Board gender diversity and Scope 3 carbon emissions: The moderating impact of national culture

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Abstract

This study examines the impact of board gender diversity on carbon emissions performance, focusing on Scope 3 emissions, and assesses how cultural environments moderate this relationship. Using a robust econometric approach, we analyze data over a 15 year period from 336 multinational companies listed among the top 500 firms in the 2020 Forbes Global 2,000. The findings reveal that board gender diversity significantly enhances carbon emissions performance by reducing Scope 3 emissions, with the effect being more pronounced in jurisdictions with higher levels of board diversity. The study also indicates that a higher critical mass of female directors is necessary for substantial reductions in Scope 3 emissions, compared to Scope 1 and 2 emissions. Additionally, the study's findings show that cultural factors play a pivotal role in the impact of board gender diversity on carbon emissions performance. The positive effect of gender-diverse boards on emissions reduction is more substantial in cultures characterized by high uncertainty avoidance, long-term orientation, and indulgence. Overall, the study underscores the importance of culturally tailored approaches to corporate governance that account for the moderating influence that national culture plays on the effectiveness of gender-diverse boards in meeting sustainability targets.

Keywords: Board Gender Diversity; Carbon Emissions Performance; Scope 3 Emissions; Cultural dimension; Corporate Governance; Environmental, Social and Governance (ESG)

1. Introduction

The United Nations (UN) 2030 Agenda for Sustainable Development created 17 Sustainable Development Goals (SDGs). The sustainable development agenda of the UN calls on multinational enterprises (MNEs) to address climate change by setting and implementing targets to reduce carbon emissions (Beelitz & Merkl-Davies, 2019; Linnenluecke et al., 2019; Mahmoudian et al., 2023). MNEs are predominantly based in high-carbon-emitting countries and operate in environmentally sensitive or carbon-intensive industries. Unsurprisingly, reducing carbon emissions has become central to a great many corporate Environmental, Social, and Governance (ESG) commitments (Abbasi et al., 2024; Mahmoudian et al., 2023).

The voluntary nature of the multi-stakeholder approach to achieving the SDGs necessitates that MNEs adopt self-monitoring structures to regulate their carbon emissions (UN, 2015; Simpson et al., 2022). Corporate governance serves as a critical self-monitoring mechanism for ensuring compliance with environmental regulations (Samaha et al., 2015), and board gender diversity has been identified as a governance tool that can enhance board effectiveness in addressing climate change issues (Elsayih et al., 2021; Konadu et al., 2021; Mahmoudian et al., 2023). Consequently, there have been increasing calls for greater female representation in the governance structures of business organizations, government institutions, and political offices (Abbasi et al., 2024; Jamal, 2018). This aligns with SDG 5 on gender diversity, which highlights the need to promote women's full and effective participation as well as equal opportunities for leadership at all levels of decision-making in political, economic, and public life. Board gender diversity is one of the popular strategies in the SDGs era for strengthening sound policies for achieving gender diversity. Many countries, including Belgium, France, Germany, Iceland, India, Israel, Italy, Norway, and the Netherlands, among others, have begun enforcing legislation promoting gender equality and the empowerment of women on corporate boards (OECD, 2025).

Although some investigations have examined the nexus between board gender diversity and carbon emissions performance, a review of the extant literature reveals certain gaps that the current study seeks to address. First, existing studies on board gender diversity and carbon emissions reduction have primarily focused on Scope 1 and Scope 2 emissions (e.g., Elsayih et al., 2021; Konadu, 2021; Nuber & Velte, 2021), while Scope 3 emissions remain largely underexplored. Researchers have called for greater attention to Scope 3 emissions (He et al., 2013), as they provide a more comprehensive measure of the emissions indirectly attributable to organizations through their value chains. Many believe that accounting for Scope 3 emissions is particularly crucial, as they typically represent around 90% of a company's total emissions (McKinsey & Company, 2024). Measuring these emissions can potentially enable organizations to identify energy-efficiency and cost-saving opportunities, manage resource and energy risks in their supply chains (World Resources Institute, 2022), and improve the energy efficiency of their products. Addressing Scope 3 emissions can promote positive engagement with employees, suppliers, business partners, and other stakeholders, thereby encouraging collaborative efforts to reduce emissions (Deloitte, 2022). Achieving net-zero carbon emissions will ultimately require organizations to tackle Scope 3 emissions. Therefore, further research is needed to clarify the role of board gender diversity in driving Scope 3 emissions reduction. This would help ensure well-supported conclusions on how gender-diverse boards contribute to reducing carbon emissions in MNEs and, by extension, to the realization of the SDGs.

Second, limited research has examined how cultural environments moderate the relationship between board gender diversity and carbon emissions performance. Culture, defined as a shared way of life among members of a society (Hofstede, 2001; North, 1990), has been shown to influence various firm-level outcomes (Gyapong & Afrifa, 2021; Naghavi et al., 2021). Prior research on environmental performance suggests that national cultural contexts shape firms' sustainability decisions and outcomes (Griffin et al., 2021; Tsai et al., 2020; Wang et al., 2021). For instance, Griffin et al. (2021) found that national culture, particularly the individualism dimension, positively moderates the relationship between firm-level environmental performance and firm value. Wang et al. (2021) reported that feminist-oriented national cultures promote proactive climate adaptation and resilience, while cultures characterized by high uncertainty avoidance inhibit such initiatives. Similarly, emerging research suggests that national culture can influence the impact of board diversity on firm outcomes (Gyapong & Afrifa, 2021). Different cultural frameworks have shaped varying perspectives on society, business, and environmental responsibility (Wang et al., 2021). There is increasing expectations for private sector entities to contribute to the realization of the 2030 Agenda for Sustainable Development (Helfaya et al., 2023), particularly SDG 13 on climate action (Abbasi et al., 2024; Mahmoudian et al., 2023). Therefore, it is imperative to evaluate the extent to which the progress of MNEs towards reducing carbon emissions is related to board gender diversity.

Our study aims to examine the impact of board gender diversity on carbon emissions performance, particularly concerning Scope 3 emissions, and to evaluate the moderating effect of cultural environments on the relationship between board gender diversity and carbon emissions performance. Baseline results indicate that board gender diversity significantly enhances carbon emissions performance by reducing Scope 3 emissions. Supplementary analysis shows that this effect is both statistically and economically more pronounced for Scope 3 emissions than for Scope 1 and 2 emissions. The findings further reveal that a higher critical mass of female directors is required to meaningfully reduce Scope 3 emissions (four female directors) compared to Scope 1 and 2 emissions (three female directors). Additional analyses reveal that jurisdictions with higher board gender diversity, including Western Europe and North America, require greater female representation on corporate boards to effectively reduce carbon emissions compared with jurisdictions with lower board gender diversity, such as in Asia.

Furthermore, board gender diversity has a greater impact on reducing Scope 3 emissions in non-carbon-intensive industries than in carbon-intensive industries. Regarding cultural moderating effects, the findings indicate that the positive impact of board gender diversity on reducing Scope 3 emissions is more pronounced in cultures with higher uncertainty avoidance, long-term orientation, and greater indulgence. No significant moderating effects are found for the cultural dimensions of power distance, masculinity/femininity, and individualism/collectivism.

The rest of the paper has four parts. The literature review and hypotheses development are discussed in Section 2, followed by the research methodology in Section 3. The results are presented in Section 4, followed by a discussion of the study's key findings and implications in Section 5.

2. Literature review and hypotheses development

2.1. Theoretical framework

The study's main three theoretical frameworks are legitimacy theory, critical mass theory, and social facilitation theory. Legitimacy theory explains the motivation for corporate entities to address carbon emissions and environmental pollution through corporate governance mechanisms such as board gender diversity. Critical mass theory suggests that the number of female directors should be sufficient before they can appreciably reduce carbon emissions. Social facilitation theory reinforces the critical mass theory by suggesting that the presence of other female directors on the board can enhance a female director's performance (Kassin et al., 2019).

Legitimacy theory posits an implied social contract between society and organizations, as organizations are subsystems within the larger society (Dowling & Pfeffer, 1975). Once an organization is unable to demonstrate concern for society, it loses its legitimacy and may have no justifiable reason for its existence, as it no longer adds value. Legitimacy theory underpins organizations' environmental sustainability endeavors because stakeholders seek to assess compliance with the boundaries set by social norms and values (Mobus, 2005). Given the prevalence of environmental pollution, it is one critical area in which a great many organizations have not met societal expectations. The social contract between society and the organization appears to be in jeopardy in this regard. The demands on companies have shifted from primarily financial gains to greater concern for the community and the environment. Because organizations benefit from the resources provided by society, many believe that those gains should at least in part be used to improve the environment and the welfare of society. Therefore, it is not surprising that reducing carbon emissions is one of the key areas in which many stakeholders expect corporate ESG commitments (Kassinis et al., 2016; Orazalin et al., 2024).

The 'critical mass' terminology is borrowed from the nuclear physics discipline, and it refers to the amount of a substance needed to sustain a chain reaction (Reed, 2018). Within the context of sociology, critical mass theory explains the circumstances under which imitated, reciprocal, or widely adopted behaviors are initiated within collective groups, and how such behaviors become self-sustaining within a group (Chijoke-Mgbame et al., 2020). When a group of people adopts a common behavior, they constitute a 'critical mass' that can influence decisions and behaviors or bring about social change because of the strength of their numbers (Childs et al., 2008). Critical mass theory holds that interdependent decisions by a group of people can lead to collective action, as a critical, sizable number of people is needed to effect policy changes or bring about a revolution (You, 2021). Consequently, a reasonable number of female directors is required to constitute a critical mass on the board to effect changes in environmental sustainability matters such as carbon emissions (Birindelli et al., 2020; Chijoke-

Mgbame et al., 2020). Thus, highly gender-diverse boards with a reasonable number of women constituting a critical mass may be able to minimize carbon emissions and achieve better carbon emissions performance than less gender-diverse boards with a smaller number of female representatives.

The social facilitation theory, a branch of social psychology, explains how the presence of others affects an individual's performance in social settings (Kassin et al., 2019; Triplett, 1898). The real, imagined, or implied presence of others could either have the positive impact of facilitating an individual's performance (called social facilitation) or the negative impact of discouraging or impairing performance (referred to as social inhibition). When an individual is familiar with the task, social facilitation primarily occurs when it is performed in the presence of others, such as co-actors, competitors, or an audience. On the other hand, unfamiliarity with a task, lack of knowledge about an activity, or inability to perform a task can lead to social inhibition when such activities or tasks are carried out in the presence of others. Improved performance in the presence of others (i.e., social facilitation) is caused by co-action effects and audience effects (Xu et al., 2020). The co-action effect is a phenomenon in which increased task performance occurs due to the mere presence of others performing the same task (co-actors). This audience effect occurs when co-actors are present simultaneously with the presence of passive spectators or an audience (Li et al., 2022).

In relation to the discourse on board gender diversity and carbon emissions management, the presence of other female directors on the board can facilitate the performance of a female director (Kassin et al., 2019). However, for a female director to be influenced by the presence of other female directors, the number of females on the board of directors would have to be sufficient or at least reasonable (You, 2021). Research has indicated that women, on average, may exhibit higher levels of empathy and compassion (Nadeem et al., 2020; Haque et al., 2026). In this context, the presence of other female directors on a board could foster a more supportive environment in which a female director feels encouraged to contribute to discussions and decisions, including those related to reducing the environmental impact of organizational activities, such as carbon emissions. Taken together, it is expected that highly gender-diverse boards will facilitate female directors' performance in decision-making that minimizes an organization's carbon emissions. Thus, gender-diverse boards may perform better in reducing carbon emissions than boards with fewer female representatives.

2.2. Background on Scope 1, 2, and 3 emissions

Scope 3 emissions are now widely acknowledged as a key factor in corporate greenhouse gas (GHG) impact, prompting greater attention from businesses and policymakers (Butt et al., 2025). These emissions, which originate from activities outside a company's direct operations, such as supply chain processes, product use, and waste disposal, often constitute the largest share of an organization's total carbon footprint. Though the figure can vary by industry and company, Scope 3 emissions typically are the largest share of a corporation's GHG impact and account for around 90% of a company's total emissions (McKinsey & Company, 2024). In fact, Scope 3 emissions are estimated to be 5.5 times greater than the combined total of Scope 1 and Scope 2 emissions (Business for Social Responsibility (BSR), 2020).

Thus, Scope 3 emissions are increasingly recognized as more critical to address than Scope 1 and Scope 2 emissions. As a result, there has been a shift in focus from Scope 1 and Scope 2 emissions towards Scope 3 emissions. This aims to provide a more comprehensive assessment of corporate carbon risks and hold firms accountable for emissions across their entire supply chain (Gopalakrishnan et al., 2021). However, Scope 3 carbon emissions are considered significantly more complex and challenging to tackle than Scope 1 and 2 emissions (Busch et al., 2022), as they encompass the entire supply chain of a business and necessitate engagement with external stakeholders. Substantial operational effort is required to engage with a firm's suppliers to gather and evaluate relevant data (Patchell, 2018; Villena &

Dhanorkar, 2020) and to focus on complex lifecycle analyses to produce high-quality data (Busch et al., 2022; Villena & Dhanorkar, 2020).

It is acknowledged that Scope 3 emissions result from operations, activities, or assets not directly controlled by an organization (Deloitte, 2022). But as Scope 3 emission sources usually account for most of an organization's GHG emissions, they often offer significant opportunities for emissions reduction and organizations may still implement strategies to influence the activities that generate these emissions (United States (US) Environmental Protection Agency (EPA), 2025). Such strategies may include selecting suppliers with low carbon footprints, encouraging customers to reduce product-related emissions, specifying eco-friendly procurement standards, forming partnerships to develop low-carbon technologies, utilizing carbon-trading mechanisms, implementing recycling and circular economy practices (Butt et al., 2025; Hailemariam & Erdiaw-Kwasie, 2023; McKinsey & Company, 2024; Oyewo et al., 2025).

2.3. Hypotheses development

2.3.1. Impact of board gender diversity on carbon emissions performance

The roles of women in society typically differ from those of men. Women tend to adopt different prosocial behaviors than men. Prosocial behaviors consist of actions regarded as beneficial to others, including helping, sharing, comforting, guiding, rescuing, and defending others (Dovidio et al., 2017; Eagly, 2009). Prosocial behaviors can be directed towards either helping individuals or supporting the collective (Eagly, 2009). Compared to men, women are typically believed to be more communal and relational (i.e., friendly, unselfish, concerned with others, and emotionally expressive). Conversely, compared to women, men are frequently considered to be more agentic (i.e., masterful, assertive, competitive, and dominant) (e.g., Eagly, 2009; Spence & Buckner, 2000). This may explain why female directors' approaches to environmental issues, which are more collective-focused, often differ from those of their male counterparts (Adams & Funk, 2014; Liao et al., 2015). Consequently, female directors have been found to be proactive in formulating and implementing strategies that minimize environmental risks (Bear et al., 2010; Frias-Aceituno et al., 2012; Hollindale et al., 2017), This positively impacts environmental performance by reducing carbon emissions (García Martín & Herrero, 2020; Haque, 2017), including Scope 3 emissions.

Critical mass and social facilitation theories support the hypothesis that the presence of a reasonable number of female directors may enhance carbon emissions management. According to the social facilitation theory, the presence of other female directors (as the audience observing a fellow female director's actions) will bring an audience effect: a female director will more likely make decisions that align with the typically more compassionate nature of women in an attempt to meet the expectations of other observing female directors (Nuber & Velte, 2021). In effect, social facilitation theory reinforces the critical mass theory in positing that a high concentration of female directors enhances corporate environmental performance. Empirically, studies have shown that board gender diversity lowers corporate carbon emissions (Elsayih et al, 2021; Konadu et al., 2021; Moussa et al., 2020; Nuber & Velte, 2021; Tingbani et al., 2020) and that a critical mass of female board members has a positive influence on carbon emissions policies (Nuber & Velte, 2021). These discussions lead to the following hypotheses:

H1a: Greater board gender diversity enhances carbon emissions performance by reducing Scope 3 emissions rates.

H1b: A critical mass of female directors is needed to enhance carbon emissions performance by reducing Scope 3 emissions rates.

Based on the argument that women are often more stakeholder-focused, risk-averse, and ethically driven (Frias-Aceituno et al., 2012; Konadu et al., 2021), female directors can play an important role in steering the activities of the board towards these eco-friendly choices and emissions reduction strategies (Oyewo et al., 2025). Indeed, evidence exists that gender diversity improves carbon emissions performance (Elsayih et al, 2021; Moussa et al., 2020; Nuber & Velte, 2021; Tingbani et al., 2020). Female directors have been found to implement strategies that minimize environmental risks (Bear et al., 2010; Hollindale et al., 2017). Therefore, we argue that because of the increasing importance of tackling Scope 3 emissions, and the influence of female directors in corporate carbon footprint issues, more gender diverse boards will focus their efforts more on Scope 3 emissions than Scope 2 and 1 emissions. In addition, we posit that because of the challenges that Scope 3 emissions pose to corporations, a higher critical mass of female board members is needed to achieve better results than with Scope 1 and Scope 2 emissions. Previous studies have shown that a critical mass of people with specific expertise and understanding of a particular matter is needed when dealing with challenging tasks (Garcia-Meca et al., 2023; Sharma, 1999; Torchia et al., 2011). Therefore, we propose the following hypotheses.

H2a: The effect of board gender diversity on carbon emissions performance is likely to be higher for Scope 3 emissions rates than for Scope 2 and Scope 1 emissions.

H2b: A higher critical mass of female directors is needed to enhance carbon emissions performance in terms of reducing Scope 3 emissions rates in comparison to Scope 2 and Scope 1 emissions.

2.3.2. Moderating impact of cultural environment on the relationship between board gender diversity and carbon emissions performance

Previous research indicates that cultural dimensions may influence individuals' decisions in distinct ways (Tsai et al., 2020). We draw on Hofstede's cultural theoretical perspective to examine how culture can shape the way female directors influence Scope 3 carbon emissions. We focus on six cultural dimensions identified by Hofstede (1984, 1994, 2011; Gyapong & Afrifa, 2021), namely power distance, individualism/collectivism, masculinity/femininity, uncertainty avoidance, long-term orientation, and restraint/indulgence.

2.3.2.1. Power distance

Power distance, as conceptualized by Hofstede (1984, 1994), refers to the extent to which less powerful members of a society accept and expect that power is distributed unequally. In cultures characterized by high power distance, individuals are more likely to accept hierarchical structures and defer to authority figures without questioning their decisions. Conversely, in cultures with low power distance, there is a greater expectation for equality and less tolerance for hierarchical inequalities.

In societies with high power distance, such as many Asian and Middle Eastern countries, there is often greater acceptance of male dominance in leadership positions, including on corporate boards. Women may face significant challenges in breaking into these leadership roles due to entrenched norms that prioritize male authority and decision-making (Wang et al., 2021). Consequently, women in high power distance cultures may encounter barriers to entry and advancement on corporate boards, thereby limiting their representation and performance. Therefore, high power distance cultures might restrict the contribution of female directors to reducing carbon emissions.

Conversely, in cultures characterized by low power distance, such as many Scandinavian countries, there is less emphasis on rigid hierarchical structures and greater acceptance of egalitarian principles (Hofstede, 1984). In these cultures, women may find more opportunities to assert themselves and perform effectively on corporate boards, as there is less resistance to female leadership and decision-making (Javidan et al., 2016). Women may encounter fewer barriers to entry and advancement in such environments, leading to greater representation and participation on corporate boards.

H3a: High power distance culture negatively moderates the relationship between female directors and Scope 3 carbon emissions performance.

2.3.2.2. Uncertainty avoidance

Uncertainty avoidance indicates the degree to which members of a society feel threatened by ambiguous or unknown situations and try to reduce uncertainty through rules, regulations, and structured environments (Hofstede, 1984, 1994). In cultures with high uncertainty avoidance, there may be a preference for stability and predictability, which can lead to resistance to change and innovation, including the alteration of traditional gender roles. Consequently, women may face greater resistance when seeking to enter male-dominated fields such as corporate governance. Conversely, in cultures with low uncertainty avoidance, there is often greater openness to diversity and experimentation, creating opportunities for women to thrive on corporate boards.

H3b: High uncertainty avoidance culture negatively moderates the relationship between female directors and Scope 3 carbon emissions performance.

2.3.2.3. Individualism vs. collectivism

Individualism describes how much a society expects individuals to look after themselves and their immediate families, while collectivism highlights the importance of group cohesion and loyalty to the broader community. In individualistic cultures, such as those in Western countries, there tends to be more support for women's autonomy and self-expression, which can lead to greater opportunities for female representation and participation on corporate boards. As a result, an individualistic cultural environment may enable women directors to effectively reduce carbon emissions. Collectivism may also have a positive moderating influence, as collective societies might prioritize the collective's interests over individual concerns. Given that environmental issues are inherently collective and that women are often perceived as more communal and relational than men (Eagly, 2009; Spence & Buckner, 2000), in a collectivist cultural setting it is reasonable to expect that female directors could be more effective at reducing Scope 3 emissions. However, in collectivist cultures, women may also face stronger social pressures to conform to traditional gender roles and to prioritize family obligations over career advancement, which could limit their participation and effectiveness on corporate boards and in reducing carbon emissions. Therefore:

H3c: Individualistic culture positively moderates the relationship between female directors and Scope 3 carbon emissions performance.

2.3.2.4. Masculinity vs. femininity

Masculinity refers to the extent to which a society values traditionally masculine traits such as assertiveness, competitiveness, and achievement orientation (Hofstede, 1984, 1994). At the same time, femininity emphasizes the importance of nurturing, cooperation, and quality of life. In cultures with high masculinity, there may be stronger expectations for men to occupy leadership roles, and women may face greater barriers to advancement on corporate boards. Conversely, cultures with high femininity tend to be more supportive of women's participation in leadership positions and may value collaboration and consensus-building, thereby enhancing female performance on corporate boards and reducing carbon emissions.

H3d: Masculinity culture negatively moderates the relationship between female directors and Scope 3 carbon emissions performance.

2.3.2.5. Long-term vs. short-term orientation

Long-term orientation indicates the extent to which a society values long-term planning, persistence, and perseverance rather than short-term gratification and tradition. In cultures with this orientation, there may be a greater emphasis on investing in human capital and promoting gender equality to achieve sustainable economic growth and competitiveness.

As a result, women might receive more support for their participation and performance on corporate boards in such cultures. Conversely, in cultures with a short-term orientation, there may be a greater focus on immediate results and on maintaining traditional gender roles, which can hinder women's progress in corporate governance and reduce their influence on the firm's carbon emissions.

H3e: Long-term orientation culture positively moderates the relationship between female directors and Scope 3 carbon emissions performance.

2.3.2.6. Restraint vs. indulgence

Restraint cultures control the gratification of needs by ensuring strict compliance with social norms and by strictly prescribing gender roles. In contrast, indulgent cultures allow the free gratification of human desires for enjoying life and are characterized by loosely prescribed gender roles (Hofstede, 2011). In environments with a restraint culture, there may be greater acceptance of male dominance in leadership positions in order to maintain the status quo of 'breadwinning' assigned to men, whilst women accept their assigned 'home-making' roles. This can hinder women's advancement in corporate governance (Attah-Boakye et al., 2020), leading to less influence on the firm's carbon emissions performance. However, in societies with indulgent cultures, there may be greater emphasis on promoting gender equality to allow women to aspire and become, in order to fulfil their desire for self-achievement (Naghavi et al., 2021; Tsai et al., 2020). Consequently, women may find more support for their participation and performance on corporate boards in indulgent cultures, leading to more influence on the firm's carbon emissions performance.

H3f: Restraint culture negatively moderates the relationship between female directors and Scope 3 carbon emissions performance.

3. Method and data

3.1. Data sources

Data for this study are primarily sourced from the London Stock Exchange Group (LSEG) Datastream database (formerly Refinitiv/Datastream). An increasing number of studies utilize data extracted from reputable proprietary databases such as LSEG Datastream to measure environmental and financial performance (Doni et al., 2022).

Data collection spans a 15-year period from 2006 to 2020. The analysis focuses on the top 500 companies on the 2020 list of the Forbes Global 2,000. We exclude 160 financial services companies because the nature of their business operations and the regulatory framework for environmental management differ markedly from those of non-financial firms (Tingbani et al., 2020). Financial institutions have historically been excluded or treated differently in many Scope 3 analyses because their primary activities do not involve manufacturing or direct supply chains, but rather capital allocation. The GHG Protocol's original Scope 3 standard did not adequately capture "financed emissions", namely those emissions from the activities financed through lending, investment, and underwriting (UN Environment Program Finance Initiative (UNEP FI), 2015). This reduces our sample to 340 non-financial firms. After removing four companies with no available ESG data, the final sample is 336 firms. Due to firm-year observations with missing or incomplete data on carbon emissions and key corporate governance variables, the final sample has 4,550 firm year observations across 32 countries and five geographical regions.

Thus, the study examines firms drawn from a broad range of geographical regions to ensure international coverage and cross-regional comparability. The sample includes companies from the Americas (2,020 observations from Brazil, Canada, Mexico, and the US), the Asia Pacific region (1,310 observations from Australia, China, Hong Kong, India, Japan, Singapore, South Korea, Taiwan, and Thailand), Western Europe (1,093 observations from Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the

Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom), Russia (with 71 observations), and the Middle East (56 observations from Saudi Arabia and United Arab Emirates). This geographical diversity enhances the external validity of the analysis and allows the findings to reflect a wide range of institutional and economic contexts.

Additional data were collected from the World Bank on Institutional Quality (World Governance Indicators) and Economic Prosperity (Gross Domestic Product (GDP)). Data on cultural dimensions were obtained from Hofstede Insights.

3.2. Variables and measurement

3.2.1. Dependent variables.

Scope 3 Emissions Rate is our primary dependent variable, measured as total CO_2 and CO_2-equivalent Scope 3 emissions (in tons) (Baboukardos, 2017; Konadu et al., 2021). Our data from the LSEG Datastream database adheres to the GHG Protocol for emission classification.[2] The database includes the following gases in calculating total emissions: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorinated compounds (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

As an alternative measure, we also used the *Scope 3 Emissions Intensity*, calculated as the ratio of Scope 3 emissions to firm revenue (Elsayih et al., 2021; Luo & Tang, 2014). Both *Scope 3 Emissions Rate* and *Scope 3 Emissions Intensity* have negative polarity, meaning that lower values indicate better carbon emissions performance (Oyewo et al., 2025).

The *Scope 1 Emissions Rate* variable is the direct emissions from sources owned or controlled by the company, which are measured as direct CO_2 and CO_2-equivalent emissions in tons (Konadu et al., 2021). The *Scope 2 Emissions Rate* variable is the indirect emissions

[1] We recognize the difficulty of measuring Scope 3 emissions, given that these emissions do not originate from sources owned or directly controlled by the organization but are a result of activities within its supply chain (US EPA, 2025). However, since the LSEG Datastream database adheres to the GHG Protocol for quantifying Scope 3 emissions, this should minimize the potential inaccuracies inherent in measuring Scope 3 emissions.

from the consumption of purchased electricity, heat, or steam at the facility where they are generated, and is measured as tons of indirect CO_2 and CO_2-equivalent emissions (Konadu et al., 2021).

3.2.2. Independent Variables

Following previous studies, *Board Gender Diversity* is measured by the percentage of female directors on board of directors (Konadu et al., 2021; Tingbani et al., 2021). The concept of a critical mass of female directors is captured using four binary variables. *1+ Female Directors* is coded 1 if there is at least one female director on the board, and 0 otherwise (representing the first stage of critical mass in Model 1). *2+ Female Directors* is coded 1 if there are at least two female directors, , and 0 otherwise (Model 2). *3+ Female Directors* is coded 1 if there are at least three female directors, and 0 otherwise (Model 3) *4+ Female Directors* is coded 1 if there are at least four female directors, and 0 otherwise (Model 4). This approach aligns with prior studies that have examined the impact of critical mass in environmental accounting research (e.g., Cordeiro et al., 2020; Konadu et al., 2021; Nuber & Velte, 2021).

3.2.3. Moderating variables

As discussed in the Section 2.3.2, we draw on Hofstede's cultural theoretical perspective and use the Hofstede Cultural Index to measure cultural orientation across six dimensions: power distance (high vs. low), uncertainty avoidance (high vs. low), individualism vs. collectivism, masculinity vs. femininity, long-term vs. short-term orientation, and restraint vs. indulgence (Gyapong & Afrifa, 2021; Hofstede, 2011). Each of the six Hofstede cultural dimensions is measured on a scale from 1 to 100 (Hofstede Insights). Using the theoretical mean score of 50, on each cultural dimension, countries are coded 0 as low with scores up to 50 and coded 1 as high with scores of 51 and above. Using the above, we created the binary variables of *Power Distance*, *Uncertainty Avoidance*, *Individualism vs. Collectivism*, *Masculinity vs. Femininity*, *Long-term vs. Short-term Orientation*, and *Restraint vs. Indulgence*.

3.2.4. Control variables

We use five types of control variables: firm-level governance variables, firm characteristic variables, a firm specific SDGs Agenda variable, two country level control variables, and fixed effect variables.

We include firm-level governance variables as control variables, as prior literature suggests they influence a firm's environmental performance (Liao et al., 2015; Nuber & Velte, 2021; Uyar et al., 2022). These variables include board size (*Board Size*), board meetings (*Board Meetings*), board independence (*Board Independence*), Chief Executive Officer (CEO) duality is when the CEO also serves as the board chair (*CEO Duality*), sustainability-linked pay (*Sustainability-linked Pay*), and the presence of a sustainability committee (*Sustainability Committee*).

Additionally, we control for firm-specific characteristics that may affect the selection and implementation of environmental sustainability projects (Alexeyeva, 2024; Doni et al., 2021; Song & Rimmel, 2021), including revenue (*Firm Size*), market capitalization (*Firm Market Presence*), current ratio (*Firm Liquidity*), and return on assets (*Firm Profitability*).

Furthermore, to account for the potential impact of the 2030 Agenda for Sustainable Development, we include *SDGs Agenda*. *SDGs Agenda* is a dichotomous variable coded 1 if the firm mentions the SDGs.

Two country-level governance control variables are also incorporated. For economic prosperity we use *Economic Development*, measured as the log of GDP (Uyar et al., 2022). Our institutional quality variable is *Institutional Quality*, which is based on a factor analysis using the World Governance Indicators of Voice and Accountability, Political Stability and Lack of

Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption (Olajumoke et al., 2026). See Appendix C for details.

We also included firm and year fixed effect variables. A summary of variable measurement and data sources is presented in Table 1.

<Insert Table 1 about here>

3.3. Panel model and data analysis techniques

The regression model for our panel data is stated in Equation 1:

$$CARP_{i,t} = \alpha_0 + Board\ Gender\ Diversity_{i,t} + Controls_{i,t} + e_{i,t} \qquad \textbf{\textit{(Eq. 1)}}$$

$$i = 1,\ldots,N,\ \ t = 1\ldots.., T$$

where *CARP* represents the carbon emissions performance of firm *i,* at time *t*. *CARP* can be the variables *Scope 3 Emissions Rate*, *Scope 3 Emissions Intensity*, *Scope 1 Emissions Rate*, or *Scope 2 Emissions Intensity*. *Board Gender Diversity* represents board gender diversity, while *Controls* is the vector of control variables discussed in Section 3.2.4. $e_{i,t}$ represents the stochastic error term.

Descriptive statistics, multiple regression analysis with fixed-effect ordinary least squares (OLS), instrumental-variable (two-stage least squares, 2SLS) regression, and propensity score matching (PSM) were used to analyze the data.

4. Results and analysis

4.1 Descriptive statistics and correlation matrix

The descriptive statistics of variables are presented in Table 2. Results in Table 2 show that, as expected, the average *Scope 3 Emissions Rate* (M = 23,097,656.09 metric tons of CO_2) is higher than *Scope 1 Emissions Rate* (M = 7,273,378.10 metric tons of CO_2) and *Scope 2 Emissions Rate* (M = 1,467,227.46 metric tons of CO_2). This provides empirical evidence that

Scope 3 emissions offer significant opportunities for MNEs to reduce their carbon footprint. At 17%, the average percentage of female board members among firms is relatively low. However, the maximum score of 64% indicates that some firms maintain a high level of gender diversity with a larger proportion of female board members. On average, firms held nearly nine (8.54) board meetings per year. Boards are generally quite large, with an average of 12 directors and characterized by a higher level of independence. With 77% of board members being outside directors, this suggests that firms generally maintain a strong presence of independent directors. CEO duality appears to be a common practice at 53% of sample MNEs. In contrast, with only 31% of firms linking executive pay to sustainability performance, this is still an emerging practice. However, with 76% of boards already having a sustainability committee, it is a widespread governance practice.

<Insert Table 2 about here>

Overall, these findings regarding carbon emissions levels, board gender diversity, corporate governance practices, firm characteristics, and country level governance variables provide a robust context for exploring the research question among leading MNEs.

The Pearson correlation matrix in Table 3 shows that none of the correlation coefficients between the independent variables exceeds |0.80|. Therefore, multicollinearity is unlikely to pose a serious concern, as the correlations among variables are generally low (Tabachnick et al., 2007). We conduct multiple regressions on the independent variables to calculate the Variance Inflation Factors (VIFs) as an additional check for multicollinearity. In the results (analysis conducted but full results not tabulated), we find that for all regressions the VIF coefficients stay below 5.0 and within the recommended threshold of 10.0 (Kennedy, 1998). This indicates that the independent variables are moderately correlated (below 5.0), and multicollinearity is unlikely to be a concern.

<Insert Table 3 about here>

4.2. Impact of board gender diversity on carbon emissions performance: Baseline results

Table 4 reports the baseline results on the impact of board gender diversity on carbon emissions performance (Hypothesis H1a). The results using the main measurement (*Scope 3 Emissions Rate*) and alternative measurement (*Scope 3 Emissions Intensity*) are presented in Columns 1 and 2, respectively. To assess how board gender diversity directly affects emissions attributable to the firm, results on the impact on Scope 1 and Scope 2 emissions are shown in Columns 3 and 4, respectively (Hypothesis H2a).

<Insert Table 4 about here>

These findings indicate that board gender diversity has a significant negative relationship with Scope 3 emissions when using either the main measurement of *Scope 3 Emissions Rate* ($b = -0.721$, $p < 0.01$; Table 4, Column 1) or the alternative measurement of *Scope 3 Emissions Intensity* ($b = -0.748$, $p < 0.01$; Table 4, Column 2). These results support Hypothesis H1a and confirm that board gender diversity is an effective mechanism for reducing carbon emissions in MNEs (Elsayih et al., 2021; Konadu et al., 2021).

Further analysis on Scope 1 (Table 4, Column 3) and Scope 2 (Table 4, Column 4) emissions reveals a negative association with *Board Gender Diversity*. However, the effect is only significant for Scope 1 at $p < 0.10$ and not statistically significant for Scope 2. Although the relationship is negative across all Scope emission variables, our results show that board gender diversity has a greater impact on Scope 3 than on Scope 1, and no significant impact on Scope 2 emissions. In terms of economic significance, the impact of board gender diversity is higher for Scope 3 emissions: a 10-percentage-point increase in board gender diversity is associated with an approx 7% reduction in Scope 3 emissions, compared to an approx 0.9% reduction in Scope 1 emissions. This finding supports Hypothesis H2a and highlights the pivotal role of board gender diversity in managing supply chain-related emissions.

The greater effect of gender diversity on Scope 3 emissions than on Scope 1 and Scope 2 further supports the argument that women are more environmentally conscious and inclined to support sustainability initiatives. Female directors appear more committed to ensuring that MNEs go beyond reducing emissions under their direct control and addressing emissions associated with their value chains. MNEs play a significant role in global carbon emissions due to their extensive operations, supply chains, and cross-border investment flows. They often outsource production to countries with less stringent environmental regulations, thereby contributing to higher emissions in developing regions. Given that MNE investments in developing countries often shift emissions geographically rather than reducing them, board gender diversity is important for addressing Scope 3 carbon emissions issues.

Similar results emerge when board gender diversity is assessed using binary classifications representing different levels of critical mass. This approach evaluates the incremental influence of female presence on boards by using the variables *1+ Female Directors*, *2+ Female Directors*, *3+ Female Directors*, and *4+ Female Directors* in Models 1 through 4, respectively, in Table 5. We run four regression models using these binary classifications and apply controls across each. This method is consistent with previous studies on critical mass theory in environmental accounting (Cordeiro et al., 2020; Konadu et al., 2021; Nuber & Velte, 2021).

<insert Table 5 about here>

In Table 5, Panel A (*Scope 3 Emissions Rate*), Columns 1, 2, and 3 are not statistically significant. However, in Column 4, where a critical mass of at least four female directors is considered, the coefficient is negative and statistically significant ($b = -0.151$, $p < 0.01$). This result implies that a critical mass of at least four female directors is necessary to achieve a meaningful reduction in Scope 3 emissions in MNEs. The economic significance of this finding is notable: the coefficient suggests that the presence of at least four female board members results in an approx 14% reduction in the *Scope 3 Emissions Rate*, further emphasizing the importance of reaching this threshold to meaningfully impact Scope 3 emissions.

Results in Table 5, Panel B, Column 3 reveal that a critical mass of at least three female directors is required to significantly diminish *Scope 1 Emissions Rate* ($b = -0.035$, $p < 0.01$). This is consistent with the results in Table 5, Panel C, Column 3, which indicate that a critical mass of at least three female directors is required to reduce *Scope 2 Emissions Rate* ($b = -0.034$, $p < 0.05$). Taken together, these results support Hypothesis H1b: a critical mass of four female directors is needed to reduce Scope 3 emissions significantly. They also support Hypothesis H2b, which posits that Scope 3 emissions require a higher critical mass of female directors (four) compared to Scope 1 and Scope 2 emissions (three each).

These findings provide empirical support for both the critical mass theory and social facilitation theory, which argue that a substantial presence of female directors enhances board effectiveness and influence over sustainability practices (Nuber & Velte, 2021). While previous research suggests that a critical mass of at least two female directors can reduce emissions directly attributable to the firm (Scope 1), this study reveals that a higher threshold of four is needed to influence the more complex and externally linked Scope 3 emissions. This underscores the need for greater gender representation on boards of MNEs to effectively address environmental impacts along the value chain. The voluntary nature of carbon emissions reporting requires that effective corporate governance mechanisms be put in place if the goal is to seriously address Scope 3 emissions. Meanwhile, board gender diversity is important for achieving emissions reduction in MNEs because boards with more women tend to have stronger monitoring and risk management practices, which are essential for firms with global operations.

4.3. Moderating impact of cultural environments on the relationship between board gender diversity and carbon emissions performance

To evaluate all six parts of Hypotheses 3 on the impact of MNEs' cultural environments on the relationship between board gender diversity and carbon emissions performance , we conduct an additional analysis in which board gender diversity is interacted with each of Hofstede's six cultural dimensions. The results presented in Table 6 report the moderating effects of the six cultural dimensions examined.

<insert Table 6 about here>

Column 1 of Table 6 presents the moderating effect of *Power Distance* on the relationship between *Board Gender Diversity* and *Scope 3 Emissions Rate*. The coefficient for *Board Gender Diversity* is negative and statistically significant (b = -0.697, $p < 0.05$). The interaction term between *Board Gender Diversity* and *Power Distance* is also negative but not statistically significant. This indicates that board gender diversity is associated with lower Scope 3 emissions, regardless of the level of power distance. Consequently, Hypothesis H3a is rejected.

The moderating effect of uncertainty avoidance is reported in Column 2 of Table 6. The results indicate that *Board Gender Diversity* does not have a statistically significant effect on *Scope 3 Emission Rates* in countries with low uncertainty avoidance. However, the interaction term is negative and statistically significant (b = -0.818, $p < 0.05$), suggesting that the negative association between *Board Gender Diversity* and *Scope 3 Emissions Rate* is observed only in countries with higher uncertainty avoidance. Therefore, Hypothesis H3b is also rejected. A plausible explanation for this finding is that cultures characterized by high uncertainty avoidance tend to be more risk-averse (Beugelsdijk & Frijns, 2010; Kwok & Tadesse, 2006) and try to avoid potential threats, including environmental and climate-related risks. Organizations operating within such cultural contexts are more likely to prioritize risk management practices and respond more actively to environmental concerns. As a result, gender-diverse boards in these settings may find a more responsive environment for implementing carbon-reduction strategies. This finding aligns with prior research (e.g., Mohsni et al., 2021), which shows that high uncertainty avoidance strengthens the association between board gender diversity and the adoption of risk-mitigating strategies. In contrast, in low uncertainty avoidance cultures where there is greater tolerance for ambiguity and risk, organizations may not perceive climate-related issues as threats requiring immediate intervention. Consequently, in these contexts, the influence of gender-diverse boards on the promotion of proactive environmental strategies may be diminished. This might explain the lack of a statistically significant relationship between *Board Gender Diversity* and *Scope 3 Emissions Rate* in low uncertainty avoidance settings.

Column 3 of Table 6 presents the results of the moderating effect of *Individualism vs. Collectivism* on the relationship between *Board Gender Diversity* and the *Scope 3 Emissions Rate*. The coefficient for *Board Gender Diversity* is negative and statistically significant ($b = -1.335$, $p < 0.05$), while the interaction term between *Board Gender Diversity* and *Individualism vs. Collectivism* is positive but not statistically significant. This suggests that board gender diversity contributes to reducing Scope 3 emissions in both individualistic and collectivist cultural contexts. Consequently, Hypothesis H3c is rejected.

The analysis of the moderating effect of *Masculinity vs. Femininity* is reported in Column 4 of Table 6. The coefficient for *Board Gender Diversity* is negative and statistically significant ($b = -1.050$, $p < 0.01$), whereas the interaction term between *Board Gender Diversity* and *Masculinity vs. Femininity* is positive but not statistically significant. This suggests that board gender diversity reduces Scope 3 emissions in cultures characterized by both masculinity and femininity. Hence, Hypothesis H3d is rejected.

The moderating effect of *Long-term vs. Short-term Orientation* is presented in Column 5 of Table 6. The findings show a non-significant negative effect of *Board Gender Diversity* on *Scope 3 Emissions Rate* in countries with a short-term orientation. However, the interaction term is negative and statistically significant (b = -0.909, $p < 0.05$), suggesting that the negative association between board gender diversity and Scope 3 emissions is significant only in countries with a long-term orientation. Therefore, Hypothesis H3e is supported. In societies that prioritize long-term goals, such as sustainability, female directors may find a more favorable environment for promoting environmental responsibility and carbon management strategies. These cultures are more likely to embrace long-term value creation, making Scope 3 emission reductions more of a strategic priority rather than a regulatory burden. In this context, gender-diverse boards are more likely to influence corporate decisions that align with sustainability objectives (Naghavi et al., 2021; Tsai et al., 2020). By contrast, in short-term-oriented cultures where the focus is often on short-term results, there may be less appetite for investing in initiatives, such as Scope 3 emissions reduction, that require a long-term vision and sustained effort. As a result, the presence of female directors who encourage sustainable practices may not be sufficient to overcome the broader cultural emphasis on short-term gains. Thus, the effectiveness of board gender diversity in driving environmental performance is limited.

Finally, Column 6 of Table 6 reports the results of the moderating effect of *Indulgence vs. Restraint*. The findings indicate a non-significant negative association between *Board Gender Diversity* and *Scope 3 Emissions Rates* in countries characterized by restrained cultures. The interaction term between *Board Gender Diversity* and *Indulgence vs. Restraint* is negative and statistically significant (b = -0.853, $p < 0.05$). This suggests that board gender diversity reduces Scope 3 emissions only in cultures characterized by indulgence. This finding supports Hypothesis H3f, suggesting that in indulgent cultures there is a stronger cultural foundation for proactive engagement in environmental strategies. As these cultures are typically more open to innovation, progressive social norms, and gender equality, female board members may face fewer institutional barriers and consequently are more empowered to advocate for long-term, strategic initiatives, such as Scope 3 emissions reduction (Naghavi et al., 2021; Tsai et al., 2020). In contrast, restraint cultures, which tend to emphasize social norms, controlled behavior, and a more conservative approach to change, may be less receptive to gender equality and environmental innovation, thereby limiting the ability of female directors to influence board decisions on sustainability. This might explain the lack of a statistically significant relationship between board gender diversity and Scope 3 emission levels and restraint cultures.

4.4. Additional analyses and robustness tests

4.4.1 Board gender diversity and carbon emissions performance analysis based on geographical regions

Given that gender diversity and female representation on top management teams vary across countries (Jamal, 2018; Kolev & McNamara, 2022), we conduct further subsample analyses by geographical region. We focused on the three regions that accounted for over 90% of the sample: Americas, Asia Pacific, and Western Europe. Descriptive statistics for the three largest geographical regions are presented in Appendix A. Using *Scope 3 Emissions Rate* as the dependent variable, Table 7 reports the results using *Board Gender Diversity* as the main independent variable, whereas Table 8 reports our supplementary analysis on critical mass for female director influence.

<insert Table 7 about here>

<insert Table 8 about here>

The results in Table 7 show that the impact of board gender diversity on carbon emissions performance is negative and statistically significant in the Asia Pacific (b = -2.755,

$p < 0.01$) and Western Europe regions ($b = -0.425$, $p < 0.10$), but not significant in the Americas region.

Results in Table 8 show that in the Americas region, a critical mass of at least four female directors is required to reduce Scope 3 emissions significantly (Column 4). In the Asia Pacific region, although a critical mass of at least three female directors is required (Column 7), the impact of board gender diversity on reducing Scope 3 emissions is higher when there are at least four female directors (Column 8). In Western Europe, a critical mass of at least four female directors is required to reduce Scope 3 emissions significantly (Column 12).

The results in Table 8 are generally consistent with those in Table 5, Panel A, indicating that a critical mass of at least four female directors is required to reduce Scope 3 emissions significantly. However, the result that a critical mass of at least three female directors is required in the Asia Pacific region (with a mean gender diversity rate of 7.27%) in comparison to a critical mass of at least four female directors in Americas (with a mean gender diversity rate of 20.52%) and Western Europe regions (with a mean gender diversity rate of 23.75%). This reveals that jurisdictions with higher board gender diversity rates require more female directors/female representation on senior management team to reduce carbon emissions. This should not be interpreted as suggesting that women alone drive emission reductions. Rather, it reflects the interaction between board composition, institutional expectations, and the organizational complexity of managing Scope 3 emissions. In contexts where organizational gender diversity and sustainability governance are more mature and where stakeholder expectations are higher, a greater collective presence of women may be necessary for their perspectives to translate into board-level influence.

The critical mass theory posits that a reasonable number of female directors is required to constitute a critical mass on the board in effecting changes on environmental sustainability matters (Birindelli et al., 2020; Chijoke-Mgbame et al., 2020). Our results empirically validate that in MNEs, highly gender-diverse boards with a reasonable number of women constituting a critical mass may be able to better minimize carbon emissions and achieve lower carbon emissions in comparison to less gender-diverse boards.

4.4.2. Board gender diversity and carbon emissions performance in carbon-intensive and non-carbon-intensive industries

Noting that levels of carbon emissions and overall environmental pollution vary by industry, further sample analysis was carried out by disaggregating results by the carbon intensity of the industries in which MNEs operate. Following the approach adopted in prior studies (e.g., Baboukardos, 2017; Konadu et al., 2021), companies were classified into carbon-intensive and non-carbon-intensive industries. Industries such as industrial products, materials, energy, and utilities are grouped into carbon-intensive sectors due to their high emissions intensity. In contrast, industries such as health care, technology, consumer products, real estate, and telecom are classified as non-carbon intensive.

The analysis was rerun using the main (*Scope 3 Emissions Rate*) and alternative (*Scope 3 Emissions Intensity*) measurements as reported in Table 9. Results for carbon-intensive industries are presented in Columns 1 and 2, while those of non-carbon-intensive sectors are presented in Columns 3 and 4.

<insert Table 9 about here>

Results show that board gender diversity has a significant negative impact on carbon emissions under both rate and intensity measures of Scope 3 carbon emissions management in carbon-intensive and non-carbon-intensive industries. This is consistent with the result in Table 4, suggesting that our baseline results are robust to subsample analysis based on industry carbon emissions intensity. A closer examination of our Table 9 results shows that board gender diversity has a greater impact on reducing carbon emissions in non-carbon-intensive industries ($b = -1.030$, $p < 0.01$) than in carbon-intensive industries ($b = -0.583$, $p < 0.05$). This can be traced to higher board gender diversity in non-carbon-intensive industries (average of 19.10%) than in carbon-intensive industries (average of 16.19%). This result corroborates the argument that improving board gender diversity could be an effective strategy for reducing Scope 3 emissions in the supply chain.

4.4.3. Treatment of endogeneity

The literature (Konadu et al., 2021) suggests that there may be endogeneity between board gender diversity and carbon emissions performance. To address this concern, we employ two-stage least squares (2SLS) regression (Elsayih et al., 2021; Ullah et al., 2021) and propensity score matching (PSM) regression (Tawiah et al., 2022).

In applying two-stage least squares (2SLS), we follow prior literature by using the variable *Industry Board Gender Diversity* as an instrument for firm-level board gender diversity (Solal & Snellman, 2019). Specifically, the instrument is constructed using industry classifications provided by the LSEG (Refinitiv) database and employs a leave-one-out approach, whereby the industry-level measure is calculated as the average board gender diversity of all other firms within the same industry, excluding the focal firm. Each firm is then assigned this leave-one-out industry average. This approach mitigates concerns that the instrument may be mechanically correlated with the firm-level measure. Given the broad industry coverage within the Refinitiv dataset, the resulting instrument provides sufficient variation for the empirical analysis. It is expected to be correlated with firm-level board gender diversity, while remaining plausibly exogenous to firm-specific outcomes, thereby satisfying the relevance and exclusion restrictions required for a valid instrument.

The results of the first and second stages of the 2SLS are reported in Columns 1 and 2 in Table 10. The main result (stage two) of the 2SLS indicates that board gender diversity continues to have a significant negative impact on Scope 3 emissions.

<insert Table 10 here>

In applying the PSM (Table 11), we split the sample into treatment and control groups based on the median score for board gender diversity. The variable *Board Gender Diversity Dummy* is coded 1 for the treatment group, which comprises companies with board gender diversity greater than the median, and coded 0 for the control group, which comprises companies with board gender diversity equal to or less than the median. In the first stage of the PSM technique (Table 11, Column 7), propensity scores of board gender diversity (pscores) were derived by regressing *Board Gender Diversity Dummy* on covariates using nearest neighbor/ greedy matching (Tawiah et al., 2022). We then matched each observation in the treatment group (high gender diversity) with one in the control group (low gender diversity) that had the closest propensity score within the maximum caliper distance of 0.005. The matching procedure reduced the number of observations to equal counts in the treatment (1,577) and control groups (1,577), yielding a total of 3,154 observations applied in the second stage.

<insert Table 11 here>

We conduct pre-matching (Columns 1 to 3 of Panel A) and post-matching (Columns 4 to 6 of Panel B) tests to verify that the matching procedure reduces differences in the attributes of the two groups. At the pre-matching stage, there are significant differences in the attributes (i.e., mean scores) of the treatment (Column 1) and control (Column 2) groups, as revealed by the t statistics (Column 3). After matching (Columns 4 to 6), the mean differences in attributes between the two groups are no longer significant, indicating that the PSM procedure successfully eliminates observable differences between the two groups.

In the second stage of the PSM technique, we substituted the pscores for the endogenous variable using the *Scope 3 Emissions Rate* (Column 8) as the dependent variable. Results show that board gender diversity is still significantly and negatively associated with carbon emissions performance. Overall, the results reported in Table 11 (Column 8) are consistent with the baseline results (Table 4), establishing that our results are robust to endogeneity concerns.

4.4.4. Treatment of sample selection bias

Estimating the scale of Scope 3 emissions is characteristically complex, resource-intensive, and time-consuming (Deloitte, 2022), and it is unlikely that all sample companies report or disclose information on Scope 3 emissions. Further, for MNEs that disclose scope emissions, it is unlikely they will disclose information for each of the 15 years under investigation. This could give rise to sample selection bias. To address this issue and assess the robustness of our results to sample selection bias, we employ a two-step Heckman procedure (Heckman, 1979; Tawiah et al., 2024), as reported in Table 12.

<insert Table 12 here>

In the first stage (reported in Column 1), the disclosure of Scope 3 emissions is modelled using a probit model. We define the *Scope 3 Emissions Dummy* as 1 if a company in our sample reported Scope 3 emissions in a given year and 0 otherwise. To satisfy the exclusion criterion in the first stage of the Heckman procedure, according to which there should be at least one independent variable that is included in the selection equation but not in the outcome equation (Heckman, 1979), we use *Industry Board Gender Diversity* (i.e., industry-level board gender diversity) as our instrumental variable. We then regress *Scope 3 Emissions Dummy* on the instrumental variable and control variables to derive the Inverse Mills ratio as shown in Table 12 (Column 1). In the second stage (reported in Columns 2 and 3), we regress the main dependent variable *Scope 3 Emissions Rate* (Column 2) and an alternative measurement of the dependent variable *Scope 3 Emissions Intensity* (Column 3), on *Board Gender Diversity* and the Inverse Mills ratio derived from the first stage, along with control variables.

The first-stage Heckman selection equation is estimated using the full sample comprising 5,040 firm-year observations, as reported in column (1). This stage captures the determinants of selection into the outcome equation and is therefore estimated prior to restricting the sample. In contrast, the second-stage outcome equations, reported in columns (2) and (3), are estimated on the restricted subsample of 4,550 firm-year observations for which Scope 3 emissions data are available. This reduction in sample size reflects the availability of non-missing outcome data required for the estimation of Scope 3 emissions measures, and the outcome models are thus conditioned on this selected subsample consistent with the Heckman correction framework. The results of both models confirm a significant negative impact of board gender diversity on Scope 3 emissions (Table 12, Columns 2 and 3). We conclude that our baseline result is robust to sample selection bias.

4.4.5. Sensitivity analysis: Moderating impact of cultural environment on the relationship between board gender diversity and carbon emissions performance

In Table 6, we categorized countries into cultural dimensions based on whether their Hofstede scores were 51-100 (high) or 0-50 (low). To assess the sensitivity of our results to the alternative classification method, we use the mean score to split each cultural dimension into two parts: high (> mean) or low (≤ mean) (García-Sánchez et al., 2013). The mean scores for the dimensions are 49.48 for Power Distance, 55.34 for Uncertainty Avoidance, 68.39 for Individualism vs. Collectivism, 60.78 for Masculinity vs. Femininity, 50.80 for Long-term vs. Short-term Orientation, and 54.32 for Indulgence vs. Restraint. We reran the interaction analysis using these classification criteria, and the results are reported in Table 13.

<insert Table 13 here>

The results reported in Table 13 are also identical to those of Table 6 for power distance, masculinity vs. femininity, long-term vs. short-term orientation, and indulgence vs. restraint. This corroborates the baseline results on the influence of these cultural dimensions on carbon emissions reduction. Some differences emerged regarding uncertainty avoidance and individualism vs. collectivism. Specifically, in relation to uncertainty avoidance, Table 6 shows that *Board Gender Diversity* has no significant effect on *Scope 3 Emissions Rate* on its own, with only the interaction term *Board Gender Diversity* and *Uncertainty Avoidance* being significantly negative, indicating that board gender diversity can reduce scope 3 emissions only in countries with high uncertainty avoidance. In contrast, Table 13 demonstrates that both the main effect of *Board Gender Diversity* and its interaction with *Uncertainty Avoidance* are negatively significant, suggesting that board gender diversity is effective in reducing scope 3 emissions in both contexts characterized by high and low uncertainty avoidance. Regarding the cultural dimension of individualism vs. collectivism, both Table 6 and Table 13 show a significant negative main effect of *Board Gender Diversity* on *Scope 3 Emissions Rate*. However, the interaction term with *Individualism vs. Collectivism* is positive and statistically significant only in Table 13, indicating that the significant effect of *Board Gender Diversity* on *Scope 3 Emissions Rate* is weaker in countries with an individualistic cultural context.

We acknowledge the limitations of using the actual mean score to categorize countries into cultural dimensions, as this may produce inconsistent results compared to using the theoretical mean. However, the consistency observed across most cultural dimensions confirms that our results are overall robust to alternative measurements of the cultural variables.

5. Conclusions

In this study, we employ several econometric models on large MNEs to show that board gender diversity enhances carbon emissions performance by significantly reducing Scope 3 emissions. Compared with Scope 1 and 2 emissions, our results show that the impact of gender diversity is more pronounced for Scope 3 emissions, which aligns with the argument that women are more eco-conscious and oriented toward the greater good of society. Consistent with prior studies (Abbasi et al., 2024), this study found that board gender diversity has a greater impact on reducing carbon emissions in non-carbon-intensive industries than in carbon-intensive industries.

Regarding the cultural context, we find that the masculinity vs. femininity dichotomy, power distance, and individualism vs. collectivism do not significantly moderate the negative relationship between board gender diversity and Scope 3 emissions. However, cultures characterized by high uncertainty avoidance, long-term orientation, and indulgence are found to strengthen the positive impact of board gender diversity on Scope 3 carbon emissions reduction.

This study makes significant contributions to both the academic literature and practical policy on corporate governance and environmental sustainability. First, we expand the literature on gender diversity and carbon emissions (e.g., Abbasi et al., 2024; Elsayih et al., 2021; Konadu et al., 2021; Liao et al., 2015; Nuber & Velte, 2021; Tingbani et al., 2020). While existing studies highlight the positive role of female directors, they mainly concentrate on carbon disclosure, regulatory aspects, or Scope 1 and Scope 2 emissions. By exploring the under-investigated link between board gender diversity and Scope 3 emissions, this research enhances our understanding of how board composition affects broader environmental objectives. Our study provides solid empirical evidence supporting the idea that board gender diversity is not only a matter of social equity, but also a strategic tool for improving environmental performance that can lead to both financial and non-financial benefits (Mahmoudian et al., 2023; Nadeem et al., 2021). We show that a critical mass of at least four female directors is necessary to achieve significant reductions in Scope 3 emissions, thereby underlining the importance of substantial female representation on corporate boards.

Second, this study makes significant contributions to the literature on board diversity in MNEs by focusing on carbon emission performance. With few exceptions (e.g., Barroso et al., 2024; Konadu et al., 2021; Nuber & Velte, 2021), most research on board gender diversity in MNEs has concentrated on examining its effects on financial performance, corporate social responsibility (CSR) disclosure, corporate innovation, or governance quality (Attah-Boakye et al., 2020; Chijoke-Mgbame et al., 2020; Frias-Aceituno et al., 2012; García-Meca et al., 2024). Our study goes beyond these performance outcomes and contributes to this literature by illustrating the influence of board gender diversity on the specific environmental performance measure of carbon emissions performance, and particularly Scope 1, 2, and 3 emissions. While previous research on board gender diversity and emissions reduction mainly focused on Scope 1 and Scope 2 emissions (e.g., Elsayih et al., 2021; Konadu, 2021; Nuber & Velte, 2021), there remained a significant gap in understanding how these dynamics relate to Scope 3 emissions. By drawing attention to this underexplored area, this study advances the literature by broadening the discussion on corporate environmental accountability and revealing the broader implications of board gender diversity as a vital component of board composition that can affect indirect emissions throughout an organization's value chain.

Third, our study contributes to the literature on informal institutions in accounting research (Leventis et al., 2024; Orij, 2010; Sarhan et al., 2024; Tsakumis et al., 2007). While prior studies emphasize the relevance of culture in influencing firm outcomes, they have largely overlooked carbon emissions and, more importantly, the intersection between national culture and board gender diversity. Responding to the call by Leventis et al. (2024), we explore how multiple informal institutions, namely, gender and culture, jointly influence accounting-related outcomes, such as carbon emissions. Our findings underscore the importance of cultural context in shaping the effectiveness of gender-diverse boards, with implications for sustainability reporting and international accounting standards. In particular, we find that cultures characterized by high uncertainty avoidance, long-term orientation, and indulgence amplify the positive impact of board gender diversity on emissions reduction. This contributes to the emerging literature at the intersection of culture, governance, and environmental performance by offering insights into how international accounting practices might be adapted to reflect cultural variations in sustainability disclosures and performance metrics. Furthermore, our findings suggest that gender-diverse boards, especially within culturally supportive environments, can enhance carbon emissions reductions. This has broader implications for environmental accountability and the evolution of international sustainability standards that account for cultural diversity.

Fourth, the study offers meaningful contributions to critical mass theory by empirically demonstrating that a substantial presence of female directors is necessary to drive meaningful environmental outcomes, particularly in complex areas such as Scope 3 emissions. It also extends Hofstede's cultural dimensions theory by illustrating how national cultural characteristics can either facilitate or constrain the effectiveness of gender-diverse boards in achieving sustainability goals. These insights suggest that corporate governance strategies should be tailored to cultural contexts to maximize the impact of gender diversity on environmental performance, thereby deepening our understanding of how gender and culture interact within global sustainability efforts.

Despite its contributions, this study has some limitations. Our focus on large MNEs may limit the generalizability of the findings to smaller companies or firms in less developed markets. Measuring Scope 3 emissions is challenging, and even though we used estimates from the LSEG Datastream database which adheres to the GHG Protocol, inaccuracies in our measurements may persist. Future studies may consider alternative data sources for measuring Scope 3 emissions. We also acknowledge that the traditional binary approach used to code the critical mass of female directors does not account for regional differences in board size. Since the influence of female directors may depend on board size, with smaller boards requiring fewer women to exert influence, this approach could introduce bias. Future research should consider dynamic measures that account for variations in board size. Furthermore, we recognize that since cultural dimensions were assessed at the national level, they may not fully capture the diversity of cultural influences within individual countries or organizations.

Future studies could examine how board gender diversity affects carbon emissions in a broader range of organizational contexts, including small and medium-sized enterprises (SMEs) and firms in developing economies. Longitudinal research tracking changes in board composition and emissions performance over time could offer deeper insights into the causal dynamics. Additionally, future studies might explore the mechanisms by which gender-diverse boards influence emissions performance, including decision-making processes, risk management practices, and stakeholder engagement strategies. Qualitative approaches, such as case studies or interviews with board members, could complement quantitative analyses by offering a richer understanding of these mechanisms. Finally, given the significant moderating role of cultural factors identified in this study, future research should explore how organizational cultures, beyond national cultural dimensions, affect the relationship between board gender diversity and environmental performance. This could include examining how internal values, leadership styles, and employee engagement influence the effectiveness of gender-diverse boards in achieving sustainability objectives.

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Table 1
Variable definitions and their measurement.

Variables	Measurement/ Supporting Literature
Dependent variables	
Scope 3 Emissions Rate	Measured as log of Scope 3 carbon emissions in metric tons (Baboukardos, 2017).
Scope 3 Emissions Intensity	Computed as the ratio of Scope 3 carbon emissions to revenue (Elsayih et al, 2021; Mahmoudian et al., 2023; Nuber & Velte, 2021).
Scope 2 Emissions Rate	Measured as log of Scope 2 carbon emissions in metric tons (Konadu et al., 2021).
Scope 1 Emissions Rate	Measured as log of Scope 1 carbon emissions in metric tons (Konadu et al., 2021).
Independent variables	
Board Gender Diversity	Percentage of board members that are female (Tingbani et al., 2021).
1+ Female Directors	Binary variable coded 1 if there is at least one female director on the board, and 0 otherwise (representing the first stage of critical mass in Model 1) (Cordeiro et al., 2020; Nuber & Velte, 2021).
2+ Female Directors	Binary variable coded 1 if there are at least two female directors (the second stage of critical mass), and 0 otherwise (Model 2) (Cordeiro et al., 2020; Nuber & Velte, 2021).
3+ Female Directors	Binary variable coded 1 if there are at least three female directors (the third stage of critical mass), and 0 otherwise (Model 3) (Cordeiro et al., 2020; Nuber & Velte, 2021).
4+ Female Directors	Binary variable coded 1 if there are at least four female directors (the fourth stage of critical mass), and 0 otherwise (Model 4) (Cordeiro et al., 2020; Nuber & Velte, 2021).
Firm-level Governance control variables	
Board Size	Number of directors on the board (Nuber & Velte, 2021).
Board Meetings	Total number of board meetings held in a year (Disli et al., 2022).
Board Independence	Percentage of independent directors on the board (Elsayih et al., 2021).
CEO Duality	Binary variable coded 1 if the CEO functions as Board Chair, and 0 otherwise (Nuskiya et al, 2021).
Sustainability-linked Pay	Binary variable coded 1 if payment or compensation of executive board members is connected to sustainability performance, and 0 otherwise (Lu & Wang, 2021).
Sustainability Committee	Binary variable coded 1 if Sustainability Committee exists in a year, and 0 otherwise (Elsayih et al., 2021).
Firm characteristic control variables	
Firm Size	Log of firm revenue (Peel, 2018).
Firm Market Presence	Log of Market capitalization (Elsayih et al., 2021).
Firm Liquidity	Current Ratio computed as current assets to current liabilities (Mahmoudian et al., 2023; Tingbani et al, 2020).
Firm Profitability	Return on Assets ratio computed as pre-interest, pre-tax operating profit (EBIT) divided by average total assets (Song & Rimmel, 2021).
SDGs Agenda	Binary variable coded 1 if presence of SDGs on agenda in a year, starting from 2016-2020, and 0 otherwise.
Country Governance control variables	
Economic Development	Log of Gross Domestic Product (GDP) (Nuber & Velte, 2021).

Institutional Quality	Factor analysis of six World Governance Indicators: Voice and Accountability, Political Stability and Lack of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption (Cuadrado-Ballesteros & Bisogno, 2020). See Appendix C for more details.
Hofstede Cultural Dimension Moderating variables	
Power Distance	Hofstede Cultural Dimension binary variable coded 1 as High with scores of 51 to 100 and coded 0 as Low with scores from 0 to 50.
Uncertainty Avoidance	Hofstede Cultural Dimension binary variable coded 1 as High with scores of 51 to 100 and coded 0 as Low with scores from 0 to 50.
Individualism vs. Collectivism	Hofstede Cultural Dimension binary variable coded 1 as Individualism with scores of 51 to 100 and coded 0 as Collectivism with scores from 0 to 50.
Masculinity vs. Femininity	Hofstede Cultural Dimension binary variable coded 1 as Masculinity with scores of 51 to 100 and coded 0 as Femininity with scores from 0 to 50.
Long-term vs. Short-term Orientation	Hofstede Cultural Dimension binary variable coded 1 as Long-term Orientation with scores of 51 to 100 and coded 0 as Short-term Orientation with scores from 0 to 50.
Indulgence vs. Restraint	Hofstede Cultural Dimension binary variable coded 1 as Indulgence with scores of 51 to 100 and coded 0 as Restraint with scores from 0 to 50.

Table 2
Descriptive statistics of main variables.

Variable	Minimum	Maximum	Median	Mean	Standard Deviation
Scope 3 Emissions Rate (Tons per annum)	78,049.00	1,637,000,000.00	5,078,450.00	23,097,656.09	95,347,008.73
Scope 3 Emissions Intensity (Tons per annum)	4.04	49,212.45	162.25	397.77	1,823.92
Scope 1 Emissions Rate (Tons per annum)	11,591.00	255,161,000.00	174,565.30	7,273,378.10	22,878,490.77
Scope 2 Emissions Rate (Tons per annum)	624.29	69,726,400.00	268,334.50	1,467,227.46	3,887,583.58
Board Gender Diversity	0.08	0.64	0.17	0.17	0.13
Board Size	5.00	20.00	12.57	12.02	3.477
Board Meetings	4.00	14.00	8.00	8.54	6.06
Board Independence	0.05	1.00	0.85	0.77	0.29
CEO Duality	0.00	1.00	1.00	0.53	0.50
Sustainability-linked Pay	0.00	1.00	0.00	0.31	0.46
Sustainability Committee	0.00	1.00	1.00	0.76	0.43
Firm Size (US dollars in millions)	179.90	572,754.00	27,739.00	48,385.31	61,007.64
Firm Market Presence (US dollars in millions)	97.32	2,428,612.00	37,050.50	71,045.30	126,489.09
Firm Liquidity	0.09	31.84	1.29	1.58	1.28
Firm Profitability	0.00	65.15	7.52	9.48	7.81
Economic Development (in US dollars)	3,237.29	117,500.21	47,099.98	44,634.21	15,370.92
Institutional Quality	27.39	97.66	82.13	80.09	11.07
Power Distance	18.00	95.00	40.00	49.48	16.35
Uncertainty Avoidance	8.00	99.00	46.00	55.34	26.62
Individualism vs. Collectivism	17.00	91.00	80.00	68.39	21.02
Masculinity vs. Femininity	5.00	95.00	62.00	60.78	17.22
Long-term vs. Short-term Orientation	0.00	100.00	36.00	50.80	26.97
Indulgence vs. Restraint	0.00	97.00	68.00	54.32	17.89

Note: See Table 1 for variable definitions.

Table 3

Pearson Correlation matrix.

	SC3	SCR	SC1	SC2	BGD	CM1	CM2	CM3	CM4	BDS	BDM	BIN	CCD	SLP	SCM	FSZ	MKP	LQD	PRF	PWD	IDV	MSC	UAV	LTO	IDG	ECD	INQ
SC3	1																										
SCR	0.953***	1																									
SC1	0.490***	0.413***	1																								
SC2	0.305***	0.163***	0.575***	1																							
BGD	0.142***	0.144***	-0.016	-0.153***	1																						
CM1	0.100**	0.104***	-0.032	-0.143***	0.830***	1																					
CM2	0.129***	0.119***	0.010	-0.103***	0.863***	0.910***	1																				
CM3	0.138***	0.115***	0.018	-0.104***	0.833***	0.759***	0.834***	1																			
CM4	0.172***	0.148***	0.084**	-0.069*	0.748***	0.521***	0.573***	0.686***	1																		
BDS	0.196***	0.138***	0.178***	0.014	0.241***	0.277***	0.306***	0.389***	0.444***	1																	
BDM	0.085**	0.066*	0.089**	0.042	-0.072*	-0.132***	-0.114***	-0.073*	-0.024	0.007	1																
BIN	0.108***	0.094**	0.103***	-0.090**	0.574***	0.640***	0.626***	0.569***	0.418***	0.222***	-0.163***	1															
CCD	-0.028	-0.026	-0.043	0.004	0.041	0.057	0.044	0.020	-0.014	-0.042	0.025	-0.024	1														
SLP	0.154***	0.115***	0.211***	0.083**	0.289***	0.276***	0.287***	0.281***	0.204***	0.129***	0.044	0.338***	-0.071*	1													
SCM	0.134***	0.106***	0.041	0.036	-0.005	-0.039	-0.045	-0.039	0.055	0.038	-0.008	-0.034	-0.003	0.064*	1												
FSZ	0.381***	0.088**	0.348***	0.508***	0.019	0.003	0.055	0.094**	0.104***	0.216***	0.082**	0.067*	-0.010	0.149***	0.118***	1											
MKP	0.202***	0.078*	0.001	0.197***	0.233***	0.273***	0.297***	0.257***	0.108***	-0.006	-0.011	0.194***	0.024	0.129***	0.040	0.449***	1										
LQD	-0.134***	-0.064*	-0.249***	-0.108***	-0.213***	-0.151***	-0.194***	-0.281***	-0.270***	-0.129***	-0.098**	-0.175***	0.075*	-0.161***	0.051	-0.227***	0.077*	1									
PRF	-0.193***	-0.136***	-0.328***	-0.178***	-0.002	0.064*	0.041	-0.048	-0.209***	-0.278***	-0.136***	0.011	0.071*	-0.034	-0.031	-0.188***	0.364***	0.334***	1								
PWD	-0.003	-0.025	0.113***	0.103***	-0.279***	-0.393***	-0.397***	-0.311***	-0.124***	-0.019	0.144***	-0.246***	0.201***	-0.087**	-0.018	0.066*	-0.192***	0.042	-0.127***	1							
IDV	-0.031	-0.009	-0.093**	-0.145***	0.592***	0.663***	0.668***	0.543***	0.308***	0.042	-0.012	0.467***	0.052	0.267***	-0.056	-0.076*	0.314***	-0.057	0.160***	-0.632***	1						
MSC	-0.009	-0.001	-0.129***	-0.019	-0.231***	-0.168***	-0.185***	-0.210***	-0.221***	0.024	0.079*	-0.408***	0.087**	-0.188***	0.057	-0.024	0.036	0.119***	0.056	-0.174***	0.080*	1					
UAV	0.074*	0.039	0.152***	0.121***	-0.328***	-0.469***	-0.437***	-0.320***	-0.098**	0.153***	0.160***	-0.372***	0.108***	-0.119***	0.077*	0.125***	-0.269***	-0.003	-0.257***	0.678***	-0.666***	0.074*	1				
LTO	0.085**	0.035	0.107***	0.136***	-0.474***	-0.598***	-0.560***	-0.436***	-0.164***	0.110***	0.050	-0.445***	-0.153***	-0.168***	0.092**	0.171***	-0.280***	-0.041	-0.295***	0.450***	-0.797***	0.076*	0.719***	1			
IDG	-0.031	0.014	-0.118***	-0.122***	0.458***	0.554***	0.541***	0.423***	0.177***	-0.110***	-0.080*	0.321***	0.064*	0.179***	-0.046	-0.141***	0.298***	0.022	0.212***	-0.644***	0.835***	-0.007	-0.691***	-0.810***	1		
ECD	-0.062*	-0.043	-0.103***	-0.084**	0.145***	0.232***	0.238***	0.116***	-0.004	-0.056	-0.040	0.098**	0.310***	-0.071*	-0.054	-0.056	0.253***	0.159***	0.216***	-0.199***	0.490***	0.393***	-0.310***	-0.457***	0.396***	1	
INQ	-0.076*	-0.072*	-0.165***	-0.080*	0.216***	0.232***	0.252***	0.210***	0.155***	0.094**	-0.127***	0.008	-0.090**	0.088**	0.005	-0.046	0.010	-0.099**	-0.078*	-0.631***	0.357***	0.149***	-0.234***	-0.052	0.363***	-0.108***	1

Notes: See Table 1 for variable definitions. **Variable codes**: SC3 = Scope 3 Emissions Rate; SCR = Scope 3 Emissions Intensity; SC1 = Scope 1 Emissions Rate; SC2 = Scope 2 Emissions Rate; BGD = Board Gender Diversity; CM1 = critical mass of 1+ Female Directors; CM2 = critical mass of 2+ Female Directors; CM3 = critical mass of 3+ Female Directors; CM4 = critical mass of 4+ Female Directors; BDS = Board Size; BDM = Board Meetings; BIN = Board Independence; CCD = CEO Duality; SLP = Sustainability-linked Pay; SCM = Sustainability Committee; FSZ = Firm Size; MKP = Firm Market Presence; LQD = Firm Liquidity; PRF = Firm Profitability; PWD = Power Distance; IDV = Individualism vs. Collectivism; MSC = Masculinity vs. Femininity; UAV = Uncertainty Avoidance; LTO = Long-term vs. Short-term Orientation; IDG = Indulgence vs, Restraint; ECD = Economic Development; INQ = Institutional Quality. *** p<0.01, ** p<0.05, * p<0.10.

Table 4
Baseline results on impact of board gender diversity on carbon emissions performance.

	(1)	(2)	(3)	(4)
Variable	**Scope 3 Emissions Rate**	**Scope 3 Emissions Intensity**	**Scope 1 Emissions Rate**	**Scope 2 Emissions Rate**
Board Gender Diversity	-0.721*** (0.229)	-0.748*** (0.228)	-0.093* (.054)	-0.103 (.065)
Firm-level Governance (control)				
Board Size	0.003 (0.007)	0.004 (0.008)	0.001 (0.002)	0.001 (0.002)
Board Meetings	0.003 (0.004)	0.004 (0.004)	-0.001 (0.001)	-0.002 (0.001)
Board Independence	0.458*** (0.155)	0.498*** (0.154)	0.085** (0.035)	0.069 (0.043)
CEO Duality	-0.068 (0.056)	-0.049 (0.055)	0.002 (0.013)	-0.032** (0.016)
Sustainability-linked Pay	-0.034 (0.037)	-0.044 (0.037)	-0.014 (0.009)	0.003 (0.011)
Sustainability Committee	-0.069 (0.081)	-0.085 (0.078)	0.014 (0.015)	-0.031* (0.018)
Firm characteristics (control)				
Firm Size	0.502*** (0.159)	-0.346** (0.156)	0.662*** (0.036)	0.608*** (0.045)
Firm Market Presence	0.306*** (0.111)	0.257** (0.110)	-0.034 (0.024)	0.013 (0.030)
Firm Liquidity	0.016 (0.031)	0.015 (0.031)	-0.001 (0.008)	0.016* (0.008)
Firm Profitability	-0.007** (0.004)	-0.005 (0.004)	-0.004*** (0.001)	-0.004** (0.001)
SDGs Agenda	0.181*** (0.049)	0.199*** (0.049)	-0.028** (0.012)	0.007 (0.015)
Country Governance (control)				
Economic Development	4.489*** (0.453)	4.270*** (0.450)	-0.068 (0.103)	-0.440*** (0.128)
Institutional Quality	-0.005 (0.008)	-0.008 (0.008)	0.006** (0.002)	0.013*** (0.002)
Firm Fixed Effect	YES	YES	YES	YES
Year Fixed Effect	YES	YES	YES	YES
R^2	0.277	0.229	0.146	0.103
Observations	4,550	4,550	4,550	4,550

Notes: See Table 1 for variable definitions. Standard error in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 5
Impact of female director(s) critical mass on carbon emissions performance.

Panel A: Impact on Scope 3 Emissions

	Dependent Variable: Scope 3 Emissions Rate			
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
	(1)	**(2)**	**(3)**	**(4)**
1+ Female Directors	0.046 (0.075)			
2+ Female Directors		-0.070 (0.064)		
3+ Female Directors			-0.013 (0.060)	
4+ Female Directors				-0.151*** (0.057)
Firm-level Governance (control)	YES	YES	YES	YES
Firm characteristics (control)	YES	YES	YES	YES
SDGs Agenda	YES	YES	YES	YES
Country Governance (control)	YES	YES	YES	YES
Firm Effect	YES	YES	YES	YES
Year Effect	YES	YES	YES	YES
R^2	0.285	0.304	0.261	0.286
Observations	4,550	4,550	4,550	4,550

Panel B: Impact on Scope 1 Emissions

	Dependent Variable: Scope 1 Emissions Rate			
Variable	**(1)**	**(2)**	**(3)**	**(4)**
1+ Female Directors	-0.007 (0.015)			
2+ Female Directors		-0.015 (0.014)		
3+ Female Directors			-0.035*** (0.014)	
4+ Female Directors				-0.048*** (0.022)
Firm-level Governance (control)	YES	YES	YES	YES
Firm characteristics (control)	YES	YES	YES	YES
SDGs Agenda	YES	YES	YES	YES
Country Governance (control)	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES
Year Fixed Effect	YES	YES	YES	YES
R^2	0.148	0.135	0.148	0.152
Observations	4,550	4,550	4,550	4,550

Panel C: Impact on Scope 2 Emissions

	Dependent Variable: Scope 2 Emissions Rate			
Variable	**(1)**	**(2)**	**(3)**	**(4)**
1+ Female Directors	0.009			

	(0.020)			
2+ Female Directors		-0.022 (0.018)		
3+ Female Directors			-0.034** (0.016)	
4+ Female Directors				-0.037** (0.012)
Firm-level Governance (control)	YES	YES	YES	YES
Firm characteristics (control)	YES	YES	YES	YES
SDGs Agenda	YES	YES	YES	YES
Country Governance (control)	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES
Year Fixed Effect	YES	YES	YES	YES
R^2	0.086	0.104	0.106	0.115
Observations	4,550	4,550	4,550	4,550

Note: See Table 1 for variable definitions. Standard error in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 6
Moderating impact of cultural environment on the relationship between board gender diversity and carbon emissions performance.

	Dependent Variable: Scope 3 Emissions Rate					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Power Distance	**Uncertainty Avoidance**	**Individualism vs, collectivism**	**Masculinity vs. Femininity**	**Long-term vs. Short-term orientation**	**Indulgence vs. Restraint**
Board Gender Diversity	-0.697** (0.277)	-0.232 (0.322)	-1.335** (0.609)	-1.050*** (0.327)	-0.157 (0.329)	-0.554 (0.560)
Board Gender Diversity × Power Distance	-0.113 (0.352)					
Board Gender Diversity × Uncertainty Avoidance		-0.818** (0.359)				
Board Gender Diversity × Individualism/ Collectivism			0.650 (0.622)			
Board Gender Diversity × Masculinity/ Femininity				0.474 (0.363)		
Board Gender Diversity × Long-term vs. Short- term Orientation					-0.909** (0.364)	
Board Gender Diversity × Indulgence vs. Restraint						-0.853** (0.349)
Firm-level Governance (control)	YES	YES	YES	YES	YES	YES
Firm characteristics (control)	YES	YES	YES	YES	YES	YES
SDGs Agenda	YES	YES	YES	YES	YES	YES
Country Governance (control)	YES	YES	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES	YES	YES
Year Fixed Effect	YES	YES	YES	YES	YES	YES
R^2	0.279	0.281	0.277	0.279	0.281	0.282
Observations	4,550	4,550	4,550	4,550	4,550	4,550

Note: See Table 1 for variable definitions. Standard error in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 7
Geographical analysis of impact of board gender diversity on carbon emissions performance.

	Dependent Variable: Scope 3 Emissions Rate		
	(1)	**(2)**	**(3)**
Variable	**Americas**	**Asia Pacific**	**Western Europe**
Board Gender Diversity	-0.073 (0.406)	-2.755*** (0.637)	-0.425* (0.311)
Firm-level Governance (control)			
Board Size	-0.011 (0.016)	0.010 (0.011)	0.003 (0.014)
Board Meetings	0.022*** (0.008)	0.004 (0.008)	-0.008 (0.007)
Board Independence	0.108 (0.476)	1.066*** (0.269)	0.225 (0.207)
CEO Duality	0.122 (0.107)	-0.120 (0.088)	-0.002 (0.103)
Sustainability-linked Pay	-0.072 (0.059)	0.081 (0.111)	-0.029 (0.055)
Sustainability Committee	-0.057 (0.111)	-0.050 (0.202)	-0.050 (0.146)
Firm characteristics (control)	YES	YES	YES
SDGs Agenda	YES	YES	YES
Country Governance (control)	YES	YES	YES
Firm Fixed Effect	YES	YES	YES
Year Fixed Effect	YES	YES	YES
R^2	0.353	0.304	0.234
Observations	2,020	1,310	1,093

Note: See Table 1 for variable definitions. Standard error in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 8

Geographical analysis of impact of female director(s) critical mass on carbon emissions performance.

	Dependent Variable: Scope 3 Emissions Rate											
	Americas Region				**Asia Pacific Region**				**Western Europe Region**			
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
1+ Female Directors	0.165 (0.188)				-0.138 (0.112)				0.133 (0.114)			
2+ Female Directors		0.034 (0.101)				-0.141 (0.128)				-0.051 (0.088)		
3+ Female Directors			0.109 (0.083)				-0.426** (0.200)				-0.067 (0.089)	
4+ Female Directors				-0.117** (0.077)				-0.483* (0.272)				-0.167* (0.092)
Firm-level Governance (control)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm characteristics (control)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
SDGs Agenda	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country Governance (control)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.386	0.391	0.336	0.351	0.225	0.266	0.285	0.289	0.219	0.271	0.237	0.260
Observations	2,020	2,020	2,020	2,020	1,310	1,310	1,310	1,310	1,093	1,093	1,093	1,093

Note: See Table 1 for variable definitions. Standard error in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 9
Impact of board gender diversity on carbon emissions performance in carbon-intensive versus non-carbon-intensive industries.

	Carbon-intensive industries		Non-Carbon-intensive industries	
	(1)	**(2)**	**(3)**	**(4)**
Variable	**Scope 3 Emissions Rate**	**Scope 3 Emissions Intensity**	**Scope 3 Emissions Rate**	**Scope 3 Emissions Intensity**
Board Gender Diversity	-0.583** (0.292)	-0.638** (0.289)	-1.030*** (0.362)	-0.996*** (0.362)
Firm-level Governance (control)				
Board Size	-0.001 (0.009)	-0.001 (0.008)	0.003 (0.016)	0.003 (0.016)
Board Meetings	0.003 (0.005)	0.004 (0.005)	0.007 (0.009)	0.007 (0.009)
Board Independence	0.605*** (0.198)	0.657*** (0.197)	0.319 (0.242)	0.318 (0.242)
CEO Duality	0.011 (0.073)	0.034 (0.071)	-0.150* (0.085)	-0.147* (0.085)
Sustainability-linked Pay	-0.057 (0.046)	-0.075 (0.046)	0.035 (0.062)	0.037 (0.063)
Sustainability Committee	0.004 (0.108)	-0.024 (0.105)	-0.159 (0.114)	-0.167 (0.115)
Firm characteristics (control)	YES	YES	YES	YES
SDGs Agenda	YES	YES	YES	YES
Country Governance (control)	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES
Year Fixed Effect	YES	YES	YES	YES
R^2	0.282	0.239	0.301	0.241
Observations	3,229	3,229	1,251	1,251

Note: See Table 1 for variable definitions. Standard error in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 10
Two-stage least squares (2SLS) regression analysis results.

	Two-Stage least squares (2SLS)	
	(1)	**(2)**
Variable	Board Gender Diversity	Scope 3 Emissions Rate
Industry Board Gender Diversity	0.158*** (0.012)	-
Board Gender Diversity (predicted)	-	-1.798** (0.341)
Firm-level Governance (control)		
Board Size	0.017 (0.031)	0.023 (0.152)
Board Meetings	0.006*** (0.001)	0.004 (0.005)
Board Independence	0.077*** (0.009)	0.517*** (0.142)
CEO Duality	0.007* (0.003)	-0.050 (0.056)
Sustainability-linked Pay	0.008*** (0.002)	-0.020 (0.040)
Sustainability Committee	0.002 (0.003)	-0.059 (0.080)
Firm characteristics (control)	YES	YES
SDGs Agenda	YES	YES
Country Governance (control)	YES	YES
Firm Fixed Effect	YES	YES
Year Fixed Effect	YES	YES
R^2	0.422	0.273
Observations	4,550	4,550

Note: *Industry Board Gender Diversity* represents Industry-level board gender diversity and is defined as the leave-one-out average proportion of female directors across all firms within the same industry, based on Refinitiv industry classifications. Specifically, for each firm, the measure is computed as the average share of female directors on corporate boards of all other firms in the same industry, excluding the focal firm, and is then assigned to that firm as its industry-level value. See Table 1 for other variable definitions. Standard error in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 11

Propensity score matching (PSM).

	Pre-match sample univariate analysis of Treatment group and Control group			Post-match sample univariate analysis of Treatment group and Control group			**1st stage of PSM**	**2nd stage of PSM**
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	Treatment group (Mean)	Control group (Mean)	(t statistic) Compares Mean of Treatment and Control	Treatment group (Mean)	Control Group (Mean)	(t statistic) Compares Mean of Treatment and Control	Dependent Variable = Board Gender Diversity Dummy	Dependent Variable = Scope 3 Emissions Rate
Scope 3 Emissions Rate	6.281	6.187	-1.572*	6.330	6.229	-1.681**	-	-
Board Gender Diversity (pscore)	-	-	-	-	-	-	-	-0.808*** (0.281)
Board Size	12.341	12.864	3.509***	12.558	12.561	0.221	0.212*** (0.008)	0.011 (0.009)
Board Meetings	8.440	8.640	1.509*	8.600	8.612	0.502	0.198*** (0.006)	0.002 (0.003)
Board Independence	.855	.672	-29.399***	.864	.859	-0.297	2.577*** (0.192)	.728*** (0.194)
CEO Duality	.560	.490	-4.905***	.550	.548	-0.248	0.134** (0.066)	-0.027 (0.057)
Sustainability-linked Pay	.420	.180	-18.454***	.510	.507	-0.409	0.385*** (0.075)	-0.001 (0.040)
Sustainability Committee	.810	.690	-9.817***	.940	.943	0.591	-0.212 (0.150)	-0.086 (0.081)
Firm size	4.488	4.422	-4.935***	4.536	4.534	-0.091	-0.386*** (0.105)	0.539*** (0.155)
Firm Market Presence	4.708	4.488	-17.109***	4.782	4.779	-0.089	0.593*** (0.117)	0.357** (0.119)
Firm Liquidity	1.504	1.663	4.159***	1.427	1.431	0.296	-0.082** (0.036)	0.009 (0.029)
Firm Profitability	9.967	8.950	-4.400***	9.773	9.768	-0.266	0.319*** (0.081)	0.232*** (0.074)
SDGs Agenda	-	-	-	-	-	-	YES	YES
Country Governance (control)	-	-	-	-	-	-	YES	YES
Firm Fixed Effect	-	-	-	-	-	-	NO	YES
Year Fixed Effect	-	-	-	-	-	-	YES	YES
Pseudo R^2							0.323	-
R^2	-	-	-	-	-	-	-	0.284
Observations	2,194	2,356	-	1,577	1,577	-	4,550	3,154

Note: *Board Gender Diversity Dummy* is coded 1 for the treatment group, which comprises companies with board gender diversity greater than the median, and coded 0 for the control group, which comprises companies with board gender diversity equal to or less than the median. See Table 1 for other variable definitions. Coefficients are reported, with standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 12
Heckman two-stage procedure.

	(1)	(2)	(3)
	1st Stage	**2nd Stage using main measurement of Dependent Variable**	**2nd Stage using alternative measurement of Dependent Variable**
Variable	**Scope 3 Emissions Dummy**	**Scope 3 Emissions Rate**	**Scope 3 Emissions Intensity**
Industry Board Gender Diversity	0.051*** (0.006)	-	-
Board Gender Diversity	-	-0.744*** (0.226)	-0.771*** (0.228)
Inverse Mills ratio	-	-0.235*** (0.087)	-0.233*** (0.058)
Firm-level Governance (control)			
Board Size	0.051*** (0.007)	0.002 (0.004)	0.003 (0.001)
Board Meetings	0.006* (0.004)	0.003 (0.004)	0.003 (0.004)
Board Independence	-0.143 (0.102)	0.454*** (0.153)	0.495*** (0.153)
CEO Duality	-0.076* (0.043)	-0.057 (0.055)	-0.039 (0.054)
Sustainability-linked Pay	0.524*** (0.049)	-0.058 (0.075)	-0.060 (0.075)
Sustainability Committee	1.381*** (0.062)	-0.147 (0.234)	-0.135 (0.233)
Firm characteristics (control)			
Firm Size	-0.048 (0.065)	0.485*** (0.158)	-0.359** (0.156)
Firm Market Presence	0.220*** (0.069)	0.293** (0.112)	0.254** (0.114)
Firm Liquidity	0.011 (0.019)	0.014 (0.031)	0.014 (0.031)
Firm Profitability	-0.001 (0.003)	-0.010* (0.005)	-0.005 (0.004)
SDGs Agenda	0.314*** (0.046)	0.163*** (0.060)	0.185*** (0.060)
Country Governance (control)			
Economic Development	0.685*** (0.133)	5.282*** (0.527)	5.026*** (0.524)
Institutional Quality	0.003 (0.002)	-0.010 (0.008)	-0.013 (0.008)
Firm Fixed Effect	NO	YES	YES
Year Fixed Effect	YES	YES	YES
Pseudo R^2	0.220	-	-
R^2	-	0.279	0.232
Observations	5,040	4,550	4,550

Note: *Scope 3 Emissions Dummy* is coded 1 if a company reported Scope 3 emissions in a given year, and

0 otherwise. The first-stage Heckman selection equation is estimated using the full sample of 5,040 firm-year observations. The second-stage outcome equations are estimated on the selected subsample of 4,550 firm-year observations for which Scope 3 emissions data are available. See Table 1 for other variable definitions. Standard error in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 13
Moderating impact of cultural environment on the relationship between board gender diversity and carbon emissions performance, using mean score to split into high and low cultural orientation.

	Dependent Variable: Scope 3 Emissions Rate					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Power Distance	**Uncertainty Avoidance**	**Individualism vs. Collectivism**	**Masculinity vs. Femininity**	**Long-term vs. Short-term Orientation**	**Indulgence vs. Restraint**
Board Gender Diversity.	-0.697** (0.277)	-0.546* (0.283)	-1.335*** (0.608)	-1.050*** (0.327)	-0.157 (0.329)	-0.199 (0.295)
Board Gender Diversity × Power Distance	-0.113 (0.352)					
Board Gender Diversity × Uncertainty Avoidance		-0.418*** (0.151)				
Board Gender Diversity × Individualism vs. Collectivism			0.965** (0.422)			
Board Gender Diversity × Masculinity vs. Femininity				0.474 (0.363)		
Board Gender Diversity × Long-term vs. Short- term Orientation					-0.909** (0.363)	
Board Gender Diversity × Indulgence vs. Restraint						-0.853** (0.350)
Firm-level Governance (control)	YES	YES	YES	YES	YES	YES
Firm characteristics (control)	YES	YES	YES	YES	YES	YES
SDGs Agenda	YES	YES	YES	YES	YES	YES
Country Governance (control)	YES	YES	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES	YES	YES
Year Fixed Effect	YES	YES	YES	YES	YES	YES
R^2	0.279	0.281	0.280	0.279	0.281	0.281
Observations	4,550	4,550	4,550	4,550	4,550	4,550

Note: See Table 1 for variable definitions. Standard error in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Appendix A.
Descriptive statistics by geographical regions.

	Americas Region		Asia Pacific Region		Western Europe Region	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Scope 3 Emissions Rate (Tons per annum)	14,982,450	72,925,470	14,406,393	60,131,289	47,919,676	142,700,000
Scope 3 Emissions Intensity (per annum)	355.135	2,196.887	253.62	1,144.783	661.037	1,733.852
Scope 1 Emissions Rate (Tons per annum)	5,769,956.5	18,699,692	3,601,737.9	19,054,106	12,785,243	29,440,545
Scope 2 Emissions Rate (Tons per annum)	1,078,129	2,062,117	1,282,152.8	3,954,646.5	1,833,494.8	3,223,662.3
Board Gender Diversity	.205	.096	.073	.096	.238	.139
Board Size	11.572	2.22	11.69	4.351	13.401	3.911
Board Meetings	8.052	3.444	8.649	5.552	8.446	4.064
Board Independence	.86	.098	.536	.248	.868	.176
CEO Duality	.701	.458	.49	.5	.302	.459
Sustainability-linked Pay	.372	.484	.09	.286	.455	.498
Sustainability Committee	.73	.444	.724	.447	.881	.324
Firm Size (in millions of US dollars)	46,606.699	64,997.666	45,423.72	55,757.9	54,242.377	58,909.979
Firm Market Presence (in millions of US dollars)	91,474.806	157,045.72	45,837.552	67,980.53	60,172.167	50,601.903
Firm Liquidity	1.71	1.59	1.639	1.072	1.224	.473
Firm Profitability	10.618	7.749	8.809	7.815	7.885	7.251
Economic Development (in US dollars)	53,178.761	8,575.221	31,223.806	16,112.294	45,720.906	12,127.926
Institutional Quality	81.287	6.104	77.887	10.127	85.526	7.211
Power Distance	40.63	4.750	63.53	12.915	43.91	15.320
Uncertainty Avoidance	46.77	4.571	61.39	28.879	60.10	21.579
Individualism vs. Collectivism	89.27	8.223	35.65	19.360	73.17	10.398
Masculinity vs. Femininity	61.34	2.740	70.96	19.992	49.31	21.066
Long-term vs. Short-term Orientation	26.77	3.049	79.73	20.477	59.78	16.055
Indulgence vs. Restraint	68.06	2.564	34.74	13.567	55.38	13.351
Observations	2,020		1,310		1,093	

Note: See Table 1 for variable definitions.

Appendix B.
Sample selection and construction.

	Number
Initial sample of top firms from the 2020 Forbes Global 2000.	500
Less: Financial service firms	160
Less: Firms with no environmental, social, and governance (ESG) data	4
Number of firms in final sample	336
Number of years in study period (2006 to 2020)	15
Expected firm-year observations (336 × 15)	5,040
Less: firm-year observations with missing or incomplete data on emissions and/or corporate governance variables	490
Final firm-year observations analyzed	**4,550**

Notes: This table reports the construction of the final firm-year sample. Firm-year observations with missing or incomplete data on carbon emissions and key corporate governance variables were excluded, resulting in a final sample of 4,550 firm-year observations. The resulting dataset constitutes an unbalanced panel, which is appropriate for longitudinal analyses where firm coverage varies over time and is commonly employed in international accounting research

Appendix C. Exploratory factor analysis results for *Institutional Quality* variable.

To calculate our *Institutional Quality* variable, which represents the governance quality construct, we used the six governance indicators of Voice and Accountability, Political Stability and Lack of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption from the World Bank. The factor analysis results illustrated in the tables below provide evidence for the construct validity of the underlying latent variable. The first factor explains a large proportion of the total variance (78%), and all six observed variables load strongly on it with loadings above 0.74. This indicates that it measures a common underlying construct. Uniqueness values are low for most variables, suggesting minimal variance remains unexplained. The clear separation between Factor 1 and subsequent factors, along with a significant Likelihood Ratio (LR) test, further supports that the variables coherently reflect a single dimension of *Institutional Quality*. The factor analysis provides empirical support that the scale captures the concept it is designed to measure. Overall, the high loadings and substantial variance explained indicate good construct validity. The Kaiser-Meyer-Olkin (KMO) measures indicate excellent sampling adequacy for factor analysis. Individual KMO values for all variables range from 0.837 to 0.955, and the overall KMO is 0.888, well above the recommended threshold of 0.6. These results suggest that the correlations among variables are sufficiently strong and suitable for identifying underlying latent constructs. High KMO values reinforce that the selected indicators reliably reflect a common factor, further supporting the construct validity of the scale.

Table C.1
Exploratory factor analysis summary.

Analysis	**Details**
Number of observations	4,550
Method	Principal-component factors
Rotation	Unrotated

Analysis	Details
Retained factors	1
Number of parameters	6
LR test (independent vs. saturated)	$\chi^2(15) = 32{,}000$, $p < 0.001$

Table C.2
Eigenvalues and variance explained.

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	4.68985	4.15074	0.7816	0.7816
Factor 2	0.53912	0.16725	0.0899	0.8715
Factor 3	0.37187	0.09779	0.0620	0.9335
Factor 4	0.27407	0.19571	0.0457	0.9792
Factor 5	0.07837	0.03165	0.0131	0.9922
Factor 6	0.04672	–	0.0078	1.0000

Table C.3
Factor loadings and uniqueness.

Variable	Factor 1 Loading	Uniqueness
Voice and Accountability	0.8725	0.2388
Political Stability and Lack of Violence	0.7426	0.4485
Government Effectiveness	0.9573	0.0835
Regulatory Quality	0.9409	0.1148
Rule of Law	0.9633	0.0721
Control of Corruption	0.8047	0.3524

Table C.4
Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy

Variable	KMO
Voice and Accountability	0.9191
Political Stability and Lack of Violence	0.9165
Government Effectiveness	0.8368

Variable	KMO
Regulatory Quality	0.9098
Rule of Law	0.8445
Control of Corruption	0.9551
Overall	0.8880