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Board Gender Diversity and Carbon Trade Finance: Evidence From Multinational Corporations on the Role of Institutional Quality and Cultural Environment

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ABSTRACT

This study investigates whether board gender diversity influences carbon trade finance and ultimately achieves decarbonisation targets. Using a dataset of 5198 firm-year observations from 336 multinational corporations (MNCs) spanning 42 industries and 32 countries over the period 2006–2022, we employ panel regression analysis to uncover key insights. Our findings reveal that although board gender diversity is positively associated with carbon trade finance, a critical mass of at least four female board directors is necessary to exert significant influence. Our results highlight the critical role of institutional factors, such as high control of corruption, strong voice and accountability, government effectiveness and a strong rule of law, in enhancing the impact of board gender diversity on carbon trade finance. Additionally, cultural environments play a pivotal role in shaping the relationship between board gender diversity and carbon trade finance. Our main conclusions are robust across alternative measures and validated using two-stage least squares and propensity score matching techniques. We contribute to the literature on board gender diversity and carbon trade finance by empirically demonstrating the role of (in)formal institutional factors that influence the effectiveness of female directors in achieving sustainability outcomes. The findings offer valuable policy and practical implications for managers, regulators and stakeholders, shedding light on the interplay among board gender diversity, carbon emissions management, and the governance and cultural contexts at the country level.

1 | Introduction

The United Nations (UN) sustainable development agenda implores multinational corporations (MNCs) as primary stakeholders to improve carbon emissions management by implementing decarbonisation strategies across their business operations (Acquaye et al. 2014; Beelitz and Merkl-Davies 2019; Moses and Tauringana 2022). Against this backdrop, there have been calls to investigate business models and strategies that companies can develop to effectively incorporate carbon finance and sustainable product innovations into their business processes and supply chain management practices (e.g.,

An et al. 2021; Cong, Pang, and Peng 2020; Cui, Wang, and Wang 2020; Elias et al. 2024; Linnenluecke and Griffiths 2013; Maddikunta et al. 2022). Achieving decarbonisation¹ through carbon trade finance presents unique opportunities for MNCs to practically commit to climate actions (SDG13) and address climate change concerns (Donkor, Papadopoulos, and Spiegler 2024; Ehalaiye et al. 2024; Mora et al. 2024; Tiwari et al. 2024). Carbon trade finance (also known as ‘emissions trade finance’) could take the form of carbon trading and carbon offsets. Carbon trading involves the buying and selling of credits that permit a company or other entity to emit a certain amount of carbon dioxide or other GHGs (An et al. 2021).

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Carbon trading curbs climate change by creating a market with limited allowances for emissions whilst also accelerating investments into low-carbon sources of energy (Balci and Ali 2024; Fu, Chen, and Ding 2023; Shen et al. 2017). Carbon trade finance in the form of carbon offsetting enables MNCs to compensate for emissions by funding an equivalent carbon dioxide saving elsewhere or investing in projects that cause emissions to be reduced somewhere else in the world.²

Undoubtedly, carbon financing can incentivise companies to decarbonise by investing in cleaner technologies, such as alternative energy sources based on green electricity, thereby enhancing their environmental sustainability practices (An et al. 2021; Cui, Wang, and Wang 2020; Luo and Tang 2021). Given that such opportunities are extended to organisations within a business entity's supply chain (He, Wang, and Liu 2024; Pessot, Zangiacomi, and Fornasiero 2024), it is plausible that carbon finance can lead to a more resilient supply chain by reducing the risks of climate-related disruptions and enhancing the company's reputation among environmentally conscious consumers (Elias et al. 2024; Kang et al. 2019; Montoya-Torres, Gutierrez-Franco, and Blanco 2015). One mechanism for self-regulation that could potentially enhance carbon trade finance and decarbonisation is corporate governance (Alfi, Mohamad, and Hussainey 2024; Birkey et al. 2016; Elamer et al. 2019). Specifically, board diversity, through the inclusion of more female directors (i.e., board gender diversity), has been identified as a corporate governance mechanism that can improve board performance in achieving corporate decarbonisation targets (Chijoke-Mgbame, Boateng, and Mgbame 2020; Elsayih, Datt, and Tang 2021; Konadu et al. 2021).

Although prior empirical insights suggest that board gender diversity contributes to carbon emissions performance and environmental practices (e.g., Elsayih, Datt, and Tang 2021; Konadu et al. 2021; Nadeem et al. 2020; Tingbani et al. 2020), there remains inconclusiveness in these findings, which the current study seeks to address. First, although the relevance of board gender diversity in enhancing carbon emissions management is well acknowledged, few studies have focused on its impact on carbon trade finance. Most research has predominantly examined the relationship between board gender diversity and carbon emissions disclosure (e.g., Hollindale, Kent, and Routledge 2017; Liao, Luo, and Tang 2015; Tingbani et al. 2020) and the influence of gender diversity on environmental sustainability practices (e.g., Agyemang, Yusheng, and Ayamba 2020; Nadeem et al. 2020; Nuskiya et al. 2021). However, there is a lack of empirical evidence on the influence of board gender diversity on carbon trade finance. Given that companies often struggle to accurately measure and report their Scope 3 supply chain carbon emissions (Vickers et al. 2009), carbon offsetting as a form of carbon trade finance provides a mechanism to reduce emissions in an economic and cost-effective manner. Considering that carbon trade finance plays an important role in combating climate change, assessing the impact of governance mechanisms, such as board gender diversity, on carbon trade finance is crucial for addressing the challenges posed by climate change.

Second, the role of institutional mechanisms in influencing the link between board gender diversity and carbon trade finance

remains significantly underexamined. Consequently, our understanding of how the elements of institutional quality enhance or hinder the effectiveness of gender diversity on boards in achieving emissions reductions through carbon trade finance is limited. Prior studies focusing on board gender diversity and carbon emissions performance have primarily centred on single jurisdictions and covered limited time frames (e.g., Elsayih, Datt, and Tang 2021; Nuber and Velte 2021), without considering the impact of institutional quality in an international setting. For instance, Elsayih, Datt, and Tang's (2021) research on Australian firms' participation in the Carbon Disclosure Project utilised 425 firm-year observations but lacked an international perspective. Similarly, Konadu et al.'s (2021) study of 251 US companies listed on the S&P 500 index spanned from 2002 to 2018, comprising 2026 firm-year observations. Tingbani et al.'s (2020) research focused on 215 nonfinancial UK firms listed on the LSE, based on 860 firm-year observations. Although Moussa et al.'s (2020) study examined gender diversity's impact on carbon emissions reduction in US firms, Nuber and Velte's (2021) research targeted nonfinancial firms in the STOXX Europe 600 index over the period 2009–2018, with 3123 firm-year observations. The unaddressed empirical issues in the extant literature have spurred calls for more international studies, especially within institutional quality contexts (Vickers et al. 2009). Analysing the moderating influence of institutional quality on the relationship between board gender diversity and carbon trade finance is vital for formulating pertinent policies to tackle the challenges of engaging in carbon markets and securing financing opportunities (Bui, Moses, and Houqe 2020; Ehalaiye et al. 2024; Fu, Chen, and Ding 2023; Xu et al. 2023).

Third, the cultural environment may affect the success of female directors in achieving environmental sustainability outcomes (Griffin et al. 2021; Gyapong and Afrifa 2021). However, knowledge of the impact of cultural orientation on the association between board gender diversity and carbon trade finance is limited. Meanwhile, the cultural environment is a key consideration on issues such as carbon trade finance, which requires voluntary participation at the ethical and philanthropic rung of the CSR pyramid. Carbon trade finance decisions, which require MNCs to balance out their carbon footprints by helping to pay for emission savings in other parts of the world, may be shaped by the cultural environment where MNCs operate. Limited studies on board gender diversity and carbon emissions reduction have focused on emissions directly traceable to organisations (i.e., Scope 1 and Scope 2 emissions) but not on how cultural settings affect the decisions/commitment of MNCs to fund an equivalent carbon dioxide saving elsewhere (Elsayih, Datt, and Tang 2021; Konadu et al. 2021; Nuber and Velte 2021). Examining the impact of culture in an international setting may provide a more nuanced analysis and better understanding of the relationship between board gender diversity and carbon trade finance. This underscores the need for deeper empirical investigation into the relevance of cultural environment in strategies for decarbonisation (Elias et al. 2024; He, Tang, and Wang 2013).

In this study, we investigate whether board gender diversity is an effective strategy for improving carbon trade finance and ultimately achieving decarbonisation targets. Specifically, our study's objectives are linked to three interrelated issues: (i) whether board gender diversity influences firms' carbon

trade finance practices; (ii) the moderating effect of institutional quality on the association between board gender diversity and carbon trade finance; and (iii) the influence of cultural environment on the relationship between board gender diversity and carbon trade finance. To assess these relationships, we rely on legitimacy, gender socialisation, critical mass and institutional theories. According to legitimacy theory (Archel et al. 2009; Mahadeo, Oogarah-Hanuman, and Soobaroyen 2011), firms facing increased stakeholder demands for environmental accountability are more likely to establish gender-diverse boards to protect their legitimacy (Bui, Moses, and Houqe 2020; Ehalaiye et al. 2024). Consistent with gender socialisation theory, female board directors, who are sensitive to societal issues and possess stronger ethical orientations, can contribute to enhanced corporate sustainability (Ben-Amar, Chang, and McIlkenny 2017; Eagly and Crowley 1986; Liao, Luo, and Tang 2015). Nevertheless, the number of female board directors must reach a sufficient threshold before board gender diversity can generate positive outcomes, according to the critical mass viewpoint (Al-Shaer, Zaman, and Albitar 2024; Grzelec 2024).³ From the institutional theory perspective, formal and informal institutional factors influence the relationship between board gender diversity and environmental sustainability (DiMaggio and Powell 1991; Saqib, Allen, and Wood 2021).

Using a panel regression analysis, we analyse a sample of 5198 firm-year observations from 336 MNCs over the 2006–2022 period across 42 industries and 32 countries. Our empirical results, based on the analysis of top nonfinancial MNCs, reveal that board gender diversity is positively associated with carbon trade finance. However, a critical mass of at least four female directors is required to influence MNCs to commit to carbon trade finance. Our results support the proposition that institutional quality significantly moderates the relationship between board gender diversity and carbon trade finance. Specifically, institutional quality mechanisms, such as high control of corruption, strong voice and accountability, government effectiveness and a robust rule of law, significantly enhance the impact of board gender diversity in promoting carbon emissions finance. The findings also confirm that the cultural environment influences the relationship between board gender diversity and carbon trade finance. Female directors are more effective in achieving carbon trade finance goals in cultural environments characterised by high uncertainty avoidance and long-term orientation. Overall, our paper provides empirical evidence that board gender diversity is an effective strategy for enhancing carbon trade finance, and cultural and institutional factors may affect the effectiveness of female directors in achieving environmental sustainability outcomes.

Our study contributes to knowledge in several significant ways. Firstly, it expands the limited literature on the impact of board gender diversity on carbon trade finance, responding to the need for more investigation into carbon accounting in this area. Secondly, it elucidates the moderating role of institutional mechanisms in the nexus between board gender diversity and carbon trade finance. Thirdly, it exposes the relevance of the cultural environment in shaping the influence of board gender diversity on carbon trade finance. Finally, it analyses a sample of top MNCs, encompassing 336 firms from 42 industries and 32

countries, over a 17-year period (2006–2022), thereby providing valuable insights to supplement the limited international understanding of the association between board gender diversity and carbon emissions performance.

The remainder of the paper is structured into five parts. Section 2 presents the literature review and hypotheses development. The methodology is discussed in Section 3. Sections 4 and 5 present our empirical results and robustness tests, respectively. Finally, Section 6 provides our conclusions.

2 | Literature Review and Hypotheses Development

2.1 | Theoretical Framework

We employ a combination of legitimacy, gender socialisation, critical mass and institutional theories to explore the relationship between board gender diversity and carbon trade finance and test the moderating impacts of culture and institutional quality. Legitimacy theory posits that organisations operate within acceptable societal boundaries (Archel et al. 2009; Mahadeo, Oogarah-Hanuman, and Soobaroyen 2011), continuously striving to (re)gain their social licence to operate (Ehalaiye et al. 2024; Orazalin, Ntim, and Malagila 2024). In this context, organisations are engaged in a social contract with society, which is expected to be reflected in their institutional culture and values. Society provides economic resources, enabling the environment upon which businesses thrive. In return, organisations reciprocate by conducting their business in a manner that aligns with societal values and norms (Deegan 2019). Thus, organisations have a responsibility to demonstrate compliance with societal values to maintain their legitimacy and continue to be granted their social licence to operate (Bui, Moses, and Houqe 2020; Ehalaiye et al. 2024; Mahadeo, Oogarah-Hanuman, and Soobaroyen 2011).

Achieving decarbonisation ambitions through carbon trade finance has been noted as one way organisations can gain stakeholder acceptance on mainstream sustainability issues and an avenue to legitimise their existence. Building on this ambition and the intuition that women are arguably more compassionate and caring (Ferry 2024), a corpus of studies has linked board gender diversity to improved environmental performance (García Martín and Herrero 2020; Haque 2017; Nadeem et al. 2020). Furthermore, board gender diversity arguably provides advantages that could enhance corporate reputation (Houqe et al. 2024), collectively leading to improved performance and encouraging firms to actively recruit more female directors. Board diversity with more women creates opportunities for enhanced sustainability performance (Bui, Moses, and Houqe 2020; Ferry 2024) and improved stakeholder acceptance (Ehalaiye et al. 2024; Mahadeo, Oogarah-Hanuman, and Soobaroyen 2011), ultimately leading to better overall performance. Indeed, critical stakeholders are likely to perceive investments in carbon trade finance and improved carbon performance, driven by active gender diversity strategies, as a commitment to the social contract embedded in the ethics of legitimacy theory (Bui, Moses, and Houqe 2020; Ehalaiye et al. 2024).

Although legitimacy theory explains firms' rationale for recruiting more female directors to protect their legitimacy, gender socialisation theory suggests that men and women have different behaviours, values and attitudes towards societal issues due to their social interactions and the influence of gender roles (Eagly and Crowley 1986). Compared to their male counterparts, women are more likely to focus on communal issues, possess stronger ethical orientations and show greater compassion towards others (Carlson 1972; Ibrahim, Angelidis, and Tomic 2009). In line with this viewpoint, relevant studies document that boards with more female directors tend to increase environmental transparency and enhance sustainability performance (Ben-Amar, Chang, and McIlkenny 2017; Liao, Luo, and Tang 2015). Female board directors are associated with formulating environmental strategies, implementing green initiatives and complying with climate regulations (Atif et al. 2021; Nuber and Velte 2021; Usman et al. 2022). Based on these diverse perspectives, corporate boards with higher gender diversity tend to undertake proactive environmental actions, influence managerial decisions related to climate mitigation and mitigate environmental issues. Therefore, consistent with gender socialisation theory, it is expected that female board directors, who are sensitive to climate issues, can contribute to improved carbon emissions trading, thus achieving decarbonisation targets.

Critical mass theory posits that the number of female directors must reach a reasonable threshold before board gender diversity can achieve positive outcomes (Al-Shaer, Zaman, and Albitar 2024; Grzelec 2024). Critical mass theory traces its roots to the concept of critical mass in relation to the adoption of innovation or technology (Oliver, Marwell, and Teixeira 1985). The foundational arguments suggest that when a new idea is introduced and adopted by enough people, the rate of adoption becomes self-sustaining, driving organic growth. The point at which an innovation reaches critical mass is known as the 'threshold' in the context of the threshold model in statistical modelling (Mahakittikun, Suntrayuth, and Bhatiasavi 2021).

Critical mass theory thrives on the principle of strength in numbers. Here, a large proportion of adopters of an innovation or idea (i.e., critical mass) can bring about desired change due to the influence they wield or the attention they command. Adopters must be numerous enough to accomplish social change (You 2021). In the context of our study, when there is a reasonable or sizable number of female directors constituting a critical mass, the potential for significant change becomes apparent due to this strength in numbers (Al-Shaer, Zaman, and Albitar 2024; Birindelli, Chiappini, and Savioli 2020; Chijoke-Mgbame, Boateng, and Mgbame 2020). Given their arguable tendencies towards socialisation and compassion, female board directors can significantly influence environmental policies, leading to decarbonisation actions to reduce environmental pollution and minimise social and environmental threats (Oradi and E-Vahdati 2021).

Institutional theory explains how formal and informal institutional factors shape the impact of board gender diversity on carbon trade finance (DiMaggio and Powell 1991; Saqib, Allen, and Wood 2021). Institutions constitute a

country's political, socio-cultural, legal and economic system (Dobler 2011). According to North (1990), institutions provide the rules of the game in a society, shaping economic performance by reducing uncertainty and providing a stable structure for human interaction. Scott's (2013) institutional theory suggests that organisations conform to the norms, values and rules of their institutional environment to gain legitimacy, resources and survival. Institutions may be formal or informal. Although formal institutions are typically controlled by written rules, regulations, binding laws and legal orders (DiMaggio and Powell 1991), informal institutions are governed by socially shared rules in the society, created and enforced outside of formal or official channels. Unwritten, informal institutional factors typically include social norms, values, customs and cultural habits (Dobler 2011). Informal institutions shape a societal value system and affect policy outcomes. In the context of the current study, formal and informal/cultural factors may affect the effectiveness of female directors in achieving environmental outcomes.

2.2 | Board Gender Diversity and Carbon Trade Finance

Carbon trade finance involves the buying and selling of credits that permit a company or other entity to emit a certain amount of GHG emissions (An et al. 2021; Huang et al. 2023). Governments authorise carbon credits and carbon trading with the goal of gradually reducing overall carbon emissions and mitigating the consequences of climate change (Bredin, Hyde, and Muckley 2014). Building on the arguments that firms are likely to form gender-diverse boards to protect legitimacy (as suggested by legitimacy theory) and that female board directors tend to pursue eco-friendly initiatives (as suggested by gender socialisation theory), along with empirical studies (Konadu et al. 2021; Nuber and Velte 2021), the presence of female directors on corporate boards is expected to promote and support the financing of projects aimed at reducing emissions (i.e., decarbonisation strategy). In line with critical mass theory, highly gender-diverse boards with a sufficient number of women may enhance female directors' decision-making in reducing carbon emissions (Bui, Moses, and Houque 2020; Ferry 2024), such as setting emissions reduction targets, financing emissions reduction projects and incentivising suppliers to reduce emissions. Consequently, gender-diverse boards may promote carbon trade financing initiatives and achieve better carbon performance compared to less gender-diverse boards with fewer female representatives (Ferry 2024; Konadu et al. 2021; Nuber and Velte 2021).

Studies show that board gender diversity contributes to carbon performance and overall environmental practices (e.g., Elsayih, Datt, and Tang 2021; Konadu et al. 2021; Nadeem et al. 2020; Oyewo 2023; Tingbani et al. 2020). Konadu et al.'s (2021) examination of companies listed on the S&P 500 index from 2002 to 2018, covering 251 firms, reports that board gender diversity contributes to carbon emissions reduction. This implies that gender-diverse boards can achieve better carbon emissions management through investments in carbon reduction initiatives. Nadeem et al. (2020) document evidence linking board gender diversity to environmental innovation in the case of US-listed firms. Similarly, Tingbani

et al. (2020) conclude from their investigation of 215 listed firms on the London Stock Exchange from 2011 to 2014 that board gender diversity is positively associated with initiatives aimed at reducing GHG emissions. Oyewo (2023) finds from the study of top multinational entities covering a 15-year period (2006–2020) that board gender diversity has a significant positive impact on carbon performance. Based on the above discussion, we make our first supposition.

Hypothesis 1. *Board gender diversity is positively associated with carbon trade finance of MNCs, all else unchanged.*

2.3 | Moderating Influence of Institutional Quality on the Association Between Board Gender Diversity and Carbon Trade Finance

A growing number of studies have suggested that the presence of women on the board of directors leads to improved environmental performance (García Martín and Herrero 2020; Haque 2017; Kassinis et al. 2016). This stems partly from the argument that female directors pay closer attention to environmental issues, such as climate change (Ben-Amar, Chang, and McIlkenny 2017; Liao, Luo, and Tang 2015; Konadu 2017), which in turn motivates them to act and/or influence organisational decisions on decarbonisation. However, as suggested by institutional theory, the effectiveness of female directors in achieving emissions reduction through carbon trade finance may be affected by institutional factors, such as control of corruption, voice and accountability, political stability, government effectiveness, regulatory quality and rule of law (Cheng, Ioannou, and Serafeim 2014; North 1990).

Female directors may be more effective in pursuing a carbon trade finance agenda in jurisdictions with strong regulations on environmental protection, high control of corrupt environmental practices and government commitment to net zero because the institutional setting naturally discourages environmental pollution (Lewis, Cardy, and Huang 2019; Oyewo et al. 2024). In high-quality institutional settings, firms are naturally driven to adopt sustainable practices to comply with regulatory standards and meet stakeholder expectations. An effective legal system implies that legal sanctions and prosecutions will deter environmental polluters from unrestrained carbon emissions. Jurisdictions that hold MNCs responsible for their carbon footprints through strong voice, accountability and campaigns for firms' environmental impact could provide the leverage female directors need to advocate for carbon trade finance. On the other hand, the presence of strong institutional factors implies that female directors on corporate boards may not be required before MNCs commit to addressing carbon emissions using various strategies, compared to weak institutional settings (Ortas et al. 2015).

In essence, the institutional mechanisms ordinarily checkmate MNCs to behave in an environmentally friendly manner, as non-compliance will have repercussions that typical organisations may want to avoid (Ioannou and Serafeim 2015). Therefore, the presence of female directors may not be effective in delivering decarbonisation targets such as carbon trade finance. Hence, we propose that the institutional environment will arguably

influence the effectiveness of female directors, informing our next hypothesis.

Hypothesis 2. *Institutional quality significantly moderates the relationship between board gender diversity and carbon trade finance.*

2.4 | Moderating Influence of Cultural Environment on the Association Between Board Gender Diversity and Carbon Trade Finance

Literature suggests that women are eco-friendly, and the inclusion of more females on the board of directors can constitute a 'critical mass' in exerting considerable influence on the environmental practice of an organisation (Hollindale, Kent, and Routledge 2017; Nuber and Velte 2021), thereby leading to better carbon emissions management. However, the cultural environment may affect the effectiveness of female directors (Gyapong and Afrifa 2021; Hofstede 1994) according to the institutional theory. Cultural settings embracing sustainable environmental practices can boost the performance of female directors in achieving carbon reduction targets such as carbon trade finance, whereas a cultural environment with less focus on sustainability initiatives may diminish the effectiveness of female directors (Griffin et al. 2021). In this regard, relying on Hofstede's cultural dimensions (Hofstede 2011), cultural settings with high uncertainty avoidance, long-term orientation, restraint, femininity and collectivist orientation may embrace eco-friendly initiatives, and female directors may be more effective in achieving emissions reduction targets through carbon trade finance in such settings (Wang, Guo, and Tang 2021). Female directors may be less effective in environments with low uncertainty avoidance, short-term orientation, restraint, masculine-based and individualist cultural environments (Dobler 2011).

Conversely, minimal intervention of female directors may be required in high uncertainty avoidance, long-term orientation, restraint, femininity and collectivist cultural settings, given that such environments naturally embrace eco-friendly practices (Naghavi, Pahlevan Sharif, and Iqbal Hussain 2021). However, because cultural environments are informal institutional factors shaping behaviour as suggested by the institutional theory, we suppose that cultural orientation will have an influence on the effectiveness of female directors (Gyapong and Afrifa 2021; Naghavi, Pahlevan Sharif, and Iqbal Hussain 2021), underpinning our hypothesis that:

Hypothesis 3. *Cultural environment significantly moderates the relationship between board gender diversity and carbon trade finance.*

3 | Method and Design

3.1 | Research Strategy

We employ a quantitative method to evaluate the relationship between board gender diversity, carbon trade finance, and the moderating impact of formal and informal (cultural) institutional mechanisms. As applied in the current study, legitimacy,

gender socialisation and critical mass theories underpin the positive impact of board gender diversity on carbon trade finance in Hypothesis 1. The institutional theory provides the basis for assessing the moderating impacts of culture and institutional quality on the association between board gender diversity and carbon trade finance in Hypotheses 2 and 3. Thus, a deductive approach is employed in testing the hypothesised relationships in Hypotheses 1–3. The study adopts a longitudinal research design, analysing panel data across the Millennium Development Goals (MDGs) era (2006–2015) and the Sustainable Development Goals (SDGs) era (2016–2022), totalling a 17-year investigation timeline for the sampled MNCs. The sampling period extends up to 2022 as data for carbon trade finance after 2022 were not available for many companies at the time of the study. Focusing on the 17-year period (2006–2022) helps overcome the challenge of missing data, providing a long-term perspective on the subject.

Top companies from the 2024 Forbes list were used as the sampling frame, following prior studies (Ngu and Amran 2019). However, this study focuses on the top 500 companies on the list, excluding financial companies. We exclude financial companies because their nature of business and leverage are notably different from firms in other industries (Tingbani et al. 2020). They are also subject to different regulations. Our analysis revealed 160 financial companies and 4 nonfinancial companies with no sustainability report in the Refinitiv (now LSEG) database. After excluding these 164 nonqualifying companies, the final sample comprises 336 unique nonfinancial companies (Appendices A and B). Firm-level data on carbon trade finance, corporate governance and firm characteristics were obtained from the Refinitiv database. Country-level data on economic development and Worldwide Governance Indicators were gathered from the World Bank database, and data on cultural orientation/environment were sourced from Hofstede Insights. After merging data from these sources, the final sample comprises 5198 firm-year observations.

3.2 | Dependent Variable

3.2.1 | Main Dependent Variable

Our main dependent variable, carbon trade finance, is measured as the volume of carbon offsets and credits in metric tonnes (Wang, Zhao, and Herty 2018). Carbon offsets and credits refer to CO₂ offsets, credits and allowances in metric tonnes purchased and/or produced by the company in an accounting year. Companies within carbon-intensive sectors have emission limits, which, if exceeded, require them to purchase credits to balance it, and if below the limits, they can sell the remainder of the allowance (Huang et al. 2023). Therefore, the amount of carbon offsets and credits provides a strong indicator of an organisation's commitment to financing their emissions.

The volume of carbon offsets and credits (measured in tonnes) was taken from the Refinitiv (LSEG) database. Here, only carbon credits purchased and produced are considered: Investments in wind farms and planting trees from which the company claims to offset carbon emissions are also in scope. To normalise the variable, the logarithm transformation was obtained and used in the analysis. The variable (i.e., carbon

offsets and credits) has a positive polarity, meaning that a higher volume of carbon offsets and credits indicates a higher commitment to carbon trade financing and a strong signal of decarbonisation efforts.

3.2.2 | Alternative Measurement of the Dependent Variable

We use two alternative measurements for the dependent variable: (a) participation in carbon emissions trading and (b) supply chain emissions reduction finance.

- a. Participation in carbon emissions trading: Emissions trading (cap and trade) is a market-based approach used to control pollution by providing economic incentives for reducing pollutant emissions (Fu, Chen, and Ding 2023). If a company participates in the emissions trading scheme, a code of 1 is assigned; otherwise, 0 is assigned. If a company claims future participation in an emissions trading scheme, it is graded as false and assigned a 0 (Fu, Chen, and Ding 2023).
- b. Supply chain emissions reduction finance: Given that Scope 3 emissions often comprise the largest portion of an organisation's total emissions (Deloitte 2022; World Resources Institute 2022), reducing Scope 3 emissions by providing decarbonisation financial incentives to firms within an organisation's supply chain is a significant effort in reducing GHG emissions globally. If a firm provides financial incentives to organisations in their supply chain to reduce carbon emissions, a code of 1 is assigned; otherwise, 0 is assigned (Wang, Zhao, and Herty 2018).

3.3 | Independent Variable

Gender board diversity, as the main independent variable, was measured using the ratio of female directors to total board size (Nadeem et al. 2020; Nuber and Velte 2021; Tingbani et al. 2020). For robustness and to test the critical mass theory, we use a binary grouping of board gender diversity, following prior studies (Konadu et al. 2021; Nuber and Velte 2021):

- i. Tokenism of one female director: coded as 1 if there is only one female director and 0 otherwise.
- ii. Critical mass of two female directors: coded as 1 if there are two female directors and 0 otherwise.
- iii. Critical mass of three female directors: coded as 1 if there are three female directors and 0 otherwise.
- iv. Critical mass of four female directors: coded as 1 if there are four female directors and 0 otherwise.

3.4 | Moderating Variables

To evaluate the moderating impact of institutional factors and national culture, we conduct a moderation analysis. We use the Worldwide Governance Indicators to operationalise institutional quality (Cuadrado-Ballesteros and Bisogno 2020; Oyewo

et al. 2024). Applying a 70% threshold, we classify countries into two groups: those with high institutional quality (scores of 70 and above) and those with low institutional quality (scores below 70) across six elements of institutional quality: (i) control of corruption, (ii) voice and accountability, (iii) political stability, (iv) government effectiveness, (v) regulatory quality and (vi) rule of law.

We rely on Hofstede's six cultural dimensions to assess the cultural environment (Hofstede 2011). Each of these dimensions is measured on a scale from 1 to 100, representing the degree to which a particular cultural characteristic is present in the society. The six dimensions are as follows:

1. **Uncertainty avoidance**—reflects how a society perceives uncertainty about the future and the actions taken to mitigate its effects. Societies scoring high on uncertainty avoidance (closer to 100) tend to implement measures to control or reduce ambiguity, indicating a strong desire for predictability. Conversely, societies with low scores demonstrate low uncertainty avoidance, tolerating ambiguity and taking fewer actions to address uncertain situations.
2. **Power distance**—measures a society's acceptance of hierarchical inequality. A higher score signifies a society that accepts unequal power distribution and authority gaps as a natural part of life (high-power distance), whereas lower scores reflect societies with a preference for equality and minimising hierarchical differences (low-power distance).
3. **Short-term versus long-term orientation**—addresses how societies manage the balance between their historical roots and future challenges. Societies with low scores tend to focus on immediate issues, displaying short-term orientation, whereas higher scores reflect a long-term orientation, where present efforts are directed towards future outcomes.
4. **Indulgence versus restraint**—assesses how societies regulate desires and impulses. High scores indicate indulgence, where individuals exhibit relatively weaker control over their desires and a tendency towards seeking gratification. Lower scores reflect restraint, where strict social norms limit indulgence, leading to stronger regulation of impulses.
5. **Masculinity versus femininity**—captures the societal preference for traditionally masculine values, such as competition, achievement and success. A higher score indicates a masculine orientation, where societies are driven by success and competitive values. Lower scores reflect a feminine orientation, where the quality of life and nurturing are prioritised over competition and achievement.
6. **Individualism versus collectivism**—measures the extent to which people in a society prioritise personal independence versus group loyalty. High scores reflect individualism, where people tend to focus on personal goals and self-reliance. In contrast, low scores signify collectivism, where loyalty to a group and social cohesion are emphasised.

For our study, we categorise countries into binary groups based on these dimensions, using 51 as the median threshold (Gyapong and Afrifa 2021; Hofstede 2011). Each dimension is classified as follows:

1. **Uncertainty avoidance**: Scores below 51 (0–50) are categorised as low uncertainty avoidance (assigned 0), and scores of 51–100 are classified as high uncertainty avoidance (assigned 1).
2. **Power distance**: Scores below 51 (0–50) are categorised as low-power distance (assigned 0), and scores of 51–100 are classified as high-power distance (assigned 1).
3. **Short-term versus long-term orientation**: Scores of 0–50 indicate short-term orientation (assigned 0), whereas scores of 51–100 indicate long-term orientation (assigned 1).
4. **Indulgence versus restraint**: Scores of 0–50 reflect restraint (assigned 0), whereas scores of 51–100 reflect indulgence (assigned 1).
5. **Masculinity versus femininity**: Scores of 0–50 indicate femininity (assigned 0), and scores of 51–100 indicate masculinity (assigned 1).
6. **Individualism versus collectivism**: Scores of 0–50 reflect collectivism (assigned 0), whereas scores of 51–100 reflect individualism (assigned 1).

3.5 | Control Variables

Five corporate governance factors that have been documented in literature as determinants of carbon emissions management were included as firm-level governance control variables: board meeting, board independence, CEO duality, ESG-based compensation and ESG committee (El Saleh and Jurdi 2023; Elsayih, Datt, and Tang 2021; Liao, Luo, and Tang 2015). In line with prior studies, four firm attributes linked to environmental practices were included as control variables, such as firm size, market presence, liquidity and profitability (Doni, Corvino, and Martini 2021; Song and Rimmel 2021; Tingbani et al. 2020). Owing to the international nature of the sample selection for the study spanning various countries, country-level governance factors, such as economic development and Worldwide Governance Indicators, were included as control variables (Nuber and Velte 2021; Orazalin, Ntim, and Malagila 2024). We take measurements of Worldwide Governance Indicators from the World Bank database. To avoid multicollinearity, a factor analysis score of the six Worldwide Governance Indicators was utilised (Cuadrado-Ballesteros and Bisogno 2020). The result in Appendix B shows that the Kaiser–Meyer–Olkin (KMO) coefficient of 0.888 (above a 0.50 threshold) and significant *p* value of Bartlett's test of sphericity ($p < 0.05$) confirm the suitability of our data for factor analysis. Moreover, Component 1 explains 78.164% of variances (Table A1d). The six indicators loaded strongly on Component 1 above a 0.70 threshold (Table A1a). Thus, we retain the six indicators in our analysis.

A summary of all variables and their measurements is provided in Table 1.

TABLE 1 | Measurement of variables.

Variables	Measurement
Emissions trade finance	<p>Main measurement: Carbon offsets/credits measured as the log of the volume of carbon offsets and credits procured by a firm in metric tonnes (Huang et al. 2023; Wang, Zhao, and Herty 2018). The more the number of emissions offsets purchased (in tonnes), the better carbon emissions performance. Considering that emissions trade finance can help limit emissions, emissions trade finance has a positive polarity, implying that higher emissions trade finance implies better carbon emissions performance.</p> <p>Alternative measurement:</p> <p>a. Participation in carbon emissions trading: If a company participates in the emissions trading scheme, a code of 1 is assigned; otherwise, it takes a value of 0 (Fu, Chen, and Ding 2023).</p> <p>b. Supply chain emissions reduction finance: If a firm provides financial incentives for organisations in their supply chain to reduce carbon emissions, a code of 1 is assigned; otherwise, 0 is assigned (Wang, Zhao, and Herty 2018).</p>
Board gender diversity	<p>Ratio of total female directors to the total number of directors on the board per annum (Tingbani et al. 2020).</p> <p>Alternative measurement using binary grouping of board gender diversity (Konadu et al. 2021; Nuber and Velte 2021) as follows:</p> <p>i. Tokenism of one female director: takes a dummy value of 1 if there is only one female director and 0 otherwise.</p> <p>ii. Critical mass of two female directors: takes a dummy value of 1 if there are only two female directors and 0 otherwise.</p> <p>iii. Critical mass of three female directors: takes a dummy value of 1 if there are only three female directors and 0 otherwise.</p> <p>iv. Critical mass of four female directors: takes a dummy value of 1 if there are only four female directors and 0 otherwise.</p> <p>v. Critical mass of five female directors: takes a dummy value of 1 if there are only four female directors, and 0 otherwise.</p>
Board meeting	Number of board meetings per annum (Disli, Yilmaz, and Mohamed 2022).
Board independence	Number of outside directors to the total number of directors on the board (Elsayih, Datt, and Tang 2021).
CEO duality	Takes a dichotomous value of 1 if chairman and CEO roles are combined, otherwise takes a value of 0 (Nuskiya et al. 2021).
ESG-based compensation	Takes a dichotomous value of 1 if executive board members compensation is based on environmental performance, otherwise takes a value of 0 (Lu and Wang 2021).
ESG committee	Takes a dichotomous value of 1 if there is an existence of environmental committee, otherwise takes a value of 0 (Elsayih, Datt, and Tang 2021).
Firm size	Log of firm revenue (Ahmad and Zabri 2015; Peel 2018).
Firm market presence	Log of market capitalisation, logarithmic transformation (Elsayih, Datt, and Tang 2021).
Firm liquidity	Current assets to current liabilities ratio (Tingbani et al. 2020).
Firm profitability	Net income to total assets ratio (Song and Rimmel 2021).
MDGs/SDGs era	Takes a dichotomous value of 0 if the year 2006 to 2015 as MDGs era and a value of 1 if the year 2016 to 2022 as the SDGs era (Orazalin, Ntim, and Malagila 2024).
Economic development	Natural log of gross domestic product (GDP) (Nuber and Velte 2021).
Worldwide Governance Indicators (average of 6 items)	<p>Factor analysis average score of country governance indicators across six dimensions of regulatory quality, political stability and lack of violence, control of corruption, voice and accountability, rule of law and government effectiveness (Cuadrado-Ballesteros and Bisogno 2020).</p> <p>Applying a 70% threshold, we split countries into two groups of those with high institutional quality (scores of 70 and above) and low institutional quality (scores below 70) across the six institutional quality elements.</p>

(Continues)

TABLE 1 | (Continued)

Variables	Measurement
Cultural environment	Hofstede cultural dimensions applied to measure cultural environment (Gyapong and Afrifa 2021; Hofstede 2011) in the group of <ol style="list-style-type: none"> i. Uncertainty avoidance: Low (0–50) assigned 0 versus high (51–100) assigned 1. ii. Power distance: Low (0–50) assigned 0 versus high (51–100) assigned 1. iii. Short-term orientation (0–50) assigned 0 versus long-term orientation (51–100) assigned 1. iv. Restraint (0–50) assigned 0 versus indulgence (51–100) assigned 1. v. Femininity (0–50) assigned 0 versus masculinity (51–100) assigned 1. vi. Collectivism (0–50) assigned 0 versus individualism (51–100) assigned 1.

Note: Firm-level data on carbon trade finance, corporate governance and firm characteristics were collected from the Refinitiv (now LSEG) database. Country-level data on economic development and Worldwide Governance Indicators were gathered from the World Bank database, and data on cultural orientation/environment were taken from the Hofstede Insights database.

3.6 | Model Specification

To respectively test Hypotheses 1–3, we estimate the following panel regression Equations (1)–(3):

$$CTF_{i,t} = \alpha_0 + \alpha_1 BGD_{i,t} + \alpha_n X_{i,t} + e_{1i,t} \quad (1)$$

$$CTF_{i,t} = \alpha_0 + \alpha_1 BGD_{i,t} + \alpha_2 BGD_{i,t} * INQ_{i,t} + \alpha_n X_{i,t} + e_{2i,t} \quad (2)$$

$$CTF_{i,t} = \alpha_0 + \alpha_1 BGD_{i,t} + \alpha_2 BGD_{i,t} * CUL_{i,t} + \alpha_n X_{i,t} + e_{3i,t} \quad (3)$$

where *CTF* represents carbon trade finance of firm *i* at time *t*. *BGD* represents board gender diversity; *INQ* is institutional quality; *CUL* is cultural environment; and *X* is a vector for firm-level governance factors, firm attributes and country-level governance factors as control variables influencing carbon trade emissions. $e_{i,t}$ represents the stochastic error term.

We adopt panel regression analysis because of its benefits of accounting for variables that are not directly observed but could impact the dependent variable, improving the precision of estimated coefficients by managing multicollinearity and modeling dynamic relationships (Tawiah, Gyapong, and Wang 2024). In deciding on running a fixed or random effect analysis, the unreported result of the Hausman test reveals that the fixed-effect model is more appropriate (chi-squared *p* value <0.05; Hausman 1978). Further, the use of fixed-effect analysis enables us to control for individual heterogeneity of firms, remove the effect of time-invariant characteristics and reduce selection bias (Tawiah, Gyapong, and Wang 2024).

4 | Results

4.1 | Descriptive Analysis and Multicollinearity Diagnostics

The descriptive statistics of the variables are presented in Table 2. The average carbon offsets/credits are 247,163,000 metric tonnes, and the standard deviation of 3,551,780 metric tonnes shows a significant difference in the commitment of MNCs to finance carbon emissions reduction initiatives. Commitment to emissions trading (mean = 0.294) and supply chain emissions reduction finance (mean = 0.218) appears to be generally low. The board gender diversity rate stood at

16.60%. The correlation matrix in Table 3 shows that none of the correlation coefficients between the independent variables are up to 0.80. In the unreported results of the VIF analysis, the VIF coefficients are generally below 4.0, and the average of 3.72 is below the recommended threshold of 10. These results confirm that multicollinearity is not a concern (Tabachnick, Fidell, and Ullman 2007).

4.2 | Board Gender Diversity and Carbon Trade Finance (Baseline Results)

Table 4 presents the baseline result on the impact of board gender diversity on carbon trade finance using carbon offsets and credits as the main measurement (Column 1) and carbon emissions trading (Column 2) and supply chain emissions reduction finance (Column 3) as the alternative measurements.

From the result in Table 4, board gender diversity is positively associated with carbon offsets and credits ($\beta = 0.629$, $p < 0.01$). The impact of board gender diversity on carbon emissions trading is also positive and statistically significant ($\beta = 0.410$, $p < 0.05$). Supply chain emissions reduction finance is positively associated with board gender diversity ($\beta = 0.402$, $p < 0.05$). The effect size of board gender diversity coefficients under the three measures in Columns 1–3 is also comparable. These results provide empirical support that board gender diversity is an effective strategy for enhancing carbon emissions trading; hence, Hypothesis 1 is accepted. Our results corroborate prior literature suggesting that board gender diversity enhances carbon management performance (Elsayih, Datt, and Tang 2021; Konadu et al. 2021; Oyewo 2023). The results also support legitimacy and gender socialisation theories, which suggest that MNCs are motivated to diversify the gender composition of their boards by including female directors to enhance corporate legitimacy, preserve firm reputation and mitigate climate risks, given that female board directors promote eco-friendly decisions (Elsayih, Datt, and Tang 2021; Nuber and Velte 2021).

4.3 | Critical Mass of Board Gender Diversity Required for Carbon Trade Finance

The baseline result shows that board gender diversity is positively associated with carbon trade finance. However, to determine

TABLE 2 | Descriptive statistics of variables.

	Obs.	Min	p.25	p.75	Max.	Mean	SD
Carbon offsets/credits (metric tonnes' 000)	5198	23.22	104.00	119,519.00	1,290,320.00	247,163.00	3551.78
Carbon emissions trading	5198	0.00	0.00	1.000	1.00	0.294	0.159
Supply chain emissions reduction finance	5198	0.00	0.00	1.000	1.00	0.218	0.273
BD gender diversity	5198	0.04	0.08	0.2500	0.63	0.166	0.124
BD meeting	5198	3.00	6.00	11.00	15.00	9.00	6.00
BD independence ratio	5198	0.23	0.70	0.92	1.00	0.756	0.231
CEO/chair duality	5198	0.00	0.00	1.00	1.00	0.530	0.500
ESG-based compensation	5198	0.00	0.00	1.00	1.00	0.299	0.463
ESG committee	5198	0.00	0.00	1.00	1.00	0.721	0.422
Revenue (in million USD)	5198	179.90	14,379.50	57,900.00	572,754.00	27,739.00	61,007.64
Market capitalisation (in million USD)	5198	97.32	20,637.50	76,720.50	2,428,612.00	37,050.50	126,488.09
Pretax ROA (%)	5198	0.00	3.140	9.6800	41.32	9.481	7.778
Economic development	5198	3.51	4.57	4.74	5.77	4.61	0.03
World Gov. Index	5198	27.39	78.06	84.45	97.67	80.09	0.16

the critical mass of female directors required to achieve a notable result in this respect, we conduct an additional analysis to test critical mass theory using the main measurement of the dependent variable (Table 5A) and alternative measurements (Tables 5B and 5C).

In Table 5A, the presence of one female director (Column 1) to three female directors (Column 3) has no significant impact on carbon offsets and credits. However, the presence of four female directors has a significant positive impact (Column 4), and this remains positive and statistically significant for a critical mass of five female directors (Column 5). This evidence supports critical mass theory and prior studies that female directors may have to constitute a critical mass before they can significantly influence environmental policies. This is particularly important to a subject matter, such as carbon trade finance, which requires voluntary participation of firms. In essence, MNCs may not want to ordinarily invest in carbon trade finance to reduce emissions because of the financial implications and the need to maximise returns for shareholders. However, the presence of a sizable number of female directors on the board may be able to exert pressure on corporate entities to embrace carbon trade finance. An organisation thus enhances its corporate legitimacy by being seen as having an adequate representation of female directors who can influence the board to take eco-friendly decisions, such as investing in carbon trade finance.

In Table 5B, the results reveal that the presence of one female director (Column 1) and two female directors (Column 2) has no significant impact on carbon emissions trading. However, Columns 3–5 show that a critical mass of at least three female directors is required to significantly influence the decision of organisations to commit to carbon emissions trading.

The descriptive statistics earlier reveal the low commitment of MNCs to emissions trading (mean = 0.294). A critical mass of at least three female directors is, therefore, needed to put forth pressure on MNCs to commit to emissions trading (Table 5B). In Table 5C, a critical mass of at least four female directors is required to cause supply chain emissions reduction finance to happen (Columns 4 and 5). Meanwhile, commitment to supply chain emissions reduction finance is low (mean = 0.218). More numbers (i.e., at least four female directors) are required to make organisations commit financially to procuring carbon offsets (Table 5A). Overall, the result buttresses critical mass theory that the inclusion of more females on the board of directors can constitute a 'critical mass' in exerting considerable influence on the environmental practices of an organisation (Hollindale, Kent, and Routledge 2017; Nuber and Velte 2021), thereby leading to better carbon emissions management.

When comparing the findings of this study to prior research, existing studies suggest that a critical mass of two female directors is sufficient to reduce emissions and environmental pollution directly attributable to organisations (Konadu et al. 2021; Nuber and Velte 2021). However, our results indicate that a critical mass of four female directors is necessary to achieve meaningful engagement in carbon trade finance and to provide decarbonisation financial incentives to firms within an organisation's supply chain. These findings highlight that a higher critical mass of female directors is required to address emissions not directly attributable to the firm. Two key factors may explain this outcome. First, carbon trade finance is associated with reducing supply chain emissions (i.e., Scope 3 emissions). Given that Scope 3 emissions are more challenging to measure and mitigate than Scope 1 emissions, which are directly observable, a greater number of

TABLE 3 | Correlation matrix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Gender diversity (1)	1											
Board meeting (2)	0.034	1										
Board independence (3)	0.471***	-0.067***	1									
CEO duality (4)	0.022***	-0.045***	0.097**	1								
ESG-based compensation (5)	0.279***	0.012***	0.255***	0.041**	1							
ESG committee (6)	0.108***	0.092***	0.041***	-0.003	0.202***	1						
Firm size (7)	0.063***	0.097***	0.052***	-0.022**	0.112***	0.256***	1					
Market presence (8)	0.231***	0.031**	0.187***	0.051***	0.123***	0.221***	0.511***	1				
Liquidity (9)	-0.101***	-0.055***	-0.117***	0.005	-0.047***	-0.103***	-0.251***	-0.044**	1			
Profitability (10)	0.031**	-0.046***	0.071***	0.045***	-0.025	-0.002	-0.113***	0.199***	0.224***	1		
Economic development (11)	0.371***	-0.013	0.274***	0.126***	0.188***	0.165***	0.054***	0.212***	-0.016	-0.044***	1	
Worldwide Governance Indicators (12)	0.276***	-0.113***	0.032***	0.014	0.112***	0.112***	-0.013	-0.004	-0.082***	-0.094***	0.473***	1

*** $p < 0.01$ and ** $p < 0.05$.

TABLE 4 | Board gender diversity and carbon emissions finance (baseline result).

Variable	(1)	(2)	(3)
	Carbon offsets and credits	Carbon emissions trading	Supply chain emissions reduction finance
Board gender diversity	0.629*** (0.105)	0.410*** (0.107)	0.402** (0.089)
Firm-level governance control			
Board meeting	0.179** (0.016)	0.023 (0.010)	0.103 (0.003)
Board independence	0.236*** (0.048)	0.254*** (0.049)	0.294*** (0.043)
CEO duality	-0.065*** (0.023)	-0.068*** (0.023)	-0.031*** (0.014)
ESG-based compensation	0.290*** (0.026)	0.287*** (0.025)	0.233*** (0.038)
ESG committee	0.141** (0.028)	0.123*** (0.028)	0.125*** (0.010)
Firm characteristics (control)			
Firm size	0.654*** (0.177)	0.874*** (0.294)	0.763** (0.119)
Market presence	1.611 (0.971)	1.231** (0.995)	1.023* (0.023)
Liquidity	-0.806** (0.032)	-0.107** (0.022)	-0.115 (0.028)
Profitability	-0.025** (0.021)	-0.023** (0.020)	-0.019 (0.005)
Era (MDGs vs. SDGs)	0.118*** (0.024)	0.108*** (0.025)	0.147*** (0.037)
Country governance (control)			
Economic development	-0.102*** (0.021)	-0.087 (0.035)	-0.042 (0.029)
World Gov. Index	0.016** (0.001)	0.015** (0.002)	0.017*** (0.001)
Firm effect	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes
Year effect	Yes	Yes	Yes
R ²	0.183	0.221	0.227
N	5198	5198	5198

Note: Standard error in parentheses.
 *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

female directors on corporate boards may be needed to champion the carbon trade finance agenda and secure the buy-in of other directors, as suggested by the critical mass theory (Yarram and Adapa 2021). Second, women are generally more responsive to policies that benefit citizens, consumers and the environment (Barroso et al. 2024; Yarram and Adapa 2021). Considering the growing importance of addressing climate

change and the critical need to tackle Scope 3 emissions to realise Agenda 2030, female directors may be more inclined to focus on reducing supply chain emissions. Because Scope 3 emissions often constitute the majority of an organisation's total emissions, addressing these emissions through carbon trade finance represents a strategic and impactful approach to decarbonisation.

TABLE 5A | Impact of critical mass of female directors on the association between board gender diversity and carbon emissions finance.

Variable	DV: Carbon offsets and credits				
	(1)	(2)	(3)	(4)	(5)
Tokenism of one female director	-0.127 (0.053)				
Critical mass of two female directors		0.211 (0.057)			
Critical mass of three female directors			0.357 (0.210)		
Critical mass of four female directors				0.502*** (0.013)	
Critical mass of five female directors					0.535*** (0.159)
Firm-level governance control	Yes	Yes	Yes	Yes	Yes
Firm characteristics (control)	Yes	Yes	Yes	Yes	Yes
Era (MDGs/SDGs) control	Yes	Yes	Yes	Yes	Yes
Country governance (control)	Yes	Yes	Yes	Yes	Yes
Firm effect	Yes	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes
R ²	0.121	0.137	0.159	0.152	0.166
N	5198	5198	5198	5198	5198

Note: Standard error in parentheses.

*** $p < 0.01$.

4.4 | Moderating Impact of Institutional Quality on the Relationship Between Board Gender Diversity and Carbon Trade Finance

The results on the impact of institutional quality on the relationship between board gender diversity and carbon trade finance are presented in Table 6.

Institutional quality mechanisms, such as high control of corruption (Column 1), strong voice and accountability (Column 2), government effectiveness (Column 4) and strong rule of law (Column 6), significantly enhance the impact of board gender diversity in promoting carbon emissions finance. The institutional quality also significantly and positively moderates the relationship (Column 7). This informs the acceptance of Hypothesis 2, validating institutional theory. Environments characterised by high control of corruption may discourage unethical environmental practices (Tawiah 2023), and such an environment may provide an opportunity for female directors in line with the socialisation traits to be effective in tackling supply chain emissions through carbon trade finance. Carbon emissions reduction has dominated public debate, and in an environment marked by strong voice and accountability, organisations will want to take steps to address climate change to preserve corporate legitimacy and maintain corporate reputation (Ehalaiye et al. 2024; Wang et al. 2023). In such settings, female directors may easily convince board members on the need to embrace carbon trade

finance as a strategy for addressing climate change to assuage public opinion on environmental pollution. Thus, high voice and accountability may enhance the impact of board gender diversity in promoting carbon trade finance. Government effectiveness and rule of law may contribute to the effectiveness of board gender diversity in promoting carbon trade finance in the sense that government commitment to formulate and implement environmental laws discouraging carbon emissions can provide the supporting environment for female directors to push carbon trade finance as a mechanism to achieve decarbonisation targets and avoid environmental sanctions (Barry, Jona, and Soderstrom 2022; Ernstberger and Grüning 2013; Oyewo et al. 2024).

Overall, the results provide empirical evidence that institutional factors shape the impact of female directors in achieving emissions reduction outcomes (DiMaggio and Powell 1991; Saqib, Allen, and Wood 2021; Scott 2013). To further assess this relationship, we conduct a critical mass analysis in high and low institutional quality settings reported in Table 7. The results for high institutional quality are presented in Columns 1–5, and those for low institutional quality are reported in Columns 6–10.

In high institutional quality settings, a critical mass of at least three female directors is required to significantly influence carbon trade finance (Columns 3 and 4; Table 7). In contrast,

TABLE 5B | Impact of critical mass of female directors on the association between board gender diversity and carbon emissions finance (using alternative measurement of dependent variable).

Variable	DV: Carbon emissions trading				
	(1)	(2)	(3)	(4)	(5)
Tokenism of one female director	0.086 (0.072)				
Critical mass of two female directors		0.284 (0.187)			
Critical mass of three female directors			0.592** (0.046)		
Critical mass of four female directors				0.664*** (0.098)	
Critical mass of five female directors					0.541*** (0.072)
Firm-level governance control	Yes	Yes	Yes	Yes	Yes
Firm characteristics (control)	Yes	Yes	Yes	Yes	Yes
Era (MDGs/SDGs) control	Yes	Yes	Yes	Yes	Yes
Country governance (control)	Yes	Yes	Yes	Yes	Yes
Firm effect	Yes	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes
R ²	0.132	0.124	0.147	0.198	0.211
N	5198	5198	5198	5198	5198

Note: Standard error in parentheses.

*** $p < 0.01$ and ** $p < 0.05$.

in low institutional quality settings, a minimum of four female directors is necessary to significantly influence carbon trade finance (Columns 9 and 10). Essentially, fewer female directors are needed to achieve carbon trade finance in high institutional quality countries. One explanation for this result is that firms in such settings are naturally driven to adopt sustainable practices to comply with regulatory standards and meet stakeholder expectations (Saqib, Allen, and Wood 2021; Scott 2013).

4.5 | Moderating Impact of Culture on the Relationship Between Board Gender Diversity and Carbon Trade Finance

The results on the impact of cultural environment on the relationship between board gender diversity and carbon trade finance are presented in Table 8.

Table 8 shows that in a high uncertainty avoidance cultural environment, board gender diversity has a significant positive impact on carbon trade finance (Column 1). This result suggests that the caring nature of women, as suggested by the gender socialisation theory, would motivate female directors to take steps to avoid unpleasant surprises with respect to environmental

pollution and degradation by advocating for emissions reduction strategies such as carbon trade finance initiatives (Atif et al. 2021; Barroso et al. 2024). Moreover, people in a high uncertainty avoidance cultural environment tend to rely heavily on rules and established ways of doing things. This may create the conducive environment for female directors to push for carbon trade finance as a strategy for complying with environmental protection rules whilst achieving corporate decarbonisation targets.

A long-term orientation cultural environment also enhances the positive impact of board gender diversity on carbon trade finance (Column 3). A cultural setting that focuses on the future, rather than the past or present, should enhance the effectiveness of female directors in achieving carbon trade finance as an environmental sustainability strategy. Further, the need to retain corporate legitimacy by demonstrating that an organisation's goal aligns with societal values will provide the leverage for female directors to advocate for carbon trade finance as a forward-looking approach to addressing environmental challenges/achieving sustainability goals (Ehalaiye et al. 2024; Oyewo et al. 2024). In highly individualistic societies (Column 6), the impact of board gender diversity on carbon trade finance moves from positive (before interaction) to negative (after interaction), implying that female directors may

TABLE 5C | Impact of critical mass of female directors on the association between board gender diversity and carbon emissions finance (using alternative measurement of dependent variable).

Variable	DV: Supply chain emissions reduction finance				
	(1)	(2)	(3)	(4)	(5)
Tokenism of one female director	0.093 (0.077)				
Critical mass of two female directors		0.231 (0.122)			
Critical mass of three female directors			0.396 (0.249)		
Critical mass of four female directors				0.506*** (0.122)	
Critical mass of five female directors					0.522*** (0.075)
Firm-level governance control	Yes	Yes	Yes	Yes	Yes
Firm characteristics (control)	Yes	Yes	Yes	Yes	Yes
Era (MDGs/SDGs) control	Yes	Yes	Yes	Yes	Yes
Country governance (control)	Yes	Yes	Yes	Yes	Yes
Firm effect	Yes	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes
R^2	0.106	0.112	0.117	0.122	0.26
N	5198	5198	5198	5198	5198

Note: Standard error in parentheses.

*** $p < 0.01$.

not be effective in promoting carbon trade finance because people characteristically prioritise themselves and their own interests over the interests of a group or community in such cultural settings (Gyapong and Afrifa 2021; Hofstede 2011). Hence, decarbonisation through carbon offsets may be of less priority in such cultural settings. The statistical significance of the interaction terms in Columns 1, 3 and 6 supports the acceptance of Hypothesis 3. Although other cultural orientations do not show significant impacts on the interaction with board gender diversity, the change in the direction of the coefficients from positive (before interaction) to negative (after interaction) suggests that high-power distance societies, high-indulgence environments and male-dominated societies erode the effectiveness of female directors in promoting carbon trade finance (Griffin et al. 2021; Wang, Guo, and Tang 2021).

5 | Robustness Checks for Endogeneity

Prior studies have suggested that board gender diversity and carbon emissions performance may influence each other bidirectionally, leading to endogeneity issues (Oyewo 2023; Tingbani et al. 2020). To address this, we employ two-stage least squares (2SLS) and propensity score matching (PSM) techniques.

5.1 | 2SLS Regression

Following earlier studies (e.g., Orazalin, Ntim, and Malagila 2024; Solal and Snellman 2019; Xie et al. 2023), we use the industry average of board gender diversity to instrument company board gender diversity because it satisfies the requirements of an instrumental variable. On one hand, the industry board gender diversity rate may influence a firm's board gender diversity as suggested by the institutional theory of isomorphism (DiMaggio and Powell 1983). On the other hand, the industry average of board gender diversity may not directly affect firm-level carbon trade finance. The results of the 2SLS procedure are reported in Table 9. We test the validity of the instrument using the Cragg–Donald Wald F statistic, the Stock–Yogo weak ID test, the Kleibergen–Paap F statistic and the Hansen J (p value). All the results satisfy the statistical conditions for an appropriate instrumental variable. In the first stage of the 2SLS process (Column 1), we regress board gender diversity on the industry average of board gender diversity and control variables. In the second stage (Column 2), we replace the endogenous variable (board gender diversity) with the instrumented board gender diversity and rerun our regression using carbon offsets and credits as the main independent variable. The result shows that board gender diversity is positively and significantly associated with carbon trade finance, implying that our result continues to hold (Table 4) after addressing endogeneity.

TABLE 6 | Moderating impact of institutional quality on the relationship between board gender diversity and carbon emissions finance.

	DV: Carbon offsets and credits						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Control of corruption (CoC)	Voice and accountability (VAC)	Political stability (PoS)	Government effectiveness (GeF)	Regulatory quality (RGQ)	Rule of law (RoL)	Institutional quality (IQ)
Board gender diversity	0.722** (0.021)	-0.269 (2.708)	1.507 (0.950)	0.060 (2.240)	0.623 (2.148)	-0.010 (2.616)	0.317** (0.023)
Board gender diversity × CoC	0.992** (0.064)						
Board gender diversity × VAC		1.958** (0.734)					
Board gender diversity × PoS			0.189 (0.963)				
Board gender diversity × GeF				1.620** (0.257)			
Board gender diversity × RGQ					1.057 (2.175)		
Board gender diversity × RoL						1.695** (0.636)	
Board gender diversity × IQ							0.462** (0.016)
Firm-level governance control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm characteristics (control)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Era (MDGs/SDGs) control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country governance (control)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.183	0.127	0.183	0.182	0.122	0.138	0.133
N	5198	5198	5198	5198	5198	5198	5198

Note: Standard error in parentheses.

** $p < 0.05$

5.2 | PSM

PSM with regression analysis was employed to further correct endogeneity (Peel 2018; Tawiah et al. 2022). This procedure eliminates potential endogeneity issue whilst also minimising model misspecification (Tawiah et al. 2022; Titus 2007). Using the median score of board gender diversity at 17.0%, firms were divided into the treatment group (with above-median scores) and control group (with median and below

scores). The results of the propensity matching procedure are reported in Table 10.

In the first stage (Column 3), the propensity scores, *pscore* (i.e., probability of being assigned to a treated/control group), were generated by regressing the binary categorisation of board gender diversity (code 0 for control/untreated group and code 1 for treatment group) on the control variables. In the second stage, we match the treatment firms (without replacement) to

TABLE 7 | Impact of critical mass of female directors on the association between board gender diversity and carbon trade finance in high and low institutional quality settings.

Variable	DV: Carbon offsets and credits									
	High institutional quality					Low institutional quality				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Tokenism of one female director	0.199 (0.076)					0.072 (0.066)				
Critical mass of two female directors		0.302 (0.271)					0.209 (0.172)			
Critical mass of three female directors			0.588** (0.055)					0.334 (0.246)		
Critical mass of four female directors				0.602*** (0.112)					0.513*** (0.128)	
Critical mass of five female directors					0.648*** (0.082)					0.521*** (0.064)
Firm-level governance control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm characteristics (control)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Era (MDGs/SDGs) control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country governance (control)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.110	0.118	0.121	0.158	0.164	0.117	0.120	0.121	0.128	0.131
N	3747	3747	3747	3747	3747	1451	1451	1451	1451	1451

Note: Standard error in parentheses.
*** $p < 0.01$ and ** $p < 0.05$.

the control firms with the closest propensity score. This procedure results in a loss of data, diminishing the matched sample to 2798 observations (i.e., 1399 matched pairs), but ensures that we find close matches. Before the matching, there is a significant difference in the mean score of the treatment and control firms (Column 1). After the matching, there is no significant difference (Column 2), confirming that our matching procedure reduced the difference between the treatment and control groups, and any difference in the dependent variable can reasonably be attributable to the main independent variable.

In the second stage of the PSM (Column 4), the propensity scores generated by the first stage were then substituted for board gender diversity, and the regression was rerun using carbon offsets and credits as the dependent variable.

The results in Table 10 (Column 4) are consistent with those of Table 4 (Column 1) in which board gender diversity has a significant positive impact on carbon offsets and credits as the main measures of the dependent variable. Our results are therefore robust to endogeneity concerns.

6 | Summary and Conclusion

Although the role of female board directors in mitigating climate risks within single jurisdictions/regions is well documented in prior studies, empirical evidence on the impact of board gender diversity on carbon trade finance in multi-country contexts remains limited. It is also unclear how formal and informal institutional factors influence the link between

TABLE 8 | Moderating impact of culture on the relationship between board gender diversity and carbon trade finance.

	DV: Carbon offsets and credits					
	(1) Uncertainty avoidance (UA)	(2) Power distance (PD)	(3) Long-term/short-term orientation (LT)	(4) Indulgence/restraint (I/R)	(5) Masculinity/femininity (M/F)	(6) Individualism/collectivism (I/C)
Board gender diversity	0.651 (0.781)	1.700*** (0.433)	-1.260** (0.762)	1.467*** (0.711)	-1.660** (0.799)	1.319** (0.175)
Board gender diversity × UA	1.886*** (0.474)					
Board gender diversity × PD		-0.216 (0.890)				
Board gender diversity × LT			2.175** (0.495)			
Board gender diversity × I/R				-0.255 (0.835)		
Board gender diversity × M/F					-0.012 (0.901)	
Board gender diversity × I/C						-0.368** (0.028)
Firm-level governance control	Yes	Yes	Yes	Yes	Yes	Yes
Firm characteristics (control)	Yes	Yes	Yes	Yes	Yes	Yes
Era (MDGs/SDGs) control	Yes	Yes	Yes	Yes	Yes	Yes
Country governance (control)	Yes	Yes	Yes	Yes	Yes	Yes
Firm effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.179	0.183	0.170	0.127	0.128	0.135
N	5198	5198	5198	5198	5198	5198

Note: Standard error in parentheses.

*** $p < 0.01$ and ** $p < 0.05$.

board gender diversity and carbon trade finance. Hence, using a sample of top MNCs across 42 industries and 32 countries from 2006 to 2022, we examine the association between board gender diversity and carbon trade finance and assess the moderating roles of country-level governance and cultural factors. Our results show that board gender diversity is positively associated with carbon offsets and credits. The impact of board gender diversity on carbon emissions trading is also positive and statistically significant, thus supporting our hypothesis that board gender diversity is an effective strategy for improving carbon emissions trading. However, a critical mass of at least four female directors is required to influence MNCs to commit to carbon trade finance. Our findings support the

proposition that institutional quality significantly moderates the relationship between board gender diversity and carbon trade finance. Specifically, institutional quality mechanisms, such as high control of corruption, strong voice and accountability, government effectiveness and strong rule of law, significantly enhance the impact of board gender diversity in promoting carbon emissions finance. The cultural environment also influences the relationship between board gender diversity and carbon trade finance, and female directors are more effective in achieving carbon trade finance goals in high uncertainty avoidance and long-term orientation cultural environments. Overall, the results confirm that board gender diversity is an effective strategy for improving carbon trade

TABLE 9 | Endogeneity check using two-stage least squares (2SLS) regression.

Variable	Two-stage least squares (2SLS)	
	(1)	(2)
	1st stage DV: Board gender diversity	2nd stage DV: Carbon offsets and credits
Industry board gender diversity (instrument)	0.182*** (0.026)	
Board gender diversity (instrumented)		0.970*** (0.292)
Firm-level governance control		
Board meeting	0.240*** (0.050)	0.397*** (0.021)
Board independence	0.582*** (0.091)	1.435*** (0.054)
CEO duality	−0.301* (0.036)	−0.058 (0.145)
ESG-based compensation	0.623*** (0.042)	0.118 (0.049)
ESG committee	1.952 (0.044)	−0.426 (0.265)
Firm characteristics (control)		
Firm size	0.759*** (0.041)	0.633*** (0.182)
Market presence	0.767*** (0.095)	0.184 (0.122)
Liquidity	0.534*** (0.038)	−0.012 (0.078)
Profitability	0.096*** (0.031)	−0.011* (0.004)
Era (MDGs vs. SDGs) control	Yes	Yes
Country governance (control)	Yes	Yes
Firm effect	No	No
Industry effect	Yes	Yes
Year effect	Yes	Yes
R ²	0.476	0.166
Cragg–Donald Wald <i>F</i> statistic	51.76	—
Stock–Yogo weak ID test	17.22	—
Kleibergen–Paap <i>F</i> statistic	23.89	—
Hansen <i>J</i> (<i>p</i> value)	0.172	—
<i>N</i>	5198	5198

Note: Standard error in parentheses.
****p* < 0.01, and **p* < 0.10.

finance and ultimately achieving decarbonisation targets by MNCs (Elsayih, Datt, and Tang 2021; Konadu et al. 2021; Yarram and Adapa 2021).

Despite the call for more climate actions, emissions level is yet to abate globally. In response to the growing concern on the need for urgent action to protect the environment, the UN, through the launching of the sustainable development agenda in 2015, specifies various goals relating to environmental protection, including SDG 13 on climate change (Ehalaiye et al. 2024; Erin, Bamigboye, and Oyewo 2022). The achievement of the SDGs by 2030 requires the full and active participation of governments, intergovernmental organisations, major groups and other stakeholders (Erin, Bamigboye, and Oyewo 2022; Moses and Hopper 2022). MNCs can contribute to the achievement of the SDGs by promoting carbon trade finance within their supply chain and encouraging decarbonisation by incentivising suppliers (Cong, Pang, and Peng 2020; Maddikunta et al. 2022; Wu and Kung 2020). As empirically demonstrated by this study, board gender diversity as a corporate governance mechanism could be one of the effective strategies to achieve climate change targets as specified in SDG 13. MNCs as key stakeholders in the sustainability discourse should therefore do more in the way of diversifying the gender base of board members. The result provides empirical support for legitimacy theory and critical mass theory that the presence of a sizable number of female directors on the board of directors can exert considerable influence on the environmental practice of organisations in the way of carbon trade finance and supply chain emissions management (Chelli, Durocher, and Richard 2014; Mahadeo, Oogarah-Hanuman, and Soobaroyen 2011). The result also validates the institutional theory that formal and informal institutional factors affect the performance of female directors in achieving environmental sustainability outcomes (Dobler 2011; Griffin et al. 2021).

The study contributes to knowledge in several significant ways. Firstly, it expands the limited literature on the impact of board gender diversity on carbon trade finance, responding to the need for more investigation into carbon accounting in this area. Secondly, it elucidates the moderating role of institutional mechanisms in the nexus between board gender diversity and carbon trade finance. Thirdly, it exposes the relevance of cultural environment in shaping the influence of board gender diversity on carbon trade finance. Finally, it analyses a sample of top MNCs, encompassing 336 firms from 42 industries and 32 countries over a 17-year period (2006–2022), thereby providing valuable insights to supplement the limited international studies on the association between board gender diversity and carbon emissions performance.

Our findings offer important practical implications for practitioners, policymakers and investors. The positive impact of board gender diversity on carbon trade finance suggests that corporate boards and managers should promote boardroom diversity and increase female representation to achieve decarbonisation targets. Policymakers need to adopt/reinforce gender quotas and governance policies to support corporate-level climate mitigation efforts. Investors concerned about climate issues may consider the role of gender-diverse boards in meeting environmental goals when assessing investment opportunities. Further, the moderating role of institutional quality suggests

TABLE 10 | Propensity score matching regression result on impact of board gender diversity on supply chain emissions performance.

Variable	(1)	(2)	(3)	(4)
	Prematching	Postmatching	1st stage of PSM	2nd stage of PSM
	Difference in mean score of treatment and control	Difference in mean score of treatment and control	Board gender diversity (binary)	Carbon offsets and credits
Carbon offsets and credits	−87.103**	−43.022**	—	—
Board gender diversity (<i>pscore</i>)	—	—	—	0.214*** (0.036)
Firm-level governance control				
Board meeting	2.265***	−0.076	0.228** (0.033)	0.692 (0.039)
Board independence	−1.69	−0.149	0.587*** (0.049)	2.311*** (0.528)
CEO duality	0.13**	0.022	−0.004 (0.005)	−0.259*** (0.050)
ESG-based compensation	0.58**	0.008	0.678** (0.038)	0.709** (0.058)
ESG committee	0.32	0.003	0.514*** (0.056)	0.292 (0.061)
Firm characteristics (control)				
Firm size	7.38**	0.966	0.312*** (0.052)	1.075*** (0.056)
Market presence	−1.41***	−0.047	0.157 (0.119)	0.703*** (0.298)
Liquidity	0.231**	0.003	0.120 (0.237)	0.003 (0.031)
Profitability	0.54**	−0.001	0.901** (0.397)	−0.184** (0.042)
Era (MDGs vs. SDGs) control	—	—	Yes	Yes
Country governance (control)	—	—	Yes	Yes
Firm effect	—	—	No	Yes
Industry effect	—	—	Yes	No
Year effect	—	—	Yes	Yes
R ²	—	—	0.181	0.129
N	5198	2798	5198	2798

Note: Standard error in parentheses.

*** $p < 0.01$ and ** $p < 0.05$.

that firms need to align their sustainability strategies with national governance systems, whereas policymakers should promote and enforce institutional settings to support the impact of gender-diverse boards. Global investors, in turn, can prioritise firms with higher board gender diversity, especially in high institutional quality contexts, as part of their investment strategies. The moderating roles of cultural environments also suggest

that policymakers and regulatory bodies need to consider high uncertainty and long-term orientation cultures when developing regulatory frameworks and promoting proactive climate strategies. Overall, our findings emphasise the need for collective efforts among regulators, governments and practitioners to align corporate governance and sustainability practices with global climate mitigation initiatives.

Although our work makes important contributions to the literature, it has certain limitations that future research should address. First, our study focuses on top MNCs, limiting the generalisability of our findings and conclusions to smaller firms, especially those in emerging economies. Hence, future studies could assess the links among institutional factors, board gender diversity and climate mitigation efforts of small- and medium-sized business entities in these settings. Second, although our study assesses institutional and cultural factors as moderators, other settings, such as stakeholder pressures and industry- and country-specific environmental regulations, may also shape board gender diversity and carbon trade finance. Therefore, further research could extend our conclusions by exploring the effects of these factors. Finally, our empirical analysis, which is based on extensive quantitative data, may not fully explain the complex and causal relationships between board gender diversity and environmental sustainability. Thus, qualitative studies, including case studies and/or interviews, could offer valuable insights into climate mitigation decisions and efforts within gender-diverse corporate boards.

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Endnotes

¹ We refer to decarbonisation as firms' strategic and governance decisions to reduce and eliminate greenhouse gas emissions (GHG) across business operations and supply chain networks. In this context, we use the term decarbonisation interchangeably with 'carbon emissions reduction and/or management strategies'.

² Our conceptualisation of carbon trade finance refers to corporate decarbonisation mechanisms that incentivise cost-efficient emissions reductions through two key actions: the purchase and production of carbon credits within a given accounting year, linked to an organisation's volume of offsets and credits (Wang, Zhao, and Herty 2018). Carbon credits permit firms to emit a defined threshold of greenhouse gases, whereas carbon offsets allow them to compensate for emissions by purchasing credits corresponding to equivalent reductions. Together, these mechanisms support compliance with emissions targets and investments in climate mitigation projects.

³ We conceptualise the critical mass of board gender diversity as the optimal threshold of women on boards necessary to drive and sustain decarbonisation initiatives within organisations through carbon trade finance mechanisms. Drawing on prior literature (Konadu et al. 2021; Nuber and Velte 2021; Yarram and Adapa 2021), we speculate that a critical mass threshold such as having four or more women on boards facilitates significant influence on carbon trade finance policies. This threshold is pivotal to ensuring that decarbonisation practices, such as carbon offsetting and crediting, become self-sustaining.

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Appendix A

Geographical Region and Country Analysis of Companies

Region	Country	No. of companies
America	Brazil	2
	Canada	7
	Mexico	1
	United States	132
Asia Pacific	Australia	6
	China	42
	Hong Kong	9
	India	4
	Japan	33
	Singapore	1
	South Korea	11
	Taiwan	2
	Thailand	1
	United Arab Emirates	1
Europe and Central Asia	Russia	5
Middle East and North Africa	Saudi Arabia	4
Western Europe	Austria	1
	Belgium	1
	Denmark	2
	Finland	1
	France	17
	Germany	12
	Ireland	4
	Italy	4
	Luxembourg	1
	Netherlands	6
	Norway	2
	Portugal	1
	Spain	2
	Sweden	3
	Switzerland	4
	United Kingdom	14
Total		336

Appendix B

Factor analysis result of Worldwide Governance Indicators

TABLE B1a | Component matrix.^a

	Component 1
Control of corruption	0.805
Voice and accountability	0.872
Political stability and lack of violence	0.743
Government effectiveness	0.957
Regulatory quality	0.941
Rule of law	0.963

Note: Extraction method: principal component analysis.

^aOne component extracted.

TABLE B1b. KMO and Bartlett's test.

Kaiser–Meyer–Olkin measure of sampling adequacy	0.888
Bartlett's test of sphericity	
Approx. chi-squared	31,668.556
df	15
Sig.	<0.001

TABLE B1c. Communalities.

	Initial	Extraction
Control of corruption	1.000	0.648
Voice and accountability	1.000	0.761
Political stability and lack of violence	1.000	0.551
Government effectiveness	1.000	0.916
Regulatory quality	1.000	0.885
Rule of law	1.000	0.928

Note: Extraction method: principal component analysis.

TABLE B1D | Total variance explained.

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.690	78.164	78.164	4.690	78.164	78.164
2	0.539	8.985	87.150			
3	0.372	6.198	93.347			
4	0.274	4.568	97.915			
5	0.078	1.306	99.221			
6	0.047	0.779	100.000			

Note: Extraction method: principal component analysis.