Financial constraints and carbon emissions: an empirical investigation

Ijaz Ur Rehman, Faisal Shahzad, Muhammad Abdullah Hanif, Ameena Arshad and Bruno S. Sergi

Abstract

Purpose – *This study aims to empirically examine the influence of financial constraints on firm carbon emissions. In addition to the role of financial constraints in firm-level carbon emissions, this study also examines this influence in the presence of governance, environmental orientation and firm-level attributes.*

Design/methodology/approach – *Using pooled ordinary least square, this study examines the impact of financial constraints on firm-level carbon emissions using a panel of 1,536 US firm-year observations from 2008 to 2019. This study also used two-step generalized method of moment–based dynamic panel data and two-stage least square approaches to address potential endogeneity. The results are robust to endogeneity and collinearity issues.*

Findings – *The results suggest that financial constraints enhance the carbon emissions of the firms. The economic significance of financial constraints on carbon emissions is more pronounced for the firms that do not report environment-related expenditure investment and those that are highly leveraged. The authors further document that firms with a nondiverse gender board signify a statistically significant impact of financial constraints on carbon emissions. These results are also economically significant, as one standard deviation increase in financial constraints is associated with a 3.340% increase in carbon emissions at the firm level.*

Research limitations/implications – *Some implicit and explicit factors like corporate emissions policy and culture may condition the relationship of financial constraints with carbon emissions. Therefore, it would be worthwhile to consider these factors for future research. In addition, it is beneficial to identify the thresholds and/or quantiles at which financial constraints may significantly make a difference in enhancing carbon emissions.*

Practical implications – *The findings offer policy implications for investment in stakeholder engagement for capital acquisitions, thereby effectively enforcing environmental innovation and leading to a reduction in carbon emissions.*

Originality/value – *This study integrated governance and environment-oriented variables in the model to empirically examine the role of financial constraints on the carbon emissions of the firms in the USA over and above what has already been documented in the earlier literature.*

Keywords *Financial constraints, Carbon emissions, Stakeholders' engagement, Stakeholders' theory, Board gender diversity*

Paper type *Research paper*

(Information about the authors can be found at the end of this article.)

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1. Introduction

The UN Framework Convention on Climate Change introduced the Conference of Parties (COP1, 2, 3, ….. 26) in the climate change sphere to bring government signatories together once a year and jointly discuss solutions to fight climate change. In the Paris Agreement at COP 21 [1], it was decided to keep the average global rise in temperatures to well below 2 degrees (ideally 1.5 degrees), to bring resilient and climatically adaptive communities, and to align global finances with flowing toward reduced greenhouse gas (GHG) emissions (Xie, 2023). The commitment to aim for 1.5 degrees is crucial here because every fraction of a degree in rising temperatures will result in further tragedy and calamity. In retrospect, several countries worldwide have successfully presented their

carbon emission reduction policies as part of the global climate governance process (Ding *et al.*, 2023).

The Glasgow Climate Pact at COP26 emphasized – among other targets – the provision of climate finance (Pauw *et al.*, 2022) to reduce climate change's impacts on their citizens' lives. Moreover, this will require finances in all forms, be it public finance for the reliable development and progress of infrastructure, transitioning to a green economy, creating green jobs, green finance and privately available finance that would fund sustainable innovation and technological development, creating avenues for climate investment opportunities (UNFCCC, 2021) [2]. To achieve the Paris Climate Agreement's objectives of swift global decarbonization under the Paris Agreement on climate change, climate finance is interpreted broadly as public, private and alternative sources of financing.

As corporate policies evolve, the carbon footprints of enterprises have become an increasingly important determinant. Numerous driving forces are behind the influence of many entities to press business enterprises to adopt reductions in industrial emissions through environmentally friendly measures, including the Kyoto Protocol, the Paris Climate Change Agreement and the UN Climate Change Conference (COP26) (Alam *et al.*, 2022). Along with this push for environmental responsibility, academicians and professionals have advocated the firm's "win-win" strategies that benefit a broad array of stakeholders (i.e. Al-Tuwaijri, 2004; Clarkson *et al.*, 2011; Atif *et al.*, 2021). For companies, carbon emissions have become an essential metric for implementing sustainable business practices, aligning with external demands, and realizing financial rewards (Alam *et al.*, 2022). In this vein, Dutta *et al.* (2020) noted a notable shift among investors toward environmentally sustainable investments, evidenced by their inclusion of eco-friendly firms in their investment portfolios.

In the empirical literature, several factors encompassing firm intrinsic characteristics, company climate strategy behavior and external environmental factors related to carbon emissions reduction have been studied extensively. The mixed results of the extant empirical literature underscore the density of the issue and need to be carefully considered. For instance, the factors that positively influence the reduction of carbon emissions include politically connected firms (Jiang *et al.*, 2021), sustainability committee presence, sustainability reporting, industry category (Córdova *et al.*, 2018), choice of reporting on carbon (Córdova *et al.*, 2018) and availability of organizational slack or funding innovation (Amran *et al.*, 2016). On the contrary, state ownership (Yang *et al.*, 2019a, 2019b), firm headquarters (Córdova *et al.*, 2018) and energy prices (Chen *et al.*, 2018) have been shown to harm carbon reduction.

Financial Institutions play a significant role in channeling funds into the firms' capital investment. Having said this, financial institutions are also subject to different risks from corporate borrowers. Such types of risks grow particularly when nonfulfillment of contractual obligations is considered. When a firm performs poorly on environmental matters, it incurs direct legal liability for cleaning up pollution, damaging its reputation and uncertainty about its capacity and profitability (Mengze and Wei, 2015; Altman and Saunders, 1997). Banks can suffer direct risks associated with borrowers' legal liability for pollution cleanup, indirect risks associated with borrowers' increases in costs or revenue reductions caused by rigorous environmental strategies, and reputational risks associated with financing environmentally hostile firms or projects (Zhang, 2021). The risk also exists when banks take toxic assets as security for loans, resulting in significant value reductions (Thompson and Cowton, 2004).

Recently, several studies have examined the environmental consequences of financing constraints at the macro level or using private firms' data in China. For instance, Wang *et al.* (2022) noted financing constraints at the regional level impede the achievement of high-quality urban development. Meng *et al.* (2022) noted that compared to long-term debt, carbon emissions trading could be a positive factor for commercial credit financing in

China's highly energy-consuming industries. Chen (2023) documented that corporate social responsibility (CSR) can reduce corporate carbon intensity and alleviate funding restrictions, increasing carbon-neutral capability. Its effectiveness varies depending on the stage of the product's life cycle. CSR strongly impacts carbon intensity for state-owned enterprises, high-tech firms and big polluters. Yu *et al.* (2022) examine the role of financing constraints and pollutant emissions intensity of China's industrial enterprises. They develop an analytical framework for heterogeneous enterprises by integrating financing constraints into the partial equilibrium analysis. According to their findings, financial constraints hinder technological advancements and undermine total factor productivity, ultimately increasing pollution intensity within enterprises. While resource consumption can contribute to pollution and environmental degradation, it can also be a driving factor in advancing high-quality urban development. Zhang *et al.* (2020) noted that green innovation, including management and production, can significantly reduce organizations' financial challenges.

The current understanding of how financial constraints affect carbon emissions at the firm level is somewhat limited despite the literature describing different determinants of firm-level environmental performance. Therefore, this study expects to narrow this gap by empirically investigating how financial constraints influence the carbon emissions of US firms. Our work is closely related to Yu *et al.* (2022) and supplements their findings by examining the role of financing constraints in carbon emissions in US-listed firms. Our approach to examining the impact of financial constraints on a firm's carbon emissions departs from Yu *et al.* (2022) in the following ways. We integrated governance and environment-oriented variables in our model to empirically examine the role of financial constraints on the carbon emissions of publicly listed firms in the USA. We empirically answer a few questions that contribute to the current debate on financial constraints and carbon emissions. Do financial constraints increase the firm's carbon emissions? How does this relationship unfold when the carbon-emitting firms report on their environmental expenditure investment to minimize future risk or increase opportunities and/or when firms have high or low leverage? Whether the effect of financial constraints on carbon emissions differs for firms having diverse gender board? We empirically examine these questions by constructing a panel of 1,536 firm-year observations of US firms through the baseline and subsample analyses.

Our empirical results suggest that financial constraints enhance the firm's carbon emissions. The economic significance of financial constraints on carbon emissions is more pronounced for the firms that do not report environment-related expenditure investment and those that are highly leveraged. We further document that firms with nondiverse gender boards signify a statistically significant impact of financial constraints on carbon emissions. These results are also economically significant, as one standard deviation increase in financial constraints is associated with a 3.340% increase in carbon emissions at the firm level. Potential endogeneity may affect causal interpretations of the relationships between financial constraints and carbon emissions in our empirical settings. Unobservable factors, for instance, may affect firms' carbon emissions, thereby producing spurious results. Our baseline regression is designed to account for the firm and industry effects as one potential source of endogeneity. Reverse causality could also be another source of endogeneity. High-carbon-emitting firms may increase the risk of being financially constrained, suggesting causality from carbon emissions to financial constraints. Considering the endogeneity concerns caused by reverse causality, we apply the instrumental variable (IV) approach. We use average industrial financial constraint as an IV for financial constraint. Our baseline results remain valid after controlling exogenous factors related to financial constraints. The robustness of the IV approach is also tested through the generalized method of moments (GMM), and the results remain valid.

The remainder of the paper is as follows. Section 2 details the selected review of the literature. Section 3 shows the data and samples used in the analyses. Sections 4 and 5 present the empirical findings, conclusion and implications.

2. Literature review and hypothesis development

Why do firms face financial constraints or enjoy fewer or no constraints? The theoretical and empirical literature contains the reasons, determinants and consequences for the firms' finances (un)availability. Given the scope of this work, we first briefly present the determinants and consequences of finance (un)availability that are rooted in the environmental aspects of the firms followed by the broad array of determinants of carbon emission influenced by firm and governance-related factors followed by the role of financial constraints in carbon emissions.

Since the seminal work of Fazzari *et al.* (1988), several empirical studies have documented the antecedents and implications of financial constraints, indicating that financing constraints can significantly impact corporate investment decisions, potentially leading to resource misallocation and suboptimal investment levels. The empirical strands are broadly characterized as reasons for financial limitations at the company, macroeconomic and governance levels. Firm size and age (Beck *et al.*, 2006; Arslan *et al.*, 2006), cash holdings (Almeida *et al.*, 2004; Arslan *et al.*, 2006), dividends (Fazzari *et al.*,1988) and tax concealment and management (Bayar *et al.*, 2018) are all known drivers of financial constraints. Low levels of financial friction, reduced information asymmetry, increased legal system efficiency and higher GDP per capita report reduce macrolevel financing constraints (i.e. Beck *et al.*, 2006), whereas high competition in the banking industry increases firm-level financial constraints (Álvarez and Bertin, 2016). According to Malik *et al.* (2021), the voluntary formation of a board risk committee (BRC) minimizes financial restrictions by increasing risk oversight and improving governance practices. Furthermore, the research found that BRCs significantly indirectly influenced financial constraint risk by reducing agency costs by addressing information asymmetry.

2.1 Determinants of carbon emissions, stakeholder and finances

An extensive body of literature has investigated the factors influencing a company's environmental performance in response to the growing importance of ecological business practices. These studies are primarily categorized into three strands. The first strand of studies examines firm attributes and carbon emissions, including capital–labor ratio (Cole *et al.*, 2013), exporting propensity (i.e. Richter and Schiersch, 2017), firm size (i.e. Lee and Min, 2015; Apergis *et al.*, 2013), firm location (i.e. Ishikawa and Okubo, 2017), ownership structure (i.e. Liu *et al.*, 2019) and return on asset (Alam *et al.*, 2019). The second strand of literature modeled firm-level carbon emissions with the research and development investment (i.e. Alam *et al.*, 2019; Lee and Min 2015; Cole *et al.*, 2013), firm-level energy and sustainable investment (Atif *et al.*, 2023. According to the third strand of studies, improved corporate governance significantly improves the company's carbon footprint and environmental impact. This includes independent directors and board gender diversity (i.e. Atif *et al.*, 2021), women CEOs (Glass *et al.*, 2016), executive compensation (i.e. Haque and Ntim, 2020), board environmental orientation (Dixon-Fowler *et al.*, 2017), CEO's experience and personality (Arena *et al.*, 2018; Ortiz-de-Mandojana *et al.*, 2019), environmental compensation (Kanashiro, 2020; Moussa *et al.*, 2020), CEO power (Walls and Berrone, 2017), board size (Liao *et al.*, 2015) and institutional ownership (Kim *et al.*, 2019).

Several studies have empirically linked firm performance, profitability and financial constraints with environmental performance and documented diverse findings. Gray and Deily (1996) noted a reduced likelihood of pollution abatement compliance among more profitable firms using firm-level data from the US steel industry. Using data from 150 production mills, Shadbegian and Gray (2005) noted no or insignificant relation between abatement expenditures and productivity of input factors. Maynard and Shortle (2001) examined enterprises' voluntary rewards/incentives for environmental management. They documented that public pressure and membership in environmental groups positively

affected firms' decisions to invest and implement clean technologies and that profitable firms were likelier to do so.

Our line of inquiry is guided by the stakeholder theory of Freeman and Reed (1983). There is a growing push among stakeholders for companies to communicate and report on their approach to climate change and the risks and opportunities it presents. It involves reporting emissions and describing business processes (Sullivan and Gouldson, 2017). An enterprise has many stakeholders, including shareholders, creditors, managers, employees, the government, financial institutions and others (i.e. Qin *et al.*, 2019). In addition to maximizing shareholder wealth, companies should also consider stakeholders' demands (Donaldson and Preston, 1995). Extant literature supports the notion that companies responsible for mitigating pollutant emissions and environmental pollution should invest capital in green technological innovations and effective ways to mitigate pollution (Cai *et al.*, 2020). Capital investment is often associated with high costs, long cycles and high risks associated with technological innovation (Liu and Jiang, 2016). Therefore, when financing thresholds are high, firms trade off the environmental gains and allocate capital to production projects with short cycles, low investments and rapid results (Banerjee and Duflo, 2010). Therefore, financing constraints could hinder firms' ability to invest in technological innovations to reduce emissions. Pollutant emissions may thus increase, preventing a green transformation of firms' production mode. Stakeholder pressures compel firms to adopt substantive carbon abatement measures – besides increasing carbon transparency – have been widely acknowledged (Pinkse and Busch, 2013). Stakeholders in firms are the groups that influence the development of the firms or are affected by the firms (Qin *et al.*, 2019; Freeman, 1994). Extant literature suggests that stakeholder pressure is a principal factor that drives companies to adopt environmentally friendly behaviors due to stakeholder pressure (i.e. Ma *et al.*, 2018; Kitsikopoulos *et al.*, 2018; Lin *et al.*, 2014; Paulraj, 2009; Chen, 2008). Stakeholders control multifaceted information and resources required for firms' development (Burns *et al.*, 2016), for example, consumer opinions, government policy and an investor's financing. Earnhart and Lizal (2006) documented that it is beneficial for firms to perform well financially in the future regarding environmental performance. Their findings suggest that poor financial performance is typically accompanied by liquidity constraints that undermine pollution control investments, which supports the notion that poor financial performance hurts investments in pollution control. Therefore, a superior level of relationships with a wide array of firms' stakeholders results in access to these resources, which help firms to innovate and initiate capital investment in carbon abatement projects to reduce carbon emissions and vice versa.

Both the theoretical and empirical literature has provided evidence that corporate social initiatives and better stakeholder relationship assist firms in obtaining external financing from external sources such as banks, debt and equity (i.e. Cheng *et al.*, 2014) and improved credit ratings (Ge and Liu, 2015) and greater loan approval rates (Zhang, 2021; Wellalage and Kumar, 2021). Firms implement green practices because financial institutions, customers and other stakeholders are increasingly concerned about the environment (Jackson *et al.*, 2018). The environmental disclosures of firms influence their creditworthiness and profitability by conveying information about GHG emissions, total waste and energy consumption (i.e. Tzouvanas *et al.*, 2020). At the microlevel, it is widely debated among investors and economists whether managers should behave socially responsibly. Socially responsible investments are argued to maximize shareholders. Firms can engage in socially responsible activities that enhance their social capital, enabling them to build trust with investors and lower financing costs (Amiraslani *et al.*, 2018; Lins *et al.*, 2017). The above review highlights that several factors influence a company's environmental performance including its attributes, investment in research and development, product and process innovations, corporate governance, stakeholder pressures and financing. The review also highlights that environmental disclosures and

green practices may affect financing outcomes differently depending on how much they affect socially responsible activities and improving firms' access to external.

Financial resources are especially important in promoting environmental innovations (EI), crucial for economic growth and natural resource depletion. External factors (e.g. unfair market competition, regulations) and internal factors (e.g. lack of human capital, smaller cash flows) impediments to investing firms impede environmental investments (Thum-Thysen *et al.*, 2019). Financial obstacles have emerged as one of the most significant issues (i.e. Cecere *et al.*, 2018). To create a low-carbon economy, businesses must have the financial resources to implement ecologically friendly policies. Given a company's limited resources, increasing spending on environmentally friendly practices reduces productivity and the ability to offer other necessities. As a result, there is a trade-off between productive activity and social obligations (Ghosh and Dutta, 2022). Firms with limited external capital and insufficient internal funds cannot afford high finance costs and prefer to limit their sustainability practices due to the sustainability costs, thus lacking the ability to incorporate green technologies (Rajan and Majumdar, 2016). As a result, financial constraint exerts an inverse impact on sustainability costs for the organization. Based on the above arguments, we hypothesize that:

H1. There is a positive relationship between financial constraints and firm-level carbon emissions.

3. Research design

3.1 Econometric model

To test the hypothesis, we used pooled ordinary least square (OLS) regression to estimate the following econometric equation (1) to examine the impact of financial constraints on carbon emissions:

$$CEi,t = \beta o + \beta 1FCi,t \ + \sum Control\ \ variablesi,t + \mu i + \mu t \ + \ \varepsilon i,t \qquad (1)$$

In equation (1), $CE_{i,t}$ is the natural logarithm of carbon emission, and financial constraints *i* and *t* are measured by the size–age (SA) index as a continuous variable. We also created the dummy variable of financial constraints. All other variables are defined in Appendix.

3.2 Variables measurement

3.2.1 Independent variable: financial constraints. Following the previous studies, we used a proxy of the SA index to measure financial constraints. First, we measure the SA index following the approach of Hadlock and Pierce (2010). This approach considered the information firm age and firm size extracted from the annual report and used the following formula to measure the financially constrained SA index:

$$SA\ \ index = \ -0.737Size\ \ i,t + 0.043Sizei,t2 - 0.040Agei,t \qquad (2)$$

Here in equation (2), Size shows the natural logarithm of total assets and Age is the number of years since the firm is incorporated.

Second, we divided the SA index into two groups based on the median. Firms with a higher value of SA than the median are coded as 1 and considered financial constraint firms. In contrast, firms with a lower value of SA than the median are coded as 0 and considered unfinancial constraint firms.

3.2.2 Dependent variable: carbon emission. Following the previous studies, different methods exist to gauge environmental degradation, but the most common proxy used to

measure environmental degradation is carbon emissions intensity at the firm level (Chu *et al.*, 2022; Chen *et al.*, 2022). Hence, we considered the natural logarithm of carbon emissions at the firm level as a proxy of carbon emissions.

3.2.3 Control variables. Following the previous studies related to control variables on carbon emissions we grouped the control variables into three groups, i.e. Financial, Governance and Environmental (Martínez *et al.*, 2022; Joecks *et al.*, 2012). The governance variables include executive gender diversity, board structure, independent board director and board size. Financial variables are leverage, return on assets and firm age. Environmental variables used are policy emissions score, eco-innovation score and human rights policies. Appendix describes the control variables in detail.

3.3 Sample and data

The initial sample of this study is from 2008 to 2021 for the US listed firms. However, the panel observations were significantly dropped due to missing information on the key variables in recent years (2020–2021); therefore, we limit our analysis to firm-level data from 2008 through 2019. The Thomson Reuters–Eikon database was used to source all the required data. Our initial data set contained 36,684 firm-year observations. However, firms in the USA mentioned data related to carbon emissions voluntarily; therefore, our sample dropped to 4,875 firm-year observations because of the missing data related to carbon emissions in some years. We also dropped all the firm-year observations with missing values of control variables during the data processing stage. Hence, our final sample is 1,536 firm-years as reported in Table 1. To manage the outlier issue, we winsorize all the variables at the 1st and 99th percentile. Detailed definitions of all variables are provided in Appendix.

Table 2 panel A shows the sample distribution on a yearly basis for the period 2008–2019. Results show increasing trends on a yearly basis. It shows the growing trend of firms reporting carbon emissions. In addition, Table 2 panel b illustrates the sample distribution on the sector bases. Panel B shows that our sample has a representation of all sectors.

Table 3 reports the summary statistics of all variables used in the study. Summary statistics of Table 3 reports mean value of carbon emissions is 400,901 (tons). It shows that, on average, US firm is more inclined toward carbon emissions, which ultimately needs to be managed to avoid the environmental risk at the firm level. Our primary independent variable is financial constraints; its mean value is 0.821. It reflects that US firms are facing issues with financing on average. Descriptive statistics of board gender diversity mean value is 16.039. This mean value reflects that the representation of female directors in US firms is high.

Furthermore, the mean values of other governance variables, including executive gender diversity, board diversity, independent board director, board size and board-specific skills are 12.674, 22.326, 4.414, 10.407 and 55.193, respectively. In addition, the mean values of the firm-level variables leverage and return on assets are 3.496 and 1.471, respectively. The present study also used policy emissions score, environmental expenditures and human rights policies as control variables. The descriptive statistic of these variables is also in line with the previous studies. Table 4 presents the correlation matrix of carbon emissions with

Table 1 Sample description

Description	*Observations*
Initial observation from ASSET4 (2008 – 2019)	36,684
After dropping missing values for the main variables	4,875
After dropping missing values for control variables	1,536

Source: Authors' own creation

Table 2 Sample distribution

Panel A year-wise observations			*Panel B industry sector-wise firms distribution based on the initial sample*		
Year	*Observation*	*%*	*Sector*	*No. of firms*	*%*
2008	19	1.24			
2009	35	2.28	Oil and gas	33	8.48
2010	44	2.86	Basic material	36	9.25
2011	45	2.93	Industrials	93	23.91
2012	50	3.26	Consumer	42	10.80
2013	55	3.58	Health care	23	5.91
2014	52	3.39	Services	44	11.31
2015	102	6.64	Telecommunication	2	0.51
2016	171	11.13	Utilities	33	8.48
2017	234	15.23	Technology	52	13.37
2018	307	19.99	Invest and insurance	31	7.97
2019	422	27.47		389	100
	1,536	100			

Source: Authors' own creation

Table 3 Summary statistics

Variables	N	*Mean*	*SD*	*P25*	*Median*	*P75*
Carbon emissions (in Tons)	1,536	400901	11000000	101406	439114	2000000
Ln carbon emissions	1,536	13.039	2.252	11.528	12.991	14.509
Financial constraints	1,536	0.821	0.384	1	1	1
Board gender diversity	1,536	16.039	12.219	7.69	15.38	23.08
Policy emissions reduction	1,536	0.822	0.383	1	1	1
Eco-innovation score	1,536	0.710	0.454	0	1	1
Environmental expenditure investment	1,536	0.182	0.386	0	0	0
Executive gender diversity	1,536	12.674	12.379	0	11.435	20
Human rights policy	1,536	0.422	0.494	0	0	1
Board size	1,536	10.407	2.151	9	10	12
Board diversity	1,536	22.326	9.754	16.67	22.22	28.57
Independent board director	1,536	4.414	0.15	4.382	4.451	4.51
Leverage	1,536	3.496	1.169	3.119	3.908	4.2
Board specific skills	1,536	55.193	19.48	41.67	55.56	69.23
Return on asset	1,536	1.471	0.973	0.886	1.616	2.156

Source: Authors' own creation

all explanatory variables. These results depict that financial constraint has a positive correlation with carbon emissions. It means higher financial constraints of firms trigger the propensity for carbon emissions. Furthermore, the correlation of all variables is less than 0.50, which suggests no multicollinearity issue. Table 5 depicts the result of multicollinearity with variance inflation factor (VIF) and shows no multicollinearity issue because the average value of VIF (2) remains below a value of 10; the maximum level of VIF has been recommended (Hair *et al.*, 2006).

4. Results and discussion

Table 6 presents the baseline results between carbon emissions and financial constraints. Our main explanatory variable is financial constraints, and we use two proxies of financial constraints. In Column (1) of Table 6, the SA index is used as a proxy variable of financial constraints. Results in column 1 show that financial constraints are positively associated with carbon emissions. It means US firms facing financial issues are more prone to carbon emissions.

Table 4 Pairwise correlations

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*
(1) Carbon emissions	1.000													
(2) Financial constraints	0.078***	1.000												
(3) Board gender diversity	0.023	0.021	1.000											
(4) Policy emissions reduction	0.300***	−0.009	0.096***	1.000										
(5) Eco-innovation score	0.135***	−0.004	−0.032	0.133***	1.000									
(6) Environmental expenditure	0.094***	0.330***	−0.035	0.048*	0.019	1.000								
(7) Executive gender diversity	−0.056**	0.156***	0.046*	−0.026	−0.054**	0.045*	1.000							
(8) Human rights policy	0.002	0.242***	0.030	0.019	−0.008	0.322***	0.096***	1.000						
(9) Board size	0.322***	0.012	0.100***	0.215***	0.148***	0.065***	−0.038	0.015	1.000					
(10) Policy board diversity	0.009	−0.016	0.355***	0.162***	0.053**	−0.025	0.023	0.034	0.161***	1.000				
(11) Independent board director	0.140***	−0.010	0.084***	0.048**	0.080***	−0.019	−0.015	0.002	0.200***	0.244***	1.000			
(12) Leverage	0.027	0.057**	−0.062**	−0.009	0.004	0.150***	−0.170***	0.152***	0.048*	−0.020	−0.003	1.000		
(13) Board-specific skills	−0.166***	−0.072***	−0.037	−0.108***	−0.044*	−0.103***	0.011	−0.086***	−0.194***	0.012	−0.089***	−0.007	1.000	
(14) Return on asset	0.059**	−0.185***	−0.070***	0.027	−0.035	0.164***	−0.097***	0.220***	0.015	−0.032	0.000	0.215***	−0.039	1.000

Notes: ***, ** and * represent the significance level at 99, 95 and 90%, respectively
Source: Authors' own creation

Table 5 Variance inflation factor

Variables	*VIF*	*1/VIF*
Financial constraints	1.098	0.911
Board gender diversity	1.171	0.854
Policy emissions reduction	1.093	0.915
Eco innovation score	1.046	0.956
Environmental expenditure investment	1.18	0.847
Executive gender diversity	1.065	0.939
Human rights policy	1.196	0.836
Board size	1.153	0.868
Policy board diversity	1.247	0.802
Independent board director	1.104	0.906
Leverage	1.128	0.887
Board-specific skills	1.066	0.938
Return on asset	1.16	0.862
Mean VIF	1.131	.–

Source: Authors' own creation

Table 6 Pooled OLS regression result: carbon emissions and financial constraints

Variables	*Carbon emissions (1)*	*Carbon emissions (2)*
Financial constraints (continuous)	0.087*** (0.022)	
Financial constraints (dummy)		0.216** (0.070)
Board gender diversity	0.004*** (0.022)	0.004** (0.002)
Policy emissions reduction	1.319*** (0.075)	1.326*** (0.078)
Eco-innovation score	0.481*** (0.051)	0.474*** (0.052)
Environmental expenditure investment	0.396*** (0.155)	0.437** (0.153)
Executive gender diversity	−0.001 (0.003)	−0.001 (0.003)
Human rights policy	−0.092* (0.051)	−0.069 (0.056)
Board size	0.222*** (0.038)	0.220*** (0.038)
Policy board diversity	−0.001 (0.008)	−0.001 (0.007)
Independent board director	0.746 (0.475)	0.748 (0.464)
Leverage	−0.021 (0.041)	−0.026 (0.041)
Board-specific skills	−0.007*** (0.003)	−0.007** (0.003)
Return on asset	0.170*** (0.049)	0.159*** (0.045)
	(0.227)	(0.120)
Constant	7.033*** (2.473)	6.823** (2.404)
Industry and year FE	Yes	Yes
Observations	1,536	1,536
R-squared	0.338	0.338
Adjusted *R*-squared	0.323	0.323

Notes: Standard errors (values in parentheses shows the cluster standard errors) in parentheses ***$p < 0.01$; **$p < 0.05$ and *$p < 0.1$
Source: Authors' own creation

Furthermore, these results are also economically significant as one standard deviation increase in financial constraints (0.087) is associated with a 3.340% (0.384 × 0.087) increase in carbon emissions at the firm level. Similarly, we categorize the SA index into two groups based on the median of the SA index. Our results in Table 6 column 2 report that firms with higher financial constraints are more prone to carbon emissions than firms with lower financial constraints. Next, we report the results of the control variable, which are shown in Table 6. These findings of the control variable are in line with the prior literature. For instance, board-specific skills are negatively influencing carbon emissions. Other variables, which are policy emissions reduction, corporate eco-innovation, environmental expenditure investment, board size, independent board director and return on assets, are

positively linked with carbon emissions. Furthermore, the association of board gender diversity, executive gender diversity, human rights policy, policy board diversity and leverage with carbon emissions are insignificant.

4.1 Financial constraints and carbon emissions: addressing endogeneity

The results of our study indicate that financial constraints considerably influence the amount of carbon firms emit. Despite this, it is important to acknowledge that a firm's financial constraints can be exogenously linked to its carbon emissions. Two methods have been used to address this identification issue, namely, two-stage least squares (2SLS) and GMM. Using a 2SLS approach, we could account for carbon emissions by using the exogenous component of financial constraints.

Although a firm's industrial average financial constraint is correlated with tight financial constraints, there is little reason to believe that the industrial average of financial constraints directly influences carbon emissions. To test this assertion, we used the 2SLS. Table 7 presents our results. In the first stage, we check the relevance of our instrument. We obtain the predicted value of financial constraints by regressing them on industry average financial constraints. Column 1 of Table 7 result suggests that our instrument is positively associated with financial constraints.

Moreover, the *F*-stats of first-stage regression are reasonably high, confirming our financial instrument's validity is strong (Larcker and Rusticus, 2010). Column 2 of Table 7 reports the second stage regression results; our results show that the predicted value of financial constraint is positively associated with carbon emissions. These results prove that firms with higher financial constraints cannot reduce carbon emissions.

Our findings till now assert that companies facing financial constraints are more active toward carbon emissions. However, the results may be biased if the financial constraints are correlated with the error term. We consider the dynamic nature of the relationship between the variables to address the endogeneity issue. To reduce the possibility of bias, the study used the Arellano and Bond's (1991) dynamic panel model using the GMM. As an

Table 7 Two stage least squares regression

Variables	*Financial constraints (1)*	*Carbon emissions (2)*
Ind avg SA index	0.179*** (0.009)	–
Predicted financial constraints		0.161** (0.070)
Board gender diversity	0.002*** (0.001)	0.005** (0.002)
Policy emissions reduction	−0.036 (0.022)	1.316*** (0.079)
Eco-innovation score	0.039* (0.020)	0.484*** (0.051)
Environmental expenditure investment	−0.028 (0.024)	0.460*** (0.147)
Executive gender diversity	−0.000 (0.001)	−0.000 (0.003)
Human rights policy	−0.007 (0.019)	−0.052 (0.060)
Board size	0.006 (0.004)	0.220*** (0.038)
Policy board diversity	−0.000 (0.001)	−0.001 (0.007)
Independent board director	−0.006 (0.058)	0.737 (0.465)
Leverage	0.032*** (0.007)	−0.018 (0.040)
Board-specific skills	0.000 (0.000)	−0.007** (0.003)
Return on asset	−0.029*** (0.009)	0.142*** (0.045)
Constant	0.791*** (0.266)	7.036** (2.438)
Industry and year FE	Yes	Yes
Observations	1,536	1,536
R-squared	0.324	0.338
Adjusted *R*-squared	0.308	0.323

Notes: Standard errors are in parentheses ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$
Source: Authors' own creation

independent variable, this model includes the lag value of the dependent variable (carbon emission).

The dynamic panel regression model is presented in Table 8 using a two-step estimation strategy. Furthermore, the study runs tests to assess the instruments' validity and looks for autocorrelation among the variables. The Sargan test statistic's insignificance ($p = 0.167$) indicates that the estimated models used in this work are not subject to overidentification constraints. This implies that the instruments used are not linked with the error term, which improves the estimation's reliability.

Furthermore, the insignificance of AR(2) implies that autocorrelation does not affect the models used in this investigation. As a result, the Arellano–Bond dynamic panel data model step-two estimation results show a statistically significant positive link between the fraction of financial restraints (coefficient 0.952 significant at the 1% level) and carbon emissions.

Furthermore, the AR(1) results are significant, as reported in Table 8, which suggests that instrument variables capture the dynamicity in the econometric model. Our result in Table 8 confirms the prior findings that financially constrained firms are more prone to carbon emissions.

4.1.1 Additional analyses. Furthermore, there is the possibility that firms with financial constraints can still invest in environmental expenditure. Therefore, we settle this issue by dividing the firm into two subsamples. First, firms report environmental expenditure, and second, firms do not disclose environmental expenditure. We separately regress the financial constraints on carbon emissions for these two subsamples. Our result shows that the impact of financial constraints on carbon emissions is highly significant in statistical terms for firms that do not report the environmental expenditure investment to minimize future risk ($\beta = 0.216^{***}$) as compared to those firms that report environmental expenditure investment to minimize future risk ($\beta = 0.923^{**}$) as reported in column1 of Table 9. The impact of financial constraints on carbon emissions is lesser for firms with lower environmental expenditure ($\beta = 0.216$), as reported in column 2 of Table 9.

Table 8 Two-step GMM regression result

Variables	*Carbon emissions*
Carbon emissions	0.952*** (0.064)
Financial constraints	0.473** (0.207)
Board gender diversity	−0.017* (0.010)
Policy emissions reduction	−0.431 (0.283)
Eco innovation score	0.242 (0.292)
Environmental expenditure investment	−0.227 (0.222)
Executive gender diversity	−0.013 (0.009)
Human rights policy	−0.677*** (0.249)
Board size	0.005 (0.051)
Policy board diversity	0.011 (0.008)
Independent board Director	0.434 (0.845)
Leverage	−0.495** (0.235)
Board-specific skills	−0.004 (0.004)
Return on asset	−0.009 (0.076)
Constant	1.034 (4.068)
Observations	497
Number of groups	171
Number of instruments	46
F-statistics	0.000
Sargan test (*p*-value)	0.167
AR(1) test (*p*-value)	0.028
AR(2) test (*p*-value)	0.406

Notes: Standard errors are given in parentheses; ***$p < 0.01$; **$p < 0.05$ and *$p < 0.1$
Source: Authors' own creation

Table 9 Pooled OLS regression result: financial constraints and carbon emissions: environmental expenditure investment if the company reports on its environmental expenditure investment to minimize future risk or increase opportunities and zero otherwise

Variables	*Carbon emissions* *Environmental expenditure investment is reported*	*Carbon emissions* *Environmental expenditure investment is not reported*
Financial constraints	0.923** (0.419)	0.216*** (0.066)
Board gender diversity	0.017 (0.012)	0.004 (0.002)
Policy emissions reduction	0.553* (0.284)	1.393*** (0.082)
Eco-innovation score	0.682** (0.254)	0.554*** (0.090)
Executive gender diversity	−0.045*** (0.012)	0.007* (0.003)
Human rights policy	0.471** (0.213)	−0.132** (0.056)
Board size	0.312*** (0.056)	0.197*** (0.031)
Policy board diversity	−0.030* (0.014)	0.004 (0.007)
Independent board director	0.036 (0.402)	0.836 (0.547)
Leverage	−0.698** (0.248)	0.022 (0.033)
Board-specific skills	−0.015* (0.008)	−0.007*** (0.002)
Return on asset	0.458*** (0.122)	0.149*** (0.047)
Constant	11.938*** (2.561)	6.057** (2.660)
Industry and year FE	Yes	Yes
Observations	279	1,257
R-squared	0.505	0.342
Adjusted *R*-squared	0.438	0.324

Notes: Standard errors are in parentheses; ***$p < 0.01$; **$p < 0.05$ and *$p < 0.1$
Source: Authors' calculation

We grouped the firms into higher leverage and low leverage firms based on the median value of financial leverage. Firms with a higher leverage value than the median are coded as 1, considered highly leveraged firms, and otherwise coded as 0 and considered low-leverage firms. We separately regress equation (1) for subsamples of high- and low-leverage firms. Results of Table 10 column 1 show the impact of financial constraints on carbon emissions ($\beta = 0.306^{***}$) for high-leverage firms. Table 10, column 2 shows the impact of financial constraints on carbon emissions ($\beta = 0.274^{*}$). These results depict that

Table 10 Pooled OLS regression result: financial constraints and carbon emissions – High vs low leverage firms

Variables	*Carbon emissions* *High-leverage firms* *(1)*	*Carbon emissions* *Low-leverage firms* *(2)*
Financial constraints	0.306*** (0.075)	0.274* (0.131)
Board gender diversity	−0.001 (0.002)	0.004 (0.003)
Policy emissions reduction	1.039*** (0.102)	1.504*** (0.095)
Eco-innovation score	0.755*** (0.148)	0.307* (0.165)
Environmental expenditure investment	0.131 (0.128)	0.878*** (0.269)
Executive gender diversity	−0.005** (0.002)	−0.001 (0.004)
Human rights policy	0.024 (0.113)	−0.202*** (0.060)
Board size	0.206*** (0.042)	0.261*** (0.034)
Policy board diversity	0.004 (0.008)	−0.005 (0.008)
Independent board director	0.246 (0.647)	1.561*** (0.483)
Board−specific skills	−0.002 (0.004)	−0.010*** (0.003)
Return on asset	0.079 (0.091)	0.186*** (0.027)
Constant	8.739** (2.977)	2.442 (2.015)
Industry and year FE	Yes	Yes
Observations	753	783
R-squared	0.325	0.390
Adjusted *R*-squared	0.296	0.363

Notes: Standard errors are in parentheses; ***$p < 0.01$, **$p < 0.05$ and *$p < 0.1$
Source: Authors' own creation

financial constraints' impact on high-leverage firms' carbon emissions is more than that of financial constraints on carbon emissions from low-leverage firms. It means that when high-leverage firms face financial constraints, they are more prone to carbon emissions than low-leverage firms.

We grouped the firms into higher board gender diversity and low board gender diversity firms based on the median value of board gender diversity. A firm with a higher value of board gender diversity than the median is coded as 1 and considered a high board gender diversity firm and otherwise coded as 0 and considered a low board gender diversity firm. We separately regress equation (1) for subsamples of high and low board gender diversity firms. Results of Table 11 column 1 show the impact of financial constraints on carbon emissions ($\beta = -0.062$) for high board gender diversity firms, whereas Table 11 column 2 shows the impact of financial constraints on carbon emissions ($\beta = 0.435^{**}$). These results depict that the impact of financial constraints on carbon emissions from high-board gender diversity firms is negative and insignificant. In contrast, the impact of financial constraints on carbon emissions for low board gender diversity firms is positive and insignificant. It means that firms with lower board gender diversity face financial constraints, and they are more prone to the emissions of carbon relative to the firms with higher board gender diversity.

The baseline pooled regression model estimation supports our hypothesis. This study's results confirm that financial constraints impede firms from funding their projected investments and productivity (Lamont *et al.*, 2001; Jin *et al.*, 2019). Another plausible link that explains the adverse impact of financial constraints on carbon emissions in firm decisions concerning the trade-off between performance and tackling environmental issues. The extant literature supported this view and documented that businesses often scaled back environmental investments to safeguard their financial performance, potentially hindering effective pollution mitigation (Chan *et al.*, 2017; Zhang and Zheng, 2019). This view is further supplemented when the enforcement of regulatory measures becomes less stringent and when short-sighted executives prioritize immediate financial gains (Xu and Kim, 2022). When financing thresholds are high, firms trade off the environmental gains and allocate capital to production projects with short cycles, low investments and rapid results

Table 11 Pooled OLS regression result: financial constraints and carbon emissions (diverse gender board vs nongender diverse board)

Variables	*(1) Carbon emissions diverse gender board*	*(2) Carbon emissions Nondiverse gender board*
Financial constraints	−0.062 (0.142)	0.435*** (0.100)
Policy emissions reduction	1.330*** (0.246)	1.381*** (0.086)
Eco-innovation score	0.586*** (0.131)	0.364*** (0.078)
Environmental expenditure investment	0.243 (0.159)	0.687*** (0.189)
Executive gender diversity	0.008*** (0.003)	−0.009 (0.005)
Human rights policy	−0.320*** (0.068)	0.183 (0.145)
Board size	0.215*** (0.036)	0.193*** (0.046)
Policy board diversity	−0.007 (0.007)	0.008 (0.010)
Independent board director	1.058 (0.659)	0.697 (0.467)
Leverage	0.024 (0.042)	−0.034 (0.060)
Board-specific skills	−0.009** (0.003)	−0.007 (0.005)
Return on asset	0.059 (0.045)	0.265*** (0.060)
Constant	5.676* (0.335)	7.203** (0.301)
Industry and year FE	Yes	Yes
Observations	772	764
R-squared	0.323	0.396
Adjusted *R*-squared	0.293	0.369

Notes: Standard errors are presented in parentheses; ***$p < 0.01$; **$p < 0.05$ and *$p < 0.1$
Source: Authors' own creation

(Banerjee and Duflo, 2010). Therefore, financing constraints could hinder firms' ability to invest in technological innovations to reduce emissions.

The overall message derived from the empirical analyses suggests that financially constrained firms are more prone to carbon emissions regardless of their firm-level attributes. The findings further suggest that financially constrained firms without reported environmental investments or with high leverage show heightened sensitivity to carbon emissions in economic terms. Additionally, companies with gender-non-diverse boards exhibit a statistically significant link between financial constraints and carbon emissions. Nguyen and Phan (2020) noted that companies with high carbon costs are generally vulnerable to changes in carbon control regulations because of their high fixed costs. To reduce pollutants, these businesses may need to invest heavily in cleaner technologies that might go beyond their financial strength, resulting in them sticking to outdated, polluting production processes. This may discourage these companies from switching to carbon-efficient technologies or reducing their investment in carbon risk management. Firms operating in the high-emitting carbon industry may find it challenging to reduce carbon costs when required, particularly in financial distress. This may discourage these companies from switching to carbon-efficient technologies or reducing their investment in carbon emissions management, leading to high carbon emissions.

5. Conclusions and implications

In this study, we empirically examine the impact of financial constraints on carbon emission using a panel of 1,536 firm-year observations of US firms through baseline and subsample analyses. We used pooled ordinary least squares regression to estimate an empirical model. Potential endogeneity may affect causal interpretations of the relationships between financial constraints and carbon emissions in our empirical settings. Unobservable factors, for instance, may affect firms' carbon emissions, thereby producing spurious results. Our baseline regression is designed to account for the firm and industry effects as one potential source of endogeneity. Our results conclude that financial constraints enhance the carbon emissions of the firms. The economic significance of financial constraints on carbon emissions is more pronounced for the firms that do not report environment-related expenditure investment and those that are highly leveraged. We further document that firms with a nondiverse gender board signify a statistically significant impact of financial constraints on carbon emissions. These results are also economically significant, as one standard deviation increase in financial constraints is associated with a 3.340% increase in carbon emissions at the firm level. The subsample analyses show that financially constrained firms are more prone to carbon emissions across different firm-level attributes. The conclusions highlight the importance of firms meeting the expectations of their stakeholders by adjusting their actions and policies following the environmental trajectory (Liu and Anbumozhi, 2009; Chan *et al.*, 2014). A company's financial strategy should encompass nonfinancial stakeholders and shareholders (Titman, 1984). An effective financial strategy is necessary to give stakeholders confidence that resources are available for social goals (Cornell and Shapiro, 1987).

The results of this study have imperative managerial and policy implications for firms' management and policymakers. From a managerial point of view, a superior level and board array of stakeholder engagement must have substantial access to external finance. The findings highlight that having long-term value with the broad stakeholders, societal issues and priorities is critical. A solid engagement could help provide better access to external capital and enable resiliency during adverse shocks, thereby facilitating investments in EI for decarbonization. Managers could opt for effective mechanisms to avoid short-termism issues and align stakeholders' interests in the long term. This would, in turn, significantly assist firms in investing in environmental technologies. A holistic approach to evaluating and allocating resources to strike a balance between financial constraints and

environmental concerns. Within budget constraints, this might involve finding alternative funding sources, forming partnerships, or exploring innovative ways of reducing emissions. For policymakers, it is imperative to understand that financial flows should be aligned with low emissions for the Paris Agreement and the 2030 Agenda for Sustainable Development to succeed. Climate and investment policies that support rapid and far-reaching environmental transformations should be developed to mobilize finance away from emission-intensive projects. Within budget constraints, this might involve finding alternative funding sources, forming partnerships, or exploring innovative ways of reducing emissions. For policymakers, it is imperative to understand that financial flows should be aligned with low emissions for the Paris Agreement and the 2030 Agenda for Sustainable Development to succeed. Climate and investment policies that support rapid and far-reaching environmental transformations should be developed to mobilize finance away from emission-intensive projects.

5.1 Limitations and future research

As mentioned in the sample and data section, this study's carbon emission data coverage is limited until 2019 for the reasons explained in that section. Future research may involve a larger sample size from various geographical regions to broaden the study's scope beyond the USA. To gain a comprehensive global perspective on carbon disclosures, it is advisable to consider incorporating companies from various industries and countries, including those with varying degrees of environmental impact. A more nuanced assessment of how carbon emissions and mitigation efforts differ across different regions would increase the generalizability and robustness of the findings. Some implicit and explicit factors like corporate emissions policy and culture may condition the relationship of financial constraints with carbon emissions. Therefore, it would be worthwhile to consider these factors for future research. In addition, it is beneficial to identify the thresholds and/or quantiles at which financial constraints may significantly make a difference in enhancing carbon emissions. Therefore, future studies may consider the nonlinearities in the financial constraints and carbon emission link.

Notes

1 https://unfccc.int/process-and-meetings/the-paris-agreement

2 https://unfccc.int/sites/default/files/resource/cma2021_L16_adv.pdf

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Author affiliations

Ijaz Ur Rehman is based at the College of Business Administration, University of Sharjah, Sharjah, United Arab Emirates.

Faisal Shahzad is based at the Department of Management Sciences, COMSAT University Islamabad, Attock Campus, Attock, Pakistan.

Muhammad Abdullah Hanif is based at the Department of Management Sciences, COMSATS University Islamabad, Attock Campus, Islamabad, Pakistan.

Ameena Arshad is based at the Department of Management Sciences, COMSATS University Islamabad, Attock Campus, Attock, Pakistan.

Bruno S. Sergi is based at the Department of Economics, University of Messina, Messina, Italy and the Davis Center for Russian and Eurasian Studies and the Center for International Development at Harvard University, Cambridge, Massachusetts, USA.

Appendix

Table A1 Definition of variables

Carbon emissions	*Natural logarithm of carbon emissions*
Financial constraints	Financial constraints are measured by the SA index
Board gender diversity	Percentage of board members who are women
Policy emission reduction	Dummy variable, which is coded as 1 if the company has the policy to improve emissions reduction and 0, otherwise
Eco innovation score	Dummy variable, which is coded as 1 if the company has an Eco Innovation Score and 0, otherwise
Environmental expenditure investment	If the company reports on its environmental expenditure investment to minimize future risk or increase opportunities and 0 otherwise
Executive gender diversity	Percentage of female executive
Human rights policy	Dummy variable, which is coded as 1 if the company has the policy to ensure the respect of human rights and 0, otherwise
Board size	Number of directors on the board
Independent board director	Percentage of independent director
Leverage	Total debt to total assets
Board-specific skills	Percentage of the board member who has either an industry-specific background or a solid financial background
Policy board diversity	If a company have a policy on the induction of female on board
Return on asset	Profit to total assets

Source: Authors' compilation

Corresponding author

Bruno S. Sergi can be contacted at: bsergi@fas.harvard.edu