. By distorting current earnings, real earnings management can lead to information asymmetry between equity holders and debt holders, resulting in higher spreads between bond holders and equity holders (Ge & Kim, 2014). Therefore, firms engaging in real earnings management prefer bank debt over corporate debt (Li et al., 2019), albeit at higher interest rates (Pappas et al., 2019), as banks already possess private information identifying real earnings management. Hence, we expect that higher ABPROD (i.e., higher information asymmetry) will weaken LNEMISSIONS' negative impact. The results reported in Model (2) of Panel B in Table 6 show that the coefficient for LNEMISSIONS X ABPROD is positive and significant, suggesting that high emitter firms facing high abnormal production costs (i.e., higher real earnings management) are more likely to opt for bank debt. We may interpret this finding as implying that firms facing high information asymmetry prefer less information-sensitive financing source namely bank debt. Third, we use the three-year standard deviation of the ratio of EBIDTA to total assets (EARNVOL) as a proxy for information asymmetry, in line with Li et al. (2024). High earnings volatility indicates higher information asymmetry. The results reported in Model (3) show that the coefficient for LNEMISSIONS X EARNVOL is positive and significant, further supporting the demand-side perspective, suggesting that high emitter firms suffering from high information asymmetry tend to avoid highly sensitive financing source such as corporate debt and opt for bank debt.

To further validate the demand-side perspective, we examine whether the association between carbon risk and bank debt is less pronounced in the presence of larger shareholders that may mitigate agency problems. Sovereign wealth funds play a monitoring role of managerial actions, which may mitigate agency problems (e.g., Godsell, 2022) and reduce the tendency of high emitter firms to substitute away from bank debt to avoid bank scrutiny. To test this point view, we augment our basic model with the percentage of sovereign wealth ownership (SOVOWN) and LNEMISSIONS X SOVOWN. The results reported in Model (1) of Panel C show that the coefficient for LNEMISSIONS X SOVOWN is positive and highly significant, suggesting that high emitter firms with large sovereign wealth ownership are less likely to avoid bank debt. The intuition behind this is that sovereign wealth holders may monitor managers, which mitigates agency problems and reduce the tendency of firms to avoid bank scrutiny. We also use the percentage of insider ownership (INSIDEROWN) to check whether the presence of large insiders who can incentivize managers to act in a way that maximizes shareholders' wealth, mitigates agency problems and increases the firm's degree of reliance on bank debt. The results reported in Model (2) of Panel C show that the coefficient for LNEMISSIONS X INSIDEROWN loads positive and significant, further supporting the demand-side perspective and suggesting that the presence of inside shareholders may mitigate agency problems, which reduce the firm's tendency to avoid bank scrutiny. Additionally, we use the proportion of strategic shareholders (STRATOWN) as a proxy of ownership structure that mitigates agency problems. The intuition behind this is that large strategic shareholders are interested by the achievement of the long-term objectives of the firm, hence are more likely to monitor managers' actions. For example, Fich et al. (2015) show that investors are more concerned in monitoring firms that form a larger share their portfolio. In a similar vein, strategic investors that are interested in key objectives of the firms are likely to be open to monitoring by banks and bring synergies to the firm including relationship lending channels. The results reported in

Model (3) of Table C show that the coefficient for LNEMISSIONS X STRATOWN loads positive and significant at the 1 % level, in line with our prediction and further supporting the demand-side perspective.

We next examine the role of internal corporate governance (i.e., board size) in reducing the reluctance of high-emitter firms to utilize bank debt. We use a dummy variable equal to one if the firm has a board size that is larger than the sample median of board size (*LARGEBOARDSIZE*). Better corporate governance, specifically a larger board size mitigates the agency problems and reduces cost of debt (e.g., [Bhojraj & Sengupta, 2003](#); [Fields et al., 2012](#); [Ghouma et al., 2018](#)). The results reported in Model (1) of Panel D show that the coefficient for LNEMISSIONS X *LARGEBOARDSIZE* loads positive and significant at the 1 % level, suggesting that larger board size mitigates agency problems and reduces the tendency of high emitter firms to avoid bank scrutiny. Finally, we examine the role of environmental responsibility in mitigating carbon risk and reducing bank debt avoidance by high emitter firms. Corporate social responsibility mitigates carbon risk (e.g., [Hossain et al., 2022](#)). We augment our basic model (i.e., Model (1) of [Table 3](#)) with a dummy variable equal to one if the firm has an environmental responsibility score that is higher than the sample median and zero otherwise (LNEMISSIONS) and LNEMISSIONS X *HIGHENVPILLARSCORE*. The results reported in Model (2) of Panel D show that LNEMISSIONS X *HIGHENVPILLARSCORE* loads positive and significant, suggesting that firm environmental responsibility mitigates carbon risk, hence reduces high emitter firms' reluctance to bank debt.

Some studies document that management incentives linked to climate performance improve carbon performance ([Bose et al., 2023](#); [Ritz, 2022](#)). We next examine impact of climate linked incentives by including a dummy variable *CDPINCENTIVE* equals one if the firm has an incentive plan linked to climate performance and zero otherwise and LNEMISSIONS X *CDPINCENTIVE* to our baseline estimation. The results reported in [Table 7](#) (Model 1) show that LNEMISSIONS X *CDPINCENTIVE* loads positive and significant, suggesting that implementing management incentives linked to their carbon performance mitigates the negative impact of emissions on bank debt.

Additionally, firms' commitment to climate action can boost their reputation, improve their credit rating and mitigate agency and information asymmetry problems ([Lemma et al., 2021](#)). [Bolton and Kacperczyk \(2023b\)](#) argue that by committing to emission reduction targets

Table 7
Role of management incentives and emission reduction targets.

VARIABLES	(1) BD	(2) BD
LNEMISSIONS	−0.020*** (0.004)	−0.017*** (0.003)
CDPINCENTIVE	0.001 (0.003)	
LNEMISSIONS X CDPINCENTIVE	0.005* (0.003)	
CDPTARGETEMISSIONS		−0.002 (0.004)
LNEMISSIONS X CDPTARGETEMISSIONS		0.008** (0.003)
Constant	−0.675* (0.346)	−1.132*** (0.297)
Observations	10,604	14,307
R-squared	0.374	0.375
Control Variables	Yes	Yes
Cluster	Firm	Firm
Year FE	Yes	Yes
Indus FE	Yes	Yes
Country FE	Yes	Yes

Notes: [Table 7](#) presents results of the effect of management incentive and targets on the relationship between carbon risk and debt choice. Symbols ***, **, and * denote significance at 1 %, 5 % and 10 % levels, respectively. The full sample includes 14,307 observations from 58 countries during the 2007 and 2020 period. [Appendix 1](#) presents the description of the variables.

Table 8
Country-level environmental policies.

VARIABLES	(1) BD	(2) BD
LNEMISSIONS	0.004** (0.002)	−0.002 (0.001)
ETS	0.134*** (0.034)	
LNEMISSIONS X ETS	−0.012*** (0.002)	
HIGHCCPI		0.050** (0.024)
LNEMISSIONS X HIGHCCPI		−0.005*** (0.002)
Constant	−1.118*** (0.387)	−1.137*** (0.355)
Observations	14,307	14,307
R-squared	0.378	0.376
Control Variables	Yes	Yes
Cluster	Firm	Firm
Year FE	Yes	Yes
Indus FE	Yes	Yes
Country FE	Yes	Yes

Panel B Financial Development			
VARIABLES	(1) BD	(2) BD	(3) BD
FI	0.611*** (0.154)		
LNEMISSIONS X FI	−0.015** (0.007)		
FM		0.342*** (0.125)	
LNEMISSIONS X FM		−0.023*** (0.007)	
FD			0.588*** (0.171)
LNEMISSIONS X FD			−0.021*** (0.007)
Constant	−1.302*** (0.366)	−1.305*** (0.383)	−1.413*** (0.380)
Observations	14,307	14,307	14,307
R-squared	0.376	0.376	0.376
Control Variables	Yes	Yes	Yes
Cluster	Firm	Firm	Firm
Year FE	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes

Notes: [Table 8](#) presents the results of the role of country environmental policies and financial development in moderating the relationship between carbon risk and debt choice. Panel A presents the results of environmental policies and Panel B presents the results of financial development. Symbols ***, **, and * denote significance at 1 %, 5 % and 10 % levels, respectively. The full sample includes 14,307 observations from 58 countries during the 2007 and 2020 period. [Appendix 1](#) presents the description of the variables.

firms signal their 'willingness to decarbonize'. In fact, they find that firms with lower carbon emissions are more likely to commit and follow through with emissions reduction, as compared to high emitter firms.²¹ We expect that firms with future-oriented emission reduction strategies, such as committing to emission reduction targets can negotiate favorable lending terms with banks, mitigating the negative impact of LNEMISSIONS on bank debt. We test this conjecture by including a dummy variable *CDPTARGETEMISSIONS* equals to one for firms with an emission reduction target and zero otherwise and an interaction term

²¹ In supply-side perspective studies, [Altavilla et al. \(2024\)](#) report that banks charge lower interest rates to firms committing to emission reductions. However, [Giannetti et al. \(2023\)](#) report that, since traditionally banks specialize in lending to high emitting firms, they end up lending more and charging lower interest rates to high emitting firms

Table 9
Funding components and emissions.

VARIABLES	(1) RELATIVE_BD	(2) BD/TA	(3) CORPORATE_DEBT/TD	(4) CORPORATE_DEBT/TA	(5) TLTD/TD
LNEMISSIONS	−0.005*** (0.001)	−0.001** (0.000)	0.005*** (0.001)	0.001*** (0.000)	−0.003** (0.001)
Constant	−0.854** (0.349)	−0.235* (0.124)	1.701*** (0.368)	0.059 (0.127)	−1.016*** (0.386)
Observations	13,081	14,307	14,307	14,228	
R-squared	0.488	0.454	0.449	0.565	0.372
Control Variables	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm
Year FE	Yes	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the results of effect of emissions on other debt proxies. Symbols ***, **, and * denote significance at 1 %, 5 % and 10 % levels, respectively. The full sample includes 14,307 observations from 58 countries during the 2007 and 2020 period. [Appendix 1](#) presents the description of the variables.

LNEMISSIONS X CDPTARGETEMISSIONS to our baseline estimation. The results reported in [Table 7](#) (Model 2) show that the coefficient for LNEMISSIONS X CDPTARGETEMISSIONS is positive and highly significant, supporting our prediction that high emitter firms can mitigate the impact emissions on bank debt by demonstrating their commitment to decarbonization.²²

[Çolak and Öztekin \(2021\)](#) show that while bank lending decreased post covid-19, the impact is less profound for countries with better regulatory and institutional environment. The supply side perspective also suggests that in a country where environmental regulations are highly enforced, banks may have more environmental reputation concerns, and hence will have more incentives to distance themselves from highly-carbon-emitting borrowers. To validate this channel, we examine whether the relationship between carbon emissions and bank debt is more pronounced in countries with stringent environmental regulations. First, we use the implementation of emissions trading system, which has an objective to help firms in achieving their goal to reduce carbon emission at a low cost as an exogenous shock. Under the emissions trading system (ETS), high emitter firms finding difficulties in reducing their co2 emissions may buy emission allowances from low emitter firms. Our sample countries implemented ETS at different years. We create a dummy variable equal to one if the country has implemented the emissions trading system in a given year and zero otherwise (ETS). While the implementation of ETS is expected to strengthen policies related to climate risk, it also allows firms in countries with ETS mechanisms to emit more by paying a penalty. We augment Eq. (1) with ETS and the interaction between ETS and LNEMISSIONS. The results reported in Model (1) of [Table 8](#) show that the coefficient for LNEMISSIONS X ETS is negative and significant. This result suggests that the negative effect of carbon emissions on bank debt is exacerbated after the implementation of ETS which may indicate that banks price the risk from firms engaging in emission trading activities. We may interpret this finding as implying that high emitter firms are less able to secure bank debt in countries that implemented the emission trading system since banks are not willing to lend to these firms due to reputational concerns.

Second, we use the country's climate change performance (CCPI) from Germanwatch, Climate Action Network as a proxy of the firm's resilience to climate risk. The results reported in Model (2) of [Table 8](#) show that the coefficient for LNEMISSIONS X CCPI is negative and significant, suggesting that high emitter firms located in countries with high climate risk performance are less likely to secure bank debt. We may interpret this finding as implying that banks are less likely to lend to high emitter firms in countries with a increased climate risk awareness,

supporting the supply-side perspective.

We next check whether the decrease in bank debt is more pronounced in markets where firms have access to many financing alternatives. While this can indicate that the decrease emanates from borrowing firms which rely less on bank debt as they have other financing alternatives confirming the demand side perspective, it may also mean that the financial system may restrict financing of high-emitter firms for reputational reasons. To test this point view, we augment our basic model with measures of financial institutions' development index (FI), financial markets development (FM) and overall financial development (FD) from [Svirydzenka \(2016\)](#). The FI, FM and FD measure the access, depth and efficiency of financial institutions, financial markets and overall financial development of a country, respectively and higher scores for each of these indexes indicate higher financial development. Our first model in Panel B of [Table 8](#) reports the results of our basic model augmented with FI and LNEMISSIONS X FI. As shown the coefficient for LNEMISSIONS X FI loads negative and highly significant, suggesting that high emitter firms located in countries with developed financial institutions are less able to secure bank debt financing supporting the supply-side argument. The results reported in Model (2) of Panel B in [Table 8](#) show that the coefficient for LNEMISSIONS X FM is negative and significant at the 1 % level, suggesting high emitter firms are less able to secure bank debt as they are located in countries with developed financial markets, hence have a broader range of alternatives to bank debt financing. Additionally, we report the results when we include FD and LNEMISSIONS X FD in our baseline estimation. As shown in Model (3) of Panel B in [Table 8](#) the coefficient for LNEMISSIONS X FD loads negative and significant at the 1 % level, suggesting that high emitter firms although located in financially developed countries and having access to several financing sources alternative to bank debt are less able to secure bank debt. The reason behind this is that banks avoid lending high emitter firms for reputational concerns, in line with the supply-side perspective.

4.4. Sensitivity tests

4.4.1. Alternative bank debt proxies

We use several alternative proxies of debt structure. First, we use the ratio of bank debt to the sum of bank debt and corporate debt to total debt (RELATIVE_BD) instead of the ratio of total bank debt over total debt. The results reported in Model (1) of [Table 9](#) show that the coefficient for LNEMISSIONS is negative and significant at the 1 % level, corroborating our earlier findings. Second, we use the ratio of bank debt to total assets (BD/TA) as an alternative dependent variable. The results reported in Model (2) of [Table 9](#) show that the coefficient for LNEMISSIONS is negative and highly significant, further supporting our earlier findings. Third, we use the ratio of corporate debt to total debt

²² We thank an anonymous referee for the recommendation to examine the impact of climate incentives on the carbon risk -bank debt relationship.

Table 10
Robustness tests.

Panel A Additional Control Variables				
	(1)	(2)	(3)	
VARIABLES	BD	BD	BD	
LNEMISSIONS	−0.019*** (0.005)	−0.005** (0.002)	−0.004*** (0.001)	
QSPREAD	−3.732 (2.303)			
ROTARANK	0.192 (0.282)			
COUNTRYMEDIANANALYST	0.049 (0.032)			
BIG4	0.051 (0.064)			
CEO DUALITY		−0.018 (0.015)		
PCTINDEPBOARD		−0.000 (0.000)		
INSTOWNPERCENT		−0.077* (0.047)		
IDV			−0.019** (0.008)	
PDI			−0.045** (0.019)	
UAI			−0.001 (0.001)	
Constant	−0.008 (1.569)	−0.487 (0.542)	1.864 (1.504)	
Observations	870	6689	13,864	
R-squared	0.408	0.367	0.389	
Control Variables	Yes	Yes	YEs	
Cluster	Firm	Firm	Firm	
Year FE	Yes	Yes	Yes	
Indus FE	Yes	Yes	Yes	
Country FE	Yes	Yes	Yes	

Panel B Sensitivity tests				
	Exclude USA	Exclude UK	Exclude Japan	Exclude USA UK Japan
	(1)	(2)	(3)	(4)
VARIABLES	BD	BD	BD	BD
LNEMISSIONS	−0.004** (0.001)	−0.004*** (0.001)	−0.004*** (0.001)	−0.004** (0.002)
Constant	−0.632 (0.409)	−1.166*** (0.361)	−1.442*** (0.377)	−1.019** (0.453)
Observations	10,633	12,809	12,181	7009
R-squared	0.319	0.399	0.362	0.342
Control Variables	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm
Year FE	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes

Panel C Alternate Estimations					
	WLS	TOBIT	Change Regression	Alternate Fixed Effects	Firm-Year Clustering
	(1)	(2)	(3)	(4)	(5)
VARIABLES	BD	BD	D.BD	BD	BD
LNEMISSIONS	−0.006*** (0.001)	−0.004*** (0.001)		−0.003** (0.001)	−0.004*** (0.001)
D.LNEMISSIONS			−0.002* (0.001)		
Constant	1.762*** (0.081)	−1.449*** (0.377)	0.016 (0.012)	−1.096*** (0.359)	−1.097** (0.392)
Observations	14,307	14,307	10,414	14,307	14,307
R-squared	0.257	0.312	0.011	0.669	0.375
Control Variables	Yes	Yes	No	Yes	Yes
Change in Firm and Macro-economic controls	No	No	Yes	No	No
Cluster	No	Firm	Firm	Firm	Firm-year
Year FE	No	Yes	Yes	Yes	Yes

(continued on next page)

Table 10 (continued)

Panel C. Alternate Estimations					
	WLS	TOBIT	Change Regression	Alternate Fixed Effects	Firm-Year Clustering
	(1)	(2)	(3)	(4)	(5)
VARIABLES	BD	BD	D.BD	BD	BD
Indus FE	No	Yes	Yes	No	Yes
Country FE	No	Yes	Yes	No	Yes
ILS	No	No	No	Yes	No

Notes: This table presents the results of robustness tests. Panel A presents the results of including additional firm-level Control Variables. Panel B presents the results of some sensitivity tests (i.e., excluding countries with large number observations (United States, United Kingdom and Japan). Panel C presents results using alternate estimations to control for the unbalanced sample an alternate clustering with a Weighted least squares estimation and censoring of the dependent variable with a Tobit regression estimation), change regression, Industry-Location-Size effect (Altavilla et al., 2024), firm-year clustering, and a lead-lag model. Symbols ***, **, and * denote significance at 1 %, 5 % and 10 % levels, respectively. The full sample includes 14,307 observations from 58 countries during the 2007 and 2020 period. Appendix 1 presents the description of the variables.

(CORPORATE_DEBT/TD) as an alternative dependent variable. The results reported in Model (3) of Table 9 show that the coefficient for LNEMISSIONS loads positive and significant at the 1 % level, suggesting that firms with high carbon risk are more likely substitute away from bank debt and opt for corporate debt, confirming our prediction. Fourth, we use the ratio of corporate debt to total assets (CORPORATE_DEBT/TA) as an alternative dependent variable. The results reported in Model (4) of Table 8 show that the coefficient for LNEMISSIONS is positive and highly significant, further supporting our earlier findings. Finally, we use the ratio of term loans to total debt (TLTD) as an alternative dependent variable. The results reported in Model (5) of Table 9 show that the coefficient for LNEMISSIONS is negative and significant, suggesting that carbon emissions are negatively related to the ratio of term loans as a component of bank debt over total debt. This finding supports our earlier findings.

4.4.2. Robustness tests

To ensure the robustness of our findings, we perform several sensitivity tests. First, we control information asymmetry proxies that may affect bank debt ratio. Specifically, we augment our basic Model (Model (1) of Table 3) with the bid-ask spread (QSPREAD); the ranking of the ratio of Earnings before interest, tax and depreciation and amortization to Net property, plant and equipment (ROTARANK), based on Wu & Lai (2020); a dummy variable equals to one if the number of analysts following the firm is greater than the country year adjusted median number of analysts and zero otherwise (COUNTRYMEDIANANALYST); and a dummy variable equals to one if the firm auditor is a Big 4 firm and zero otherwise (BIG4). The results reported in Model (1) of Table 10, Panel A show that the coefficient for LNEMISSIONS remains negative and significant at the 1 % level, further corroborating our earlier findings. Second, we control for governance variables that may affect bank debt. We augment our basic model (Model (1) of Table 3) with a dummy variable equal to one if the CEO is also the Chairman of the board and zero otherwise (CEODUALITY); the percentage of independent board directors (PCTINDEPBOARD) and the percentage of institutional ownership (INSTITUTIONALOWNPERCENT). The results reported in Model (2) of Table 10, Panel A show that the coefficient for LNEMISSIONS is still negative and significant at the 1 % level, further confirming our earlier findings. Previous studies such as, Chui et al. (2021) document the influence of culture on corporate debt choice. In our third sensitivity test, we include controls for national culture to our baseline estimation. Model (3) of Table 10, Panel A presents the results when we include Hofstede's culture measures of Individualism (IDV), Power distance (PDI) and Uncertainty Avoidance (UAI) to our baseline estimation. The coefficient of LNEMISSIONS stays significant and negative confirming our main results. Previous studies such as, Chui et al. (2021) document the influence of culture on corporate debt choice. In our third sensitivity test, we include controls for national culture to our baseline estimation. Model (3) of Table 10, Panel A presents the results when we include Hofstede's culture measures of Individualism

(IDV), Power distance (PDI) and Uncertainty Avoidance (UAI) to our baseline estimation. The coefficient of LNEMISSIONS stays significant and negative confirming our main results.

Fourth, we separately exclude observations from the three countries that have the highest number of observations (United States, United Kingdom and Japan) in Models 1 to 3 in Panel B of Table 10 while simultaneously excluding observations from these three countries in Model (4) of Panel B. The coefficient for LNEMISSIONS loads negative and highly significant in Models from 1 to 5. Finally, we use run a set of alternate estimations to account for the unbalanced nature of our sample, the fractional nature of our dependent variable and unobserved variables at multiple levels. For the first alternate estimation, we run a weighted least squares to account for the unbalanced nature of our sample. The results reported in Model (1) in Panel C of Table 10 show that the coefficient for LNEMISSIONS is still loading negative and significant at the 1 % level. Second, we use a Tobit regression estimation to estimate Eq. (1) to account for the fact that our dependent may take a value of zero. The results reported in Model (2) in Panel C of Table 10 show that the coefficient for LNEMISSIONS is negative and significant at the 1 % level, again supporting our earlier findings. Third, we estimate a change regression, on a balanced panel of two consecutive (yearly) observations per firm, to rule out time-invariant factors that may drive the relationship between LNEMISSIONS and BD. Model (3) in Panel C of Table 10 show that the coefficient for LNEMISSIONS is negative and significant at the 1 % level lending support to our main findings. We provide additional robustness to our estimation with our fourth alternate estimation following Altavilla et al. (2024) and include fixed effects at industry, location (country) and size (deciles of FSIZE) (ILS) to control for unobserved heterogeneity due to a firm's size, industry and country it operates in. Our next estimation includes clustering the standard errors at firm and year level instead of firm level clustering. The results of the ILS fixed effects and firm-year clustering are presented in Table 10, Panel C, Models 4 and 5, respectively show that our results are robust to the choice of fixed effects and clustering.²³

5. Conclusion

Banks, with the disciplinary power and lessor information void, can impel firms to comply with environmental regulation and participate in emission reduction. This study hypothesized that a firm's carbon performance is positively associated with the share of bank debt in firms' total debt structure and the firm's level of information asymmetry mediates the relationship between carbon performance and the proportion of bank debt relative to total debt. Using proxies of carbon emissions, bank debt ratio, and controls in line with literature and a global sample, the study finds that carbon emissions are negatively associated with

²³ Our results remain unchanged to inclusion of other fixed effects interactions such as, country-industry, country-year and industry year.

bank debt reliance and the level of firms' information asymmetry in addition to agency issues and financing constraints mediate the relationship. The findings are robust to endogeneity concerns and show that firm emissions are prone to industry and country environmental issues. Furthermore, firm corporate governance and climate initiatives activities can mitigate the negative effect of carbon emissions on bank debt.

We offer policy implications for institutions, investors, and other stakeholders. As our study confirms the disciplinary power of financial institutions extend to environmental issues, banks can lever their positions to induce firms to reduce emissions and contribute towards net-zero goals. Carbon risk's bank debt curbing tendencies are confirmed in this study, which has implications for firms who wish to amplify their capital sources by adopting carbon risk mitigation strategies. Additionally, the research contributes to a nascent literature examining the role of climate incentives and commitments in accelerating firms towards achieving climate targets, providing research implications for future studies of carbon risks.

However, this study has some limitations that future research could address. First, while we use proxies for carbon emissions and bank debt ratio, data availability constraints may affect the precision of these measures, suggesting the need for more granular firm-level and bank-specific historical data. Second, our study focuses on the overall relationship between carbon risk and bank debt but does not explore potential variations across industries with different environmental sensitivities. Future research could examine sector-specific dynamics and how varying regulatory pressures influence financing decisions. Additionally, the evolving landscape of sustainable finance, including the rise of green bonds and sustainability-linked loans, presents an opportunity to explore alternative funding mechanisms for high-emitter firms. Further studies could also investigate how investor activism and changing stakeholder expectations impact banks' lending decisions and firms' environmental strategies over time.

Appendix 1. Variable definition.

Variable	Description	Source
Dependent Variables		
BD	Ratio of total bank debt to Total debt	Capital IQ
RELATIVE_BD	Ratio of bank debt to the sum of bank debt and corporate debt to total debt.	Capital IQ
BD/TA	Ratio of bank debt to total Assets	Capital IQ
CORPORATE_DEBT/TD	Ratio of corporate debt to total debt	Capital IQ
CORPORATE_DEBT/TA	Ratio of corporate debt to total assets	Capital IQ
TLTD/TD	Ratio of term loans to total debt	Capital IQ
Variables of Interest		
LNEMISSIONS	Natural logarithm of one plus sum of Scope 1 and Scope 2 emission	CDP
CO2INTENSITY	Total CO2 emission in tons divided by net sales-USD Million scaled by 1000	Bloomberg
Firm-level Controls		
LEV	Ratio of Total debt to total Assets	Capital IQ
FSIZE	Natural logarithm of total Assets	Capital IQ
PROFITAB	Ratio of Operating income to total Assets	Capital IQ

(continued on next column)

(continued)

Variable	Description	Source
TANG	Ratio of net property, plant and equipment to total assets	Capital IQ
Q	Ratio of the sum of market equity and book debt to Total Assets	Capital IQ
RATING	A dummy variable equals one if the firm has a long-term debt rating on S&P rating above BBB- and zero otherwise	Capital IQ
ZSCOREDDUMMY	A dummy variable equals one if the Altman Z_score is lower than 1.81 and zero otherwise	Capital IQ
MEANBD	Industry year mean of bank debt ratio	Capital IQ
Country-level controls		
LGDP	Natural logarithm of per capita Gross domestic product	International Monetary Fund
LAWORDER	Law and Order Index	ICRG
PVTCREDIT	Domestic credit to private sector as a percent of GDP	World Bank
Instrumental, Heckman selection, and exogenous shock variables		
L.CO2PERCAPITA	The first lag of CO ₂ emissions per capita is the average annual emissions per person for a country	Our World in data
L.MEDEMISSIONS	The first lag of the country year adjusted median of emissions	CDP
CDPREPORTING	A dummy variable equal to one if the firm is among our matched firms with CDP data and zero otherwise	Capital IQ; CDP database
PROPREP	Proportional representation (PROPREP), a dummy variable equals 1 if candidates are elected in a country based on the percent of votes received by them and 0 otherwise	The database of political institutions 2017 (Scartascini et al., 2018)
PARIS	A dummy variable that equals one for four years after the Paris Agreement of 2015 and zero for four years before the agreement	Authors' calculation
Variables used in Cross-sectional tests		
FCFTA	Ratio of free cash flows to total assets	Capital IQ
SHRATO	Shareholder antitakeover devices in excess of 2	Refinitiv
ANALYST_FOR_DISP	The standard deviation of the IBES forecast scaled by the absolute value of IBES median consensus forecast	Refinitiv
ABPROD	Abnormal production costs estimated following Roychowdhury (2006)	Capital IQ
EARNVOL	Earnings volatility measured as the three-year standard deviation	Capital IQ

(continued on next page)

(continued)

Variable	Description	Source
SOVOWN	of the ratio of EBITDA to total assets	
INSIDEROWN	Percentage of sovereign ownership	Capital IQ
STRATOWN	Percentage of insider ownership	Capital IQ
	Percentage of strategic ownership	Capital IQ
LARGEBOARDSIZE	A dummy variable equal to one if the firm's board size is larger than the country-year adjusted median board size, and zero otherwise	Refinitiv Datastream
HIGHENVIRONPILLARSCORE	A dummy variable equal to one if the environmental pillar score of the firm is higher than the country-year adjusted median environment pillar score, and zero otherwise	Refinitiv Datastream
FI	Financial institutions development index that measures the access, depth and efficiency of financial institutions. A higher score indicates higher financial institutions development	Sviryzdenka (2016)
FM	Financial markets development index that measures the access, depth and efficiency of financial markets. A higher score indicates higher financial markets development	Sviryzdenka (2016)
FD	Financial development index that measures the access, depth and efficiency of overall financial development. A higher score indicates higher financial development	Sviryzdenka (2016)
CDPINCENTIVE	A dummy variable equals to one if the firm provides incentives related to climate performance to the management and zero otherwise	Refinitiv Datastream
CDPTARGETEMISSIONS	A dummy variable equals to one if the firm has declared target for emission reduction and zero otherwise	Refinitiv Datastream
HIGHCCPI	A dummy variable equals to 1 if the climate change performance index (CCPI) is greater than the median CCPI	Germanwatch, Climate Action Network, 2019
ETS	A dummy variable equals one if the country has implemented Emissions Trading system	World carbon database, Dolphin, 2022
Additional controls		
QSPREAD	Bid ask spread	Refinitiv Datastream
ROTARANK	Ranking of the ratio of earnings before interest, tax and depreciation and amortization to Net	Capital IQ

(continued on next column)

(continued)

Variable	Description	Source
COUNTRYMEDIANANALYST	property, plant and equipment, based on Wu and Lai (2020)	Refinitiv Datastream
	A dummy variable equals to one if the number of analysts following the firm is greater than the country year adjusted median number of analysts and zero otherwise	
BIG4	A dummy variable equals to one if the firm auditor is a Big 4 firm and zero otherwise	Capital IQ
CEO DUALITY	A dummy variable equals to one if the CEO is also the Chairman of the board and zero otherwise	Refinitiv Datastream
PCTINDEPBOARD	The percentage of independent board members	Datastream
INSTOWNPERCENT	Percentage of institutional ownership	Refinitiv Datastream

Appendix 2. Propensity matched sample statistics.

Variable	Mean			t-test		
	Treated	Control	%bias	t	p > t	V(T)/V (C)
LEV	0.284	0.284	0.1	0.03	0.973	0.89*
FSIZE	8.824	8.888	-4.6	-2.23	0.026	0.84*
PROFITAB	0.075	0.075	0.3	0.15	0.882	1.02
TANG	0.308	0.309	-0.5	-0.2	0.841	0.71*
Q	1.277	1.284	-0.8	-0.35	0.729	0.99
ZSCOREDDUMMY	0.718	0.721	-0.5	-0.23	0.815	.
RATING	0.387	0.409	-4.5	-1.89	0.059	.
MEANBD	0.404	0.404	-0.4	-0.15	0.88	1.01
LGDPCC	10.522	10.524	-0.2	-0.09	0.931	0.98
LAWORDER	4.807	4.803	0.4	0.15	0.878	1.22*
PVTCREDIT	1.440	1.431	1.4313	0.81	0.418	0.81*

Notes: This table reports descriptive statistics for our control variables for the treatment and control group after matching. The full sample includes 14,307 observations from 58 countries during the 2007 and 2020 period. [Appendix 1](#) presents the description of the variables.

Data availability

Data will be made available on request.

References

- Agoraki, K. K., Giaka, M., Konstantios, D., & Negkakis, I. (2024). The relationship between firm-level climate change exposure, financial integration, cost of capital and investment efficiency. *Journal of International Money and Finance*, 141, Article 102994.
- Al Rabab'a, E. A. F., Rashid, A., & Shams, S. (2023). Corporate carbon performance and cost of debt: Evidence from Asia-Pacific countries. *International Review of Financial Analysis*, 88, Article 102641.
- Altavilla, C., Boucinha, M., Pagano, M., & Polo, A. (2024). *Climate risk, bank lending and monetary policy*.
- Altman, E. I. (1968). Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *The Journal of Finance*, 23(4), 589–609.
- Asimakopoulos, P., Asimakopoulos, S., & Li, X. (2023). The role of environmental, social, and governance rating on corporate debt structure. *Journal of Corporate Finance*, 83, Article 102488.
- Aswani, J., Raghunandan, A., & Rajgopal, S. (2024). Are carbon emissions associated with stock returns? *Review of Finance*, 28(1), 75–106.
- Balachandran, B., & Nguyen, J. H. (2018). Does carbon risk matter in firm dividend policy? Evidence from a quasi-natural experiment in an imputation environment. *Journal of Banking & Finance*, 96, 249–267. <https://doi.org/10.1016/j.jbankfin.2018.09.015>

- Basu, S., Vitanza, J., Wang, W., & Zhu, X. R. (2022). Walking the walk? Bank ESG disclosures and home mortgage lending. *Review of Accounting Studies*, 27(3), 779–821.
- Ben-Nasr, H. (2019). Do unemployment benefits affect the choice of debt source? *Journal of Corporate Finance*, 56, 88–107. <https://doi.org/10.1016/j.jcorpfin.2019.01.006>
- Ben-Nasr, H., Boubaker, S., & Sassi, S. (2021). Board reforms and debt choice. *Journal of Corporate Finance*, 69, Article 102009.
- Ben-Nasr, H., Bouslimi, L., Ebrahim, M. S., & Zhong, R. (2020). Political uncertainty and the choice of debt sources. *Journal of International Financial Markets Institutions and Money*, 64, Article 101142.
- Berger, A. N., El Ghoul, S., Guedhami, O., & Guo, J. (2021). Corporate capital structure and firm value: International evidence on the special roles of Bank debt. *Review of Corporate Finance*, 1(1–2), 1–41.
- Bhojraj, S., & Sengupta, P. (2003). Effect of corporate governance on bond ratings and yields: The role of institutional investors and outside directors. *The Journal of Business*, 76(3), 455–475.
- Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of Financial Economics*, 142(2), 517–549. <https://doi.org/10.1016/j.jfineco.2021.05.008>
- Bolton, P., & Kacperczyk, M. (2023a). Global pricing of carbon-transition risk. *The Journal of Finance*, 78(6), 3677–3754.
- Bolton, P., & Kacperczyk, M. (2023b). *Firm commitments* (Vol. w31244). National Bureau of Economic Research.
- Bose, S., Burns, N., Minnick, K., & Shams, S. (2023). Climate-linked compensation, societal values, and climate change impact: International evidence. *Corporate Governance: An International Review*, 31(5), 759–785.
- Bose, S., Lim, E. K., Minnick, K., Schorno, P. J., & Shams, S. (2025). Does carbon risk influence stock price crash risk? International evidence. *Journal of Business Finance and Accounting*. <https://doi.org/10.1111/jbfa.12851>
- Bose, S., Minnick, K., & Shams, S. (2021). Does carbon risk matter for corporate acquisition decisions? *Journal of Corporate Finance*, 70, Article 102058. <https://doi.org/10.1016/j.jcorpfin.2021.102058>
- Boubaker, S., Saffar, W., & Sassi, S. (2018). Product market competition and debt choice. *Journal of Corporate Finance*, 49, 204–224.
- Bua, G., Kapp, D., Ramella, F., & Rognone, L. (2024). Transition versus physical climate risk pricing in European financial markets: A text-based approach. *The European Journal of Finance*, 1–35.
- Capasso, G., Gianfrate, G., & Spinelli, M. (2020). Climate change and credit risk. *Journal of Cleaner Production*, 266, Article 121634.
- Caragnano, A., Mariani, M., Pizzutillo, F., & Zito, M. (2020). Is it worth reducing GHG emissions? Exploring the effect on the cost of debt financing. *Journal of Environmental Management*, 270, Article 110860.
- Carline, N. F., & Gogineni, S. (2021). Antitakeover provisions and investment in mergers and acquisitions: A causal reevaluation. *Journal of Corporate Finance*, 69, Article 101962.
- Cepni, O., Sensoy, A., & Yilmaz, M. H. (2024). Climate change exposure and cost of equity. *Energy Economics*, 130, Article 107288.
- Chava, S. (2014). Environmental externalities and cost of capital. *Management Science*, 60(9), 2223–2247.
- Chava, S., Livdan, D., & Purnanandam, A. (2009). Do shareholder rights affect the cost of Bank loans? *The Review of Financial Studies*, 22(8), 2973–3004. <https://doi.org/10.1093/RFS/HHN111>
- Chemmanur, T. J., & Fulghieri, P. (1994). Reputation, renegotiation, and the choice between bank loans and publicly traded debt. *Review of Financial Studies*, 7(3), 475–506.
- Chen, Y., Hassan, I., Saffar, W., & Zolotoy, L. (2021). Executive equity risk-taking incentives and firms' choice of debt structure. *Journal of Banking and Finance*, 133, Article 106274.
- Chen, Y., Saffar, W., Shan, C., & Wang, S. Q. (2023). Credit default swaps and corporate debt structure. *Journal of Corporate Finance*, 83, Article 102494.
- Chui, A. C., Li, X., & Saffar, W. (2021). National culture and the choice between bank debt and public debt. *Pacific-Basin Finance Journal*, 70, Article 101655.
- Cline, B., Fu, X., & Ta, T. (2019). Shareholder investment horizons and Bank debt financing. *Journal of Banking & Finance*, 110, Article 105656.
- Çolak, G., & Öztekin, Ö. (2021). The impact of COVID-19 pandemic on bank lending around the world. *Journal of Banking & Finance*, 133, Article 106207.
- Cumming, D., Duppati, G., Fernando, R., Singh, S. P., & Tiwari, A. K. (2024). Dynamics of carbon risk, cost of debt and leverage adjustments. *The British Accounting Review*. <https://doi.org/10.1016/j.BAR.2024.101353>, 101353.
- D'Arcangelo, F. M., Kruse, T., Pisu, M., & Tomasi, M. (2023). *Corporate cost of debt in the low-carbon transition: The effect of climate policies on firm financing and investment through the banking channel*. Available at SSRN 4691593.
- Degryse, H., Goncharenko, R., Theunisz, C., & Vadasz, T. (2023). When green meets green. *Journal of Corporate Finance*, 78, Article 102355.
- Diamond, D. W. (1984). Financial intermediation and delegated monitoring. *The Review of Economic Studies*, 51(3), 393–414.
- Diamond, D. W. (1991). Debt maturity structure and liquidity risk. *The Quarterly Journal of Economics*, 106(3), 709–737. <https://doi.org/10.2307/2937924>
- Ding, X., Ren, Y., Tan, W., & Wu, H. (2023). Does carbon emission of firms matter for Bank loans decision? Evidence from China. *International Review of Financial Analysis*, 86, Article 102556.
- Du, X., Weng, J., Zeng, Q., Chang, Y., & Pei, H. (2015). Do lenders applaud corporate environmental performance? Evidence from Chinese private-owned firms. *Journal of Business Ethics*, 143(1), 179–207. <https://doi.org/10.1007/s10551-015-2758-2>
- Ehlers, T., Packer, F., & de Greiff, K. (2022). The pricing of carbon risk in syndicated loans: Which risks are priced and why? *Journal of Banking & Finance*, 136, Article 106180. <https://doi.org/10.1016/j.jbankfin.2021.106180>
- El Ghoul, S., Guedhami, O., Kim, H., & Park, K. (2016). Corporate environmental responsibility and the cost of capital: International evidence. *Journal of Business Ethics*, 149(2), 335–361. <https://doi.org/10.1007/s10551-015-3005-6>
- EPA. (2009). Mandatory Greenhouse Gas reporting Rule: EPA's response to public comments revision of certain provisions of the mandatory reporting of Greenhouse Gases Rule. <http://www.regulations.gov>.
- Ferdous, L., Atawnah, N., Yeboah, R., & Zhou, Y. (2024). Firm-level climate risk and accounting conservatism: International evidence. *International Review of Financial Analysis*, 95, 103511. <https://doi.org/10.1016/j.irfa.2024.103511>
- Fich, E. M., Harford, J., & Tran, A. L. (2015). Motivated monitors: The importance of institutional investors' portfolio weights. *Journal of Financial Economics*, 118(1), 21–48.
- Fields, L. P., Fraser, D. R., & Subrahmanyam, A. (2012). Board quality and the cost of debt capital: The case of bank loans. *Journal of Banking & Finance*, 36(5), 1536–1547.
- Francis, B., Hasan, I., Jiang, C., Sharma, Z., & Zhu, Y. (2022). Climate Risks and Debt Specialization. Available at SSRN 4198318.
- Gallego-Álvarez, I., Segura, L., & Martínez-Ferrero, J. (2015). Carbon emission reduction: The impact on the financial and operational performance of international companies. *Journal of Cleaner Production*, 103, 149–159. <https://doi.org/10.1016/j.jclepro.2014.08.047>
- Ge, W., & Kim, J. B. (2014). Real earnings management and the cost of new corporate bonds. *Journal of Business Research*, 67(4), 641–647.
- Ghouma, H., Ben-Nasr, H., & Yan, R. (2018). Corporate governance and cost of debt financing: Empirical evidence from Canada. *The Quarterly Review of Economics and Finance*, 67, 138–148.
- Giannetti, M., Jasova, M., Loumioti, M., & Mendicino, C. (2023). “Glossy green” banks: The disconnect between environmental disclosures and lending activities (December, 2023). ECB working paper, (2023/2882).
- Ginglinger, E., & Moreau, Q. (2019). Climate risk and capital structure. *SSRN Electronic Journal*. <https://doi.org/10.2139/SSRN.3327185>
- Godsell, D. (2022). Financial reporting consequences of sovereign wealth fund investment*. *Contemporary Accounting Research*, 39(3), 2090–2129. <https://doi.org/10.1111/1911-3846.12776>
- Gompers, P., Ishii, J., & Metrick, A. (2003). Corporate governance and equity prices. *The Quarterly Journal of Economics*, 118(1), 107–156. <https://doi.org/10.1162/00355300300535162>
- Goodell, J. W., Palma, A., Paltrinieri, A., & Piserà, S. (2025). Firm-level climate change risk and corporate debt maturity. *Journal of International Money and Finance*, 152, 103275. <https://doi.org/10.1016/j.jimonfin.2025.103275>
- Haas, C., & Kempa, K. (2023). Low-carbon investment and credit rationing. *Environmental and Resource Economics*, 86(1), 109–145.
- Hasan, M. M., & Uddin, M. R. (2022). Do intangibles matter for corporate policies? Evidence from organization capital and corporate payout choices. *Journal of Banking & Finance*, 135, Article 106395.
- Homanen, M. (2018). Depositors disciplining banks: The impact of scandals. *SSRN Electronic Journal*. <https://doi.org/10.2139/SSRN.3293254>
- Hossain, A. T., Masum, A., & al. (2022). Does corporate social responsibility help mitigate firm-level climate change risk? *Finance Research Letters*, 47, Article 102791. <https://doi.org/10.1016/j.FRL.2022.102791>
- Houston, J., & James, C. (1996). Bank information monopolies and the mix of private and public debt claims. *The Journal of Finance*, 51(5), 1863–1889.
- Houston, J. F., & James, C. M. (2001). Do relationships have limits? Banking relationships, financial constraints, and investment. *The Journal of Business*, 74(3), 347–374.
- Houston, J. F., & Shan, H. (2022). Corporate ESG profiles and banking relationships. *The Review of Financial Studies*, 35(7), 3373–3417.
- Houston, J. F., Shan, H., Shan, Y., Allen, L., Dube, S., Flannery, M., ... Yu, F. (2021). *Intangible customer capital and Bank resilience* *.
- Hrazdil, K., Anginer, D., Li, J., & Zhang, R. (2024). Climate reputation and bank loan contracting. *Journal of Business Ethics*, 192(4), 875–896.
- Huang, G. Y., Shen, C. H. H., & Wu, Z. X. (2023). Firm-level political risk and debt choice. *Journal of Corporate Finance*, 78, Article 102332.
- ICAEW. (1992). *The financial aspect of corporate governance*.
- Ilhan, E., Sautner, Z., & Vilkov, G. (2021). Carbon tail risk. *The Review of Financial Studies*, 34(3), 1540–1571.
- Jackson, P. (2007). From Stockholm to Kyoto: A brief history of climate change. *UN Chronicle*, 44(2).
- Javadi, S., & Masum, A. A. (2021). The impact of climate change on the cost of bank loans. *Journal of Corporate Finance*, 69, Article 102019.
- Javakhadze, D., Ferris, S. P., & Sen, N. (2014). An international analysis of dividend smoothing. *Journal of Corporate Finance*, 29, 200–220.
- Jensen, M. C. (1986). Agency costs of free cash flow, corporate finance, and takeovers. *The American Economic Review*, 76(2), 323–329.
- Jung, J., Herbohn, K., & Clarkson, P. (2018). Carbon risk, carbon risk awareness and the cost of debt financing. *Journal of Business Ethics*, 150(4), 1151–1171. <https://doi.org/10.1007/s10551-016-3207-6>
- Kabir, M., Rahman, D., & Jamil, T. (2024). Torn between two debt types? The role of managerial ability in a firm's choice between bank loans and public debt. *Journal of Banking & Finance*, 164, Article 107205.
- Kabir, M. N., Rahman, S., Rahman, M. A., & Anwar, M. (2021). Carbon emissions and default risk: International evidence from firm-level data. *Economic Modelling*, 103, Article 105617.

- Kacperczyk, M. T., & Peydro, J. L. (2022). *Carbon emissions and the bank-lending channel*. Available at SSRN 3915486.
- Kleibergen, F., & Paap, R. (2006). Generalized reduced rank tests using the singular value decomposition. *Journal of Econometrics*, 133(1), 97–126.
- Lemma, T. T., Lulseged, A., & Tavakolifar, M. (2021). Corporate commitment to climate change action, carbon risk exposure, and a firm's debt financing policy. *Business Strategy and the Environment*, 30(8), 3919–3936.
- Lemma, T. T., Shabestari, M. A., Freedman, M., & Milo, M. (2020). Corporate carbon risk exposure, voluntary disclosure, and financial reporting quality. *Business Strategy and the Environment*, 29(5), 2130–2143. <https://doi.org/10.1002/BSE.2499>
- Li, X., Lin, C., & Zhan, X. (2019). Does change in the information environment affect financing choices? *Management Science*, 65, 5676–5696.
- Li, X., Ng, J., & Saffar, W. (2024). Accounting-driven bank monitoring and firms' debt structure: Evidence from IFRS 9 adoption. *Management Science*, 70(1), 54–77.
- Lin, C., Ma, Y., Malatesta, P., & Xuan, Y. (2013). Corporate ownership structure and the choice between Bank debt and public debt. *Journal of Financial Economics*, 109(2), 517–534.
- Lockwood, B., & Lockwood, M. (2022). How do right-wing populist parties influence climate and renewable energy policies? Evidence from OECD countries. *Global Environmental Politics*, 22(3), 12–37. https://doi.org/10.1162/GLEP_A_00659
- Massa, M., & Zhang, L. (2021). The spillover effects of hurricane Katrina on corporate bonds and the choice between bank and bond financing. *Journal of Financial and Quantitative Analysis*, 56(3), 885–913.
- Matsumura, E. M., Prakash, R., & Vera-Munoz, S. C. (2014). Firm-value effects of carbon emissions and carbon disclosures. *The Accounting Review*, 89(2), 695–724.
- Naeem, K., & Li, M. C. (2019). Corporate investment efficiency: The role of financial development in firms with financing constraints and agency issues in OECD non-financial firms. *International Review of Financial Analysis*, 62, 53–68.
- Nandy, M., & Lodh, S. (2012). Do banks value the eco-friendliness of firms in their corporate lending decision? Some empirical evidence. *International Review of Financial Analysis*, 25, 83–93. <https://doi.org/10.1016/j.irfa.2012.06.008>
- Nguyen, J. H., & Phan, H. V. (2020). Carbon risk and corporate capital structure. *Journal of Corporate Finance*, 64, Article 101713.
- Nguyen, J. H., Truong, C., & Zhang, B. (2025). The price of carbon risk: Evidence from the Kyoto protocol ratification. *Journal of Environmental Economics and Management*, 130, 103118. <https://doi.org/10.1016/j.jeem.2025.103118>
- Painter, M. (2020). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*, 135(2), 468–482.
- Palea, V., & Drogo, F. (2020). Carbon emissions and the cost of debt in the eurozone: The role of public policies, climate-related disclosure and corporate governance. *Business Strategy and the Environment*, 29(8), 2953–2972. <https://doi.org/10.1002/bse.2550>
- Pankratz, N., Bauer, R., & Derwall, J. (2023). Climate change, firm performance, and investor surprises. *Management Science*, 69(12), 7352–7398.
- Pappas, K., et al. (2019). Real earnings management and loan contract terms. *The British Accounting Review*, 51(4), 373–401.
- Perdichizzi, S., Buchetti, B., Cicchiello, A. F., & Dal Maso, L. (2024). Carbon emission and firms' value: Evidence from Europe. *Energy Economics*, 131, Article 107324.
- Perera, K., Kuruppuarachchi, D., Kumarasinghe, S., & Suleman, M. T. (2023). The impact of carbon disclosure and carbon emissions intensity on firms' idiosyncratic volatility. *Energy Economics*, 128, Article 107053.
- Phan, D. H. B., Tran, V. T., Ming, T. C., & Le, A. (2022). Carbon risk and corporate investment: A cross-country evidence. *Finance Research Letters*, 46, Article 102376.
- Pohl, C., et al. (2023). Borrower- and lender-specific determinants in the pricing of sustainability-linked loans. *Journal of Cleaner Production*, 385.
- Rauh, J. D., & Sufi, A. (2010). Capital structure and debt structure. *The Review of Financial Studies*, 23(12), 4242–4280. <https://doi.org/10.1093/RFS/HHQ095>
- Ritz, R. A. (2022). Linking executive compensation to climate performance. *California Management Review*, 64(3), 124–140.
- Roychowdhury, S. (2006). Earnings management through real activities manipulation. *Journal of Accounting and Economics*, 42(3), 335–370. <https://doi.org/10.1016/J.JACCECO.2006.01.002>
- Safiullah, M., Kabir, M. N., & Miah, M. D. (2021). Carbon emissions and credit ratings. *Energy Economics*, 100, Article 105330.
- Scartascini, C., Cruz, C., & Keefer, P. (2018). *The database of political Institutions 2017 (DPI2017)*. <https://doi.org/10.18235/0001027>
- Stuart, E. A., & Rubin, D. B. (2008). Matching with multiple control groups with adjustment for group differences. *Journal of Educational and Behavioral Statistics*, 33(3), 279–306. <https://doi.org/10.3102/1076998607306078>
- Sviryzdenka, K. (2016). Introducing a new broad-based index of financial development. In *IMF working papers*. International Monetary Fund.
- Trinks, A., Ibikunle, G., Mulder, M., & Scholtens, B. (2022). Carbon intensity and the cost of equity capital. *The Energy Journal*, 43(2), 181–214. <https://doi.org/10.5547/01956574.43.2.atr>
- Umar, M., Ji, X., Mirza, N., & Naqvi, B. (2021). Carbon neutrality, bank lending, and credit risk: Evidence from the Eurozone. *Journal of Environmental Management*, 296, Article 113156.
- Velte, P., Stawinoga, M., & Lueg, R. (2020). Carbon performance and disclosure: A systematic review of governance-related determinants and financial consequences. *Journal of Cleaner Production*, 254, Article 120063. <https://doi.org/10.1016/J.JCLEPRO.2020.120063>
- Wang, J., Qiang, H., Liang, Y., Huang, X., & Zhong, W. (2023). How carbon risk affects corporate debt defaults: Evidence from Paris agreement. *Energy Economics*, 129, Article 107275.
- Wang, X., Guo, Y., & Fu, S. (2024). Will green innovation strategies trigger debt default risk? Evidence from listed companies in China. *Finance Research Letters*, 62, Article 105216. <https://doi.org/10.1016/J.FRL.2024.105216>
- Wedari, L. K., Jubb, C., & Moradi-Motlagh, A. (2021). Corporate climate-related voluntary disclosures: Does potential greenwash exist among Australian high emitters reports? *Business Strategy and the Environment*, 30, 3721–3739.
- Wu, K., & Lai, S. (2020). Intangible intensity and stock price crash risk. *Journal of Corporate Finance*, 64, 101682.
- Zhou, Z., & Wu, K. (2023). Does climate risk exposure affect corporate leverage adjustment speed? International evidence. *SSRN Electronic Journal*. <https://doi.org/10.2139/SSRN.4291437>