Board Gender Diversity, Environmental Innovation and Corporate Carbon Emissions

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Ethical Statement

Authors Renata Konadu, Gabriel Sam Ahinful, Danquah Jeff Boakye and Hany Elbardan declare that they have no conflict of interest associated with this research.

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Abstract

This article investigates how the board diversity affects firms' carbon emissions reduction and whether environmental innovation moderates this relationship. In addition, the moderating effect of environmental innovation in carbon-intensive versus non-carbon-intensive industries is also examined. Using data of the companies listed on the Standards & Poor's 500 index from 2002-2018, the 2SLS regression results indicate a statistically significant negative relationship between board gender diversity and carbon emissions. Environmental innovation amplifies the extent of this relationship. We find evidence that the moderation effect of environmental innovation is more pronounced for carbon-intensive firms than non-carbon-intensive firms. Our findings reinforce various corporate governance initiatives and public policy being undertaken all over the globe to encourage more gender diversity in the board of directors, demonstrating that board diversity enhances better board effectiveness in satisfying the needs of broader groups of stakeholders' interests. The findings could be beneficial for stakeholders and regulators concerned with improving corporate governance mechanisms as well as reducing the carbon footprint.

Key words: Gender diversity, Corporate governance, Board of directors, Environmental innovation, Carbon emissions, Carbon-intensive industries.

1. Introduction

Environmental issues are multi-dimensional in nature, resulting from different factors. One of these environmental issues creating a lot of tension for corporations, due to the attention given by various stakeholder groups, is carbon or Greenhouse gas (GHG) emission, where its effect on climate change cannot be overlooked (Stern, 2006). Therefore, there is high information demand from investors about how corporations manage their carbon impact that does not only affect the corporations' environmental investments, but also their economic performance and value as this information is factored in investors' decisions (Ben-Amar *et al*., 2017). Corporates face increasing and multiple social, economic, and regulatory pressures to improve governance effectiveness in reducing GHG emissions. Practitioners as well as academics increasingly try to improve Corporate governance (CG) mechanisms to successfully reduce emissions (Nuber and Velte, 2021). CG mechanisms have the responsibility to formulate strategies that mitigate any such activities negative impact on the environment, society, and performance (Walls *et al*., 2012). Therefore, corporate boards should be sufficiently representative to device different strategies that address the different aspects and complex consequences of such environmental issue (Liao *et al*., 2015).

Board diversity is one of the key governance mechanisms touted to be relevant in enhancing overall firm performance. Studies (e.g., Liao *et al*., 2015; Tingbani *et al*., 2020) highlight that diversity in terms of age, experiences, education, ethnicity and gender tend to improve the knowledge, deliberations and skill set needed to handle corporate multi-dimensional and complex issues. Diversity is likely to be associated with the effectiveness of the board of directors' oversight function, which may improve organisational performance (Erhardt *et al*., 2003). Out of the various aspects of diversity, female gender diversity on boards has been asserted to be more stringent in enforcing ethical conduct and effective monitoring of agents to prevent poor returns on investment. Females on boards demonstrate social responsiveness by engaging and responding to the needs of multiple stakeholders (Glass *et al*., 2016; Nuber and Velte, 2021).

The increasing number of females on boards and their ethical vision as well as GHG becoming a global issue of great importance (Stern, 2006; Ciocirlan and Pettersson, 2012; Nuber and Velte, 2021), have led to the upsurge interest in the effect of female board participation on carbon emission performance. However, scholarly research on female representation on boards and GHG emissions reduction remain under-researched, even though

CG and corporate social responsibility (CSR) research continues to grow exponentially (Tingbani *et al*., 2020), with focus on CG and GHG disclosure. The few related studies on female representation on boards and carbon emissions focused only on the disclosure side and even have yielded contradictory outcome (Prado-Lorenzo and Garcia-Sanchez, 2010; Liao *et al*., 2015; Ben-Amar *et al*., 2017; Tingbani *et al*., 2020). As such, there has been calls for research to specifically focus on the impact of female representation on boards and GHG emissions reduction (Liao *et al*., 2015). In addition, to the best of our knowledge, there is no existing research examining the extent to which environmental innovation (as called for by Leyva-de la Hitz, 2019) by the firms influences the magnitude of the relationship between female representation on boards and GHG emissions.

This study, therefore, contributes to the scanty studies that investigate the effect of board gender diversity on absolute GHG emissions in several ways. Thus, deviating from previous studies (Liao *et al*., 2015 Ben-Amar *et al*., 2017; Tingbani *et al*., 2020), which focus on the gender diversity and carbon disclosure nexus. Specifically, using US sample our study tests the validity of the critical mass theory of gender diversity on the absolute total GHG emissions (i.e., scope1, scope 2 and scope 3 emissions) unlike previous studies (Nuber and Velte, 2021) which focus only on the sum of only two scopes of emissions, in the European context. We further examine the effect of executive and residual female directors on the disaggregated scope 1 and scope 2 GHG emissions. There is currently no existing evidence to the best of our knowledge that have investigated this heterogeneity of executive and residual gender diversity on the disaggregated GHG emissions scopes. This is particularly relevant as we explore whether females' representation on board is critical for the reduction in GHG emissions, not only for disclosure, which informs global policies and promotes board gender diversity. Additionally, we extend the applicability and predictive power of the upper echelon theory to include and integrate the board of directors (BOD), specifically female directors, as an additional critical unit of analysis. Moreover, we employ a multi-theoretical framework to explain the impact of board diversity on carbon emissions reduction as the ability of any single theory to interpret this association is likely to be limited.

Second, our paper contributes to the environmental innovation literature by examining its moderating effect on the gender diversity-carbon emissions association. To the best of our knowledge, no existing study (Nuber and Velte, 2021) exploring this relationship has considered the influence of environmental innovation. Our findings indicate that environmental

innovation is instrumental for emissions reduction in firms with female representations on board. Thus, confirming the argument that women are more sensitive to environmental related issues (Tingbani *et al*., 2020). We additionally explored whether such moderating impact is heightened for carbon intensive sectors than non-intensive sectors. Our results show that indeed the reduction of GHG emissions in carbon intensive firms is more pronounced when environmental innovation and board gender diversity interact. The findings also accentuate the pertinence of investigating the diversity-GHG emissions nexus across the different sectors and environmental sensitivities.

Third, unlike prior studies (Liao et al., 2015; Ben-Amar *et al*., 2017), we demonstrate that legal and economic constraints also influence the effect of gender diversity on GHG emissions. From the legal perspective, our findings suggest that firms with higher percentage of gender diversity record significant reduction in their emissions post the mandatory reporting era (i.e., 2012 and beyond) than the pre mandatory period (i.e., before 2010). This could be argued from the standpoint that women tend to be concerned about the risk of environmental violations and lawsuits (Liu, 2018) and therefore advocate for emission reduction policies. We also consider the periods before and after the global financial crisis (i.e., before 2007 and post 2009). It can be implied from our results that the impact of gender diversity on reducing GHG emissions is heightened when firms operate within a financially stabled economy.

Our results hold after running a propensity score matching where we match board gender diverse firms to those without gender diversity. The findings indicate a causal inference that indeed the presence of women directors play a key role in reducing GHG emissions. In sum, our study offers significant implications for directors, managers, investors, and policymakers given the increasing awareness of the importance of GHG emissions reductions.

The remainder of the paper is organised as follows. Section 2 reviews existing literature on board gender diversity and GHG emissions. The theoretical background and relevant research hypotheses are presented in Section 3. Section 4 explains the methodology employed in this study, while the methods and results are presented in Section 5. The discussion of the results is shown in Section 6 and the conclusions in Section 7.

2. Literature Review

2.1. Women representation on corporate boards

The pressure to increase female representation on corporate boards around the world has come from diverse stakeholder groups. This has resulted in various means (legislation, policies, regulations, rules) to improve the percentage of female representation on corporate boards, which currently stands at 16.9% globally (Thorne and Konigsburg, 2020). Countries such as Norway, Spain, Italy, Finland and India have all come out with legislations mandating gender quotas on boards of listed firms (Weisul, 2014; Srivastava *et al*., 2018). This inclusion of females on corporate boards have been argued from two main perspectives: ethical/social and economic/strategic. From the ethical perspective, it is argued that females are part of the social system, and therefore it is advisable to include them on corporate boards for an equitable outcome. Female representation is desirable end by itself and should not be seen as a means to an end (Brammer *et al*., 2007). It is, however, believed that there are social categorisation biases based on gender, which act as a social barriers for female board representation (Knippen *et al*., 2019). Therefore, it is suggested that competent females with networks, creativity, information and other needed resources should have the opportunity to serve on boards (Carter *et al*., 2010). However, opponents of the ethical/social perspective are of the view that corporate boards have a fiduciary duty to the shareholders and not social engineering (Dvorak, 2008); hence there is a need for an economic/business case for greater female inclusion.

From the economic/business case perspective, increasing females in the boardroom, aside from promoting diversity, creates a positive image of the firm (Catalyst, 1993). The positive image may offer the firm competitive advantage due to the support it may gain from various key stakeholders and access to valuable resources (Hillman *et al*., 2002; 2007). Firms with more gender-diverse boards gain a competitive advantage over their counterpart with less gender-diverse boards because women by their gender roles and expectations place the needs of diverse stakeholders much higher on their agenda (Adams and Funk, 2014; Tingbani *et al*., 2020). More females on the board can improve decisions and governance practices by bringing unique expertise and perspectives (Higgs, 2003). More gender-diverse boards are noted to be more innovative and creative than less gender-diverse boards (Campbell and Minguez-Vera, 2008). Female leaders are known to be very cooperative and collaborative, less hierarchical with much focus on opportunities available for increasing and enhancing employers' worth (Eagly *et al*., 2003). Additionally, Adams and Ferreira (2009) found that females, compared to male directors, are more diligent when it comes to their fiduciary duties.

The inclusion of females on boards is expected to affect environmental issues including GHG emission. The upper echelon theory postulates that directors' knowledge, experiences, and value shape their thought processes and decisions (Hambrick, 2007). Gender may account for the skills and behaviour differences of board members (Khandelwal *et al*., 2020). Female directors unlike their male counterparts mostly reach directorship position with different backgrounds including high levels of education, community and academic services and non-business roles (Hillman *et al*., 2002; Dalton and Dalton, 2010). These roles tend to improve their appreciation of the interest and demands of different stakeholders than males. The experiences and knowledge gained because of their background may enable female directors to consider much broader range of stakeholders including the natural environment relative to male directors (Bear *et al*., 2010; Post *et al*., 2011; Groysberg and Bell, 2013). Females are more relational (Galbreath, 2011) as such female directors may be willing to spend more effort to understand the interest of diverse stakeholders of the firm (Rosener, 1995).

Female directors are more attuned to environmental issues than male director due to their ethical, caring, and environmental values, which affects decision making when females are in position of power (Jaffee and Hyde, 2000; Post *et al*., 2014). Moreover, female directors are much stricter in rule following (Wowak *et al*., 2020), especially where ethical standards are concerned and mostly ready to follow the rule strictly in higher level managerial decisions (Lee *et al*., 2017). The degree of relevance attached to the consequences of ethical and environmental violations generally by female directors is high (Harris *et al*., 2006). Female directors may influence unethical behaviour because they tend to receive more blame for poor firm performance (Park and Westphal, 2013). In this regard, females in the boardroom tend to moderate the board's tone to be responsive to wide range of stakeholders and ensure that severe harm does not occur as harmless responsibility is part of their reasoning and decision making due to their care orientation philosophy (Jaffee and Hyde, 2000; Wowak *et al*., 2020). Thus, women are sensitive to environmental issues and may go all length to influence decisions regarding these issues (Nielsen and Huse, 2010).

According to the resource dependency theory, gender diverse boards are better at problem solving and decision making (Robinson and Dechant, 1997) due to the variety of resources at its disposal. With gender diversity, the board's resources capability in terms of knowledge, skills, values, experiences, and network increases. It is suggested that firms with more female directors may be socially responsible relative to male boards (Post *et al*., 2014).

Board diversity is beneficial to corporations since it increases information search and generates a range of perspectives for solving problems as well as different environmental issues (Hillman *et al*., 2007). Board gender diversity, is known to influence decisions as cognitive bases of the board members align with their decisions (Hambrick and Mason, 1984). Board gender composition affects their attitudes, norms, perspectives, and beliefs which impact on their approach to environmental issues because females and males differ traditionally, socially, and culturally.

Gender-diverse boards may also negatively impact firm performance, especially when different opinions, questions and discussions arise as a result of gender diversity of the board that lead to conflicts and delay decision-making (Lau and Murnighan, 1998). This may affect the effectiveness of the board in performing its functions. Furthermore, there is a direct relationship between risk and reward, which influences firm performance. Females are more risk-averse relative to male, and hence more gender-diverse boards may affect firm performance (Jianakoplos and Bernasek, 1998). Female directors may be side-lined, including their opinions, due to intergroup biases and may not be allowed to serve on any important board committees thereby rendering their presence ineffective and cost to the firm (Knippen *et al*., 2019). This growing debate underscores the importance of board composition in the attainment of organisational goals and meeting stakeholders' needs, therefore leaving the debate open as to whether there is a need for more female board representation, as is being advocated in recent times.

2.2. Board gender diversity and emissions

The issue of climate change and female board representation are two social issues receiving attention among policymakers and the general public (Galbreath, 2011). From the corporate perspective, these two issues have raised questions about the governance structures and how it impacts organisational outcomes especially social behaviour (Wall *et al*., 2012; Ben-Amar *et al*., 2017). Prior studies examining the effect of board gender on corporate social behaviour tend to focus on CSR leaving the board gender- GHG and climate change link under-explored (Liao *et al*., 2015; Tingbani *et al*., 2020). The multi-dimensional nature of CSR has been acknowledged, as in practice companies tend to treat environmental and social issues differently (Bansal and Gao, 2008). For instance, Boulouta (2013), demonstrated that the effect of board gender diversity on CSR is very much dependent on the social performance dimension

being examined. The study found that more gender-diverse boards reduce negative practices of the organisations.

The nature of GHG and its irreversible impact on climate globally with economic consequences makes it complex and different from other environmental pollutants (Lash and Wellington, 2007; Luo *et al*. 2012). Luo *et al*. (2012) indicate that different regulations that guide GHG reporting require specific organisational financial investment and capabilities in its management. With such requirements, a separate investigation is warranted, since GHG association with governance structures is expected to vary (Liao *et al*., 2015). We, therefore, investigate the link between board gender diversity and GHG emission to fill this gap in the literature and provide new insights on the role of environmental innovation on board gender diversity and GHG emission association.

Studies such as Bear *et al*. (2010) and Frias-Aceituno *et al*. (2012) suggest that women on boards tend to support environmental issues and are quick to pursue strategies which minimise environmental risks. Hollindale *et al*. (2017) posit that gender-diverse boards are more inclined to address emerging issues of strategic importance, including GHG emissions. Such assertion stems from the argument that women's roles and expectation in society differ from those of men and may motivate female directors to differ in their approach to environmental issues at board level relative to their male counterparts (Adams and Funk, 2014; Liao *et al*., 2015). Moreover, Ben-Amar *et al*. (2015) found strong evidence that increasing females on board enhances environmental awareness of the firm and promotes proactive strategies in responding to stakeholders needs about how firm activities impact the climate when they investigated GHG disclosure and board gender in Canada. Liao *et al*. (2015) and Tingbani *et al*. (2020) arrived at a similar conclusion in the UK that board gender diversity has a significantly positive effect on GHG disclosure.

Gender-diverse boards are more representative of the societal wide stakeholder groups and are more likely to take actions which will ensure that the economic and social behaviours of the firm are well balanced (Walsh, 2005). Furthermore, Hollindale *et al*. (2017) found that higher quality GHG disclosures are made by firms with multiple female directors which supports the critical mass theory. However, Prado-Lorenzo and Garcia-Sanchez (2010) did not find a significant association between board gender diversity and GHG disclosure, indicating that boards focus more on economic responsibility than the broader CSR view of businesses. The few related literatures mainly focused on GHG disclosure and not the impact of board

gender diversity on GHG emissions reductions (Liao *et al*., 2015). None of the prior studies investigated the impact of board female gender diversity on GHG emission reduction leaving such key aspect unexplored. Also, the role of environmental innovation on this relationship has not been examined and therefore our study provides essential findings in these regards.

3. Theoretical Background and Hypotheses

Our research examines one component of board composition that is the status as female gender, as it is expected to bring unique contributions to boards and increase commitment towards resolving environmental problems (Harjoto *et al*., 2015). There is not one universal theoretical framework; therefore, to conduct this study, we draw on several theories to develop our hypotheses. Adopting a multi-theoretical framework is expected to offer a better understanding of organisations' environmental performance issues (Haque and Ntim, 2018). To fully explain the effect of board gender diversity on organisations' GHG emissions, we combine multiple theoretical perspectives. These incorporate insights from stakeholder, resource dependence, and the upper echelons theory, thereby responding to the growing calls for theoretical integration (Shahab *et al*., 2018) in this regard. Several prior studies have demonstrated that these perspectives are well adapted to explore the relationships between CG mechanisms and performance whether solely (e.g., Gao, 2009; Jia and Zhang, 2011; McGuinness *et al*., 2017) or combined (e.g., Lau *et al*., 2016; Terjesen and Francisco, 2016; Brulhart *et al*., 2019; Elmagrhi *et al*., 2019). Each of these theories has some explanatory limitations to explain the association between board gender diversity and GHG emissions. Therefore, we discuss the findings from multiple theoretical perspectives.

3.1. Board gender diversity and corporate emissions

The role of the BOD, along with the top management team (TMT), is crucial for innovation-related and resource allocation decisions that lead to effective environmental business practices. TMT and directors take decisions based on their personalised interpretations of whatever strategic situations they may face, where this personalised understanding is subject to their experiences, values, and personalities (Hambrick and Mason, 1984). These values and personalities considerably differ from males to females. Therefore, to understand certain organisational performance aspects, including environmental performance in reducing GHG emissions, we need to consider the biases and dispositions of the most powerful actors within

organisations (Hambrick, 2007), where the gender diversity within the BOD is one of the main determinants of these biases and dispositions.

Extending upper echelons theory to BOD to study the relationship between members' characteristics and organisational performance (as called for by Finkelstein *et al*., 2008; Carpenter *et al*., 2004) is most relevant to our research. This is because it yields stronger explanations of organisational outcomes based on focusing on the gender composition of the group of directors in the board, rather than just on the individual leader alone. Originally, researchers who adopt the upper echelons theory argue that the TMT is the dominant coalition (Cyert and March, 1963); however, we argue that this concept should also be applied to the BOD. The collective cognition, capability, and interaction of the entire BOD significantly affects the organisational performance. Many previous studies confirm that organisational outcomes depend, at least partially, on the composition of the TMT (e.g., Carpenter *et al*., 2004) and the BOD. Previous studies demonstrate that the demographic characteristics of directors, which could be used as proxies of their cognitive frames, are highly related to strategy and performance outcomes (e.g., Boeker, 1997). Regarding such an examination, our study contributes by extending the upper echelons theory to include and integrate the BOD as an additional critical unit of analysis.

From stakeholder and resource dependence theoretical perspectives, sustainable carbon reduction activities could be a way to build strategic resources, including strong stakeholder relationships and a reputation for environmental awareness (Flammer, 2013). Both theories support the view that board gender diversity is a good mechanism to meet the expectations of various important stakeholders facilitating easier access for strategic resources (Freeman and Reed, 1983; Pfeffer and Salancik, 1978). It increases pressure to reduce organisations negative environmental impact to meet stakeholders' expectation to demonstrate commitments to greater accountability that may help in obtaining access to resources, by gaining the support of influential stakeholders (Branco & Rodrigues, 2006). The stakeholder theory adopts the broad multi-accountability of the management to various stakeholders with divergent interests. It will provide a better explanation for the GHG management behaviour studied in this paper. Stakeholder theory emphasises the need for a fit between organisational values and behaviour and between stakeholders' expectations (Brulhart *et al*., 2019). This fit helps the company to survive and get access to resources (Freeman, 1984). It suggests that directors are committed to meet stakeholders' expectations to obtain their approval based on the contractual relationship

with stakeholders, where diversity enhance this commitment. On the other hand, resource dependence theory suggests that female directors bring valuable resources and relationships to their boards. Females have more diverse networks compared to male managers (Ibarra,1993). Female directors are more likely to have non-business backgrounds that are added valuable resources in the portfolio of experiences (Singh *et al*., 2008; Hillman *et al*., 2002). This diversity of perspectives can enhance overall innovation concerning environmental performance.

Moreover, resource dependence theory suggests that the BOD facilitates organisations access to strategic resources by better connections with influential stakeholders (Branco and Rodrigues, 2006; Brulhart *et al*., 2019). In this context, board gender diversity can increase the representation of different stakeholders by bringing different values and personalities, biases, and dispositions to the boardroom (McGuinness *et al*., 2017). Consequently, this may increase the pressure on managers to reduce GHG emissions to satisfy influential stakeholders and thus secure access to strategic resources. From a resource-based view, the organisation reputation generated by this stakeholder orientation can also be interpreted as a rare resource (Brulhart *et al*., 2019). In this sense, the stakeholder theory and resource-based theory can be used together in supporting our argument.

The ability of each individual theoretical perspective to interpret the relationship between board gender diversity and GHG emissions could be limited. For example, stakeholder and resource dependence theories may be impaired as they focus on addressing the expectations of influential stakeholders, who may often be financial stakeholders, rather than the broader stakeholders interested in environmental sustainability. Therefore, adopting the above multi-theoretical perspectives, we expect a negative association between board gender diversity and GHG emissions.

H1: *Ceteris paribus, board gender diversity is negatively associated with greenhouse gas emissions.*

3.2. The moderating effect of environmental innovation

Due to a lack of consistency in prior research findings that often provide fragmented and contradictory evidence on the association between CG and CSR (Konadu, 2017), we argue that there is a moderating effect on the relationship between gender diversity and GHG emissions.

The equivocality of the prior research findings may be due in part to the fact that environmental protection innovation moderating role has not been considered.

Environmental innovation is new or modified techniques, systems, processes, and product designs to avoid or reduce environmental harm (Kemp and Arundel, 1998). Although investment in GHG reduction innovation requires scarce resources without generating immediate financial gain, environmental protection innovation is viewed as essential in controlling emissions. Environmental innovation is an important element of a firm's ability to be environmentally proactive and an important driver in the reduction of toxic emissions (Carrion-Flores and Innes, 2010). Environmental innovation enables firms to take advantage of the resources at its disposal, which further enhances environmental creativity (Song *et al*., 2019). Women on the boardroom bring different expertise and value, which impact on the level of innovation in the firm (Selby, 2000; Miller and Tiana, 2009).

Environmental protection innovation involves large investments with complex and somewhat ambiguous consequences that may affect each stakeholder group in a distinct way (Liao *et al*., 2015). Through environmental innovation, firms can reduce their environmental footprint, thus manage environmental pressure from stakeholders (Klassen and Whybark, 1999). Because these stakeholders may have broader objectives, a board must be sufficiently diverse to be representative and to provide better CG in addressing issues raised by various stakeholders. While male board directors are more interested in financial performance, female directors show a strong orientation toward CSR (Ibrahim and Angelidis, 1994). As an effective monitoring mechanism, female directors are more supportive of the investment in environmental protection innovation and restrict the financial opportunistic behaviours of top executives assumed by agency theory.

However, from an agency theoretical perspective, environmental innovation may negatively affect firm financial performance because managers may misallocate organisation resources to advance environmental innovation agenda (Pereira-Moliner *et al*., 2015). Such expenditure may be committed over a longer period, with high risk and a high degree of uncertainty (Griffins *et al*., 2019). Therefore, environmentally innovative firms call for boards to increase their monitoring role and utilise their expertise to ensure value for money. Griffins *et al*. (2019) suggest that female directors may help mitigate the agency problem of excessive risk-taking and excessive short-term focus, both of which affect innovation in the firm.

From a resource dependency theoretical perspective, board diversity is a resource at the firm's disposal. Diversity enhances strategic advice, resources access, networking, and knowledge (Hillman *et al*., 2000; Huse, 2007). Thus, environmentally innovative firms' management can leverage through presenting environmental impact initiatives to the board. The diverse board, with different stakeholders and pursuing objectives that go beyond the profit maximisation, offers a variety of perspectives making the board more responsive to CSR initiatives (environmental awareness, stakeholder engagement and superior innovation, etc.). This puts the firm in a better position to address its environmental issues and further enhances its environmental innovation, awareness, and stakeholder engagements (Bear *et al*., 2010).

Environmentally innovative firms may be attractive to female leaders because they may align with their strong advocacy for CSR (Cook and Glass, 2016). Kato and Kodama (2016) posit that females are interested in firms' CSR as it signals that gender diversity and ethical concerns at the workplace are highly promoted. Therefore, CSR enables firms to recruit and retain gifted female employees to improve workplace gender diversity. Although empirical evidence that innovative firms are more responsive to external calls to have more gender-diverse boards is rare, there is evidence that female directors may be more aligned with innovative firms. Chen *et al*. (2018) found that female directors improve firm value in innovative-intensive firms relative to non-innovative-intensive firms. Thus, the relative importance of firm's innovative activities on value of female directors may be significant as this may induce female directors to increase the effectiveness of their monitoring role to reduce agency cost/problem.

The level of environmental innovation commitment determines the ability to integrate environmental concerns into processes and products. Environmental innovations are important for the success of organisational strategy (Daily and Huang, 2001) because it creates the environment for offering environmental training, responding to environmental problems, creating environmental management team, and environmental auditing system (Shrivastava, 1995, Sarkis *et al*., 2010). The firm's environmental innovation practices may stimulate a firm's creativity climate which can equip it to better deal with environmental challenges and become receptive to useful and new green innovative ideas (Amabile *et al*., 1996; Li, 2014) emanating from the gender-diverse board. Therefore, we argue that while board gender diversity may provide an organisation with the direction regarding new environmental strategies, its effective implementation requires environmental innovation on the part of the firm.

H2: *The magnitude of the negative association between gender diversity and greenhouse gas emissions increases when moderated with environmental innovation.*

3.3. The moderating effect of environmental innovation in carbon-intensive industries

CG mechanisms effectiveness in reducing emissions could vary in carbon intensive versus non-carbon-intensive sectors. Liao *et al*. (2015) suggest that GC plays a more pronounced role in less carbon-intensive sectors, when found that board diversity association with GHG disclosure is significant and positive in less carbon-intensive sectors. We agree that the association could vary across carbon-intensive and less carbon-intensive sectors. However, we have a contrary argument that the moderating effect of environmental innovation on the negative association between gender diversity and GHG emissions increases in carbon-intensive than non-carbon-intensive industries. The plausible reason is that environmental innovation may have a greater impact in reducing the GHG emissions in response to the substantial regulatory institutional constraints in carbon-intensive sectors than in less intensive ones. Carbon-intensive industries are subject to higher climate change-related risks (Ben-Amar *et al*., 2017), which is of interest to females due to their nurturing role and environmental sensitivity. Hence, they are more likely to increase their monitoring role to enforce adherence to standards and environmental innovations to reduce undesirable footprints. Therefore, we expect increase investment in GHG emission reduction innovation than low carbon industries.

H3: *The moderating effect of environmental innovation on the negative association between gender diversity and greenhouse gas emissions increases for firms in carbon-intensive industries than firms in non-carbon intensive industries.*

4. Methodology

4.1. Data

Our analysis draws on GHG emissions and gender diversity indicators collected from Thomson Reuters Datastream, Eikon and Asset4 ESG databases. The sample used to test our hypotheses consists of companies listed on the Standards and Poor (S&P) 500 index from 2002-2018. The sample starts from 2002 to cover the period before mandatory GHG disclosure in 2010 for US firms emitting over 25,000 metric tonnes/year (Tomar, 2019). Because the first public reporting started in 2012, choosing 2018 as the sample year end allows time to capture the period of post-mandatory reporting. Asset 4 provides data on environmental, social and

governance (ESG) related issues for companies around the world (Thomson Reuters, 2015). Asset 4 collects GHG emissions in carbon dioxide equivalents (CO2e) from various sources such as sustainability reports, annual reports and information on corporate websites. The CO2e emissions reported by Asset 4 is in accordance with GHG Protocol Initiative reporting standards operational boundaries and scopes. Scope 1 refers to the direct emissions from fuel combustion and processing of chemical from sources owned or controlled by the company. Scope 2 represents the indirect emissions related to the generation of purchased electricity. In contrast, Scope 3 emissions emanate from upstream and downstream emission in the supply chain not owned or controlled by the company (WBSCD and WRI, 2004).

Despite the population of 500 firms on Asset 4, there were missing records for 71 firms which resulted in the collection of 6247 firm/year observations of the listed firms. Because firms in the financial sector are argued to have different regulatory and reporting measures, we follow Tauringana and Chithambo (2015) and Baboukardos (2017) to exclude them from the sample. Also, firms with no year data for total GHG emissions and gender diversity are excluded, leaving 251 firms with 2026 observations unbalanced panel data set. We focus on a single index in a country (S&P) because of the influence of the regulatory system of a country concerning environmental related issues (Foxen et al., 2005). In line with previous studies (e.g., Lewandowski, 2017), we accounted for outliers by winsorising the data at the lowest and highest one percentiles of variables employed in the analysis. The sample is further classified into carbon-intensive and non-carbon-intensive sectors following the work of Baboukardos (2017). From Table 1, industrials, materials, energy, and utilities sectors are grouped under carbon-intensive due to the intensity of their emissions (Lund, 2007; Baboukardos, 2017). The remaining sectors, namely health care, technology, consumer staples, consumer discretionary, real estates and telecom, are all classified as non-carbon-intensive sectors.

Table 1: Sector Statistics

Sectors	**GHG emissions (absolute value CO2e tonnes)**	**Firms distribution**	**Carbon Intensity Category**
Industrials	1018775434	41	Carbon intensive
Health care	177676143	40	Non-carbon intensive
Technology	222235491	43	Non-carbon intensive
Consumer Staples	398299501	29	Non-carbon intensive
Consumer Discretionary	365630114	4	Non-carbon intensive
Materials	1249641714	25	Carbon intensive
Energy	3658863430	32	Carbon intensive
Utilities	5009829536	17	Carbon intensive
Real Estates	53111377	2	Non-carbon intensive
Telecom	24700000	18	Non-carbon intensive
Total	**12178762740**	**251**	

4.2. Variables

The description of our dependent, independent and control variables are provided in Table 2.

4.2.1. Dependent Variable – Greenhouse gas emissions (GHG)

Different emissions scopes have been employed in existing studies for analysis. Some studies, such as Chen and Gao (2012) and Brouwers et al. (2012) only used Scope 1 emissions in their analysis. Others (e.g., Kleimeier and Viehs, 2018; Trumpp and Guenther, 2017; Misani and Pogutz, 2015) employed both Scopes 1 and 2 emission and the sum of both to estimate relationship. A few studies (e.g., Matsumura *et al*., 2014; Delmas *et al*., 2015) relied on all three Scopes of emissions as an estimate for carbon performance. In line with prior studies, we adopt total emissions which is the sum of all three scopes as the main proxy for GHG (carbon performance). For robustness test, we use Scopes 1 and 2 emissions individually to investigate the direct and indirect operational impacts as alternative measures. Scope 3 is excluded as a proxy due to the numerous missing firm year observations.

Table 2: Variable Description

Variables	Description
Dependent Variables	
GHG	Natural logarithm of total greenhouse gas emissions in a million metric tonnes (see Baboukardos, 2017)
Scope 1 GHG	Natural logarithm of direct emissions from sources owned or controlled by the firm
Scope 2 GHG	Natural logarithm of indirect emissions related to the generation of purchased electricity
Independent Variables	
Diversity	The percentage of female directors on board (see Nadeem *et al*., 2020)
1_FEM	Dummy variable which takes the value of 1 when there is only one female director on board and 0 otherwise (see Ben-Amar *et al*., 2017)
2_FEM	Dummy variable which takes the value of 1 when there are only two female directors on board and 0 otherwise (see Nuber and Velte *et al*., 2021)
3_FEM	Dummy variable which takes the value of 1 when there are only three female directors on board and 0 otherwise (see Atif *et al*., 2020)
Exec_FEM%	The proportion of female executive directors on board (see Gul *et al*., 2011)
Res_FEM%	The difference between female executive directors and the total proportion of female directors on board (see Gul *et al*., 2011)

Moderating Variable	
EInno	New environmental technologies and processes to reduce environmental costs and burdens in percentage (see Arena *et al*., 2018)
Control Variables	
Growth	Annual sales growth rate calculated as the ratio of the current year's net sales to the previous year's revenue (see Lawandowski, 2017)
FSize	Natural logarithm of total assets (see Lu and Herremans, 2019)
ETrain	Dummy variable which takes the value of 1 if the company trains its employees on environmental issues and 0 otherwise
CSR	Dummy variable which takes the value of 1 if the company has a CSR committee and 0 otherwise (see Liao *et al*., 2015)
Slack	This is current assets divided by current liabilities (see I.Leyva-de la Hiz *et al*., 2019)
ROI	Net profit after tax divided by invested capital (see Lewandowski 2017)
BSize	The total number of board members at the end of the fiscal year (see Pucheta-Martinez *et al*., 2019)

4.2.2. Independent Variable – Board gender diversity (FEM%)

We use three proxies to measure the presence of female on the board. The first measure we employ is the percentage of female directors on board (*FEM%*). This metric is prevalent in CG literature (Liao *et al*., 2015; Ben-Amar *et al*., 2017; Liu, 2018). We further employ the number of female directors on board as a dummy variable following the argument of tokenism and critical mass theories (Simpson *et al*., 2010; Liu *et al*., 2014; Srivastava *et al*., 2018). As an additional test, we also use the percentage of female executive directors and residual female directors on board as a proxy in our investigation.

4.2.3. Moderating variable – Environmental innovation (EInno)

Prior studies have acknowledged the difficulty in measuring environmental innovation. Some studies use research and development expenses as the proxy for innovation; however, firms are not under obligations to disclose their expenditure on environmental research and development. Consistent with Arena *et al*. (2017), we rely on the environmental innovation score by Asset4 database for this variable. Environmental innovation is measured in percentage of commitment and effectiveness in advancing research and development of eco-efficient products and services. It also reflects companies' capacity to develop new environmental technologies and processes to reduce environmental costs and burdens.

4.2.4. Control variables

Our study employs firm size, the board size, CSR committee, slack resources, ROI, environmental training and sales growth as control variables to account for the other organisational and board influences on GHG emissions. Firm size *(FSize)* is controlled as a potentially confounding variable when exploring the relationship between gender diversity and carbon performance (King and Lenox, 2001). Drawing from the work of Busch & Hoffman (2011) we control for corporate board size *(BSize)*. It has been argued that large corporate boards take longer time to arrive at effective and conclusive decisions when compared to the smaller boards. In line with previous studies (Wang *et al*., 2014; Lewandowski, 2017), lagged 1-year sales growth *(Growth)* is controlled due to its potential influence on emission reduction. CSR committee *(CSR)* is also controlled in this study as it has been argued to enhance awareness on environmental issues and reduce negative impacts such as emissions (Liao *et al*., 2015). Due to the influence of slack resources, as highlighted by Leyva-de la Hiz *et al*. (2019), we control for slack resources *(Slack)*. We include environmental training *(ETrain)* as a control variable because of the tendency for such training to create environmental awareness and reduce carbon emissions. Lagged 1-year returns on investment (*ROI*) is included as a control variable due to the potential influence of companies' previous financial and investment performance on environmental performance. We finally integrate industry and year dummies as control variables to address the panel data structure (Trumpp and Guenther, 2017).

5. Method and Results

The primary intent of our study is to investigate the effect of board gender diversity on GHG emission reduction and whether environmental innovation moderates the relationship. We rely on multivariate modelling techniques in testing our hypotheses. The estimations are as follows:

$$GHG_{it} = \alpha_0 + \beta_1 FEM\%_{it} + \beta_2 Growth_{it} + Fsize_{it} + ETrain_{it} + CSR_{it} + Slack_{it} + ROI_{it} + BSize_{it} + \sum Industry_t^i + \sum Year_t^i + \varepsilon_{it} \quad (1)$$

$$GHG_{it} = \alpha_0 + \beta_1 FEM\%_{it} + \beta_2 EInno_{it} + \beta_3 FEM\% * EInno_{it} + \beta_4 Growth_{it} + \beta_5 FSize_{it} + \beta_6 ETrain_{it} + \beta_7 CSR_{it} + \beta_8 Slack_{it} + \beta_9 ROI_{it} + \beta_{10} BSize_{it} + \sum Industry_t^i + \sum Year_t^i + \varepsilon_{it} \quad (2)$$

Where *i* represents the firm unit, *t* stands for the point of time and ε denotes the error term. Equation 1 is used to examine the first hypothesis of whether the board gender diversity reduces carbon emissions; hence, a negative coefficient β_1 is expected. Equation 2, on the other hand, tests the interaction effect of environmental innovation and gender diversity on GHG emissions reduction as pointed out in our second hypothesis. We group our sample into carbon-intensive and non-intensive. Test was conducted to determine if the interaction effect in equation 2 is more significant for carbon-intensive firms than non-intensive.

5.1.1. Data description and univariate analysis

The summary statistics of the main variables are shown in Table 3, which covers the full sample and the two subsamples of intensity and no-intensity of carbon emissions. Out of the full sample, 146 firms belong to non-carbon-intensive sectors, whereas 105 firms belong to carbon-intensive sectors. The average CO2 emissions *(GHG)* for the full sample is 855,977 tonnes (log of 5.93). Carbon-intensive firms, on the other hand, recorded an average of 2,730,512 (log of 6.44) tonnes of CO2 which is significantly higher than non-carbon-intensive firms with an average emission of 373,247 tonnes (log of 5.57).

Table 3: Descriptive statistics

	Full sample		Carbon-intensive firms		Non-carbon-intensive firms	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.
	(*N=251*)		(*N=105*)		(*N=146*)	
GHG	13.66	1.99	14.82	1.95	12.83	1.56
FEM%	19.15	8.85	16.86	7.53	20.80	9.36
EInno	59.75	26.22	61.61	25.12	58.41	26.92
Growth	6.52	15.86	5.72	17.87	7.09	14.20
Fsize	16.73	1.05	16.83	.96	16.67	1.11
Etrain	.72	.44	.76	.42	.69	.45
CSR	.79	.40	.79	.40	.79	.40
Slack	1.39	1.10	1.14	.52	1.57	1.34
ROI	13.13	11.95	11.49	12.61	14.32	11.31
BSize	11.17	1.98	11.28	1.84	11.09	2.07

Definitions of the variables are provided in the appendix. Carbon-intensive firms are those firms that belong to the Industrials, Materials, Energy and Utility sectors. Non-carbon-intensive firms are those firms that belong to Consumer Discretionary, Consumer Staples, Technology, Health Care, Real Estates and Telecom sectors. *GHG* represents the natural logarithm of the absolute greenhouse gas emission; *FEM%* stands for the percentage of board gender diversity; *EInno* is the percentage of firm environmental innovation; *Growth* represents lagged 1 year sales growth; *Fsize* is the firm size; *ETrain* stands for firm environmental training; *CSR* represents corporate social responsibility committee; *Slack* stands for firm financial slack; *ROI* is the 1 year lagged return on investments; *BSize* represents corporate board size.

With regards to the main independent variable (*FEM%*), it was found that the average percentage of gender diversity on corporate boards is 19.15% for the full sample, 16.86% for carbon-intensive firms and 20.80% for non-carbon-intensive firms. It is also revealed that the average environmental innovation score *(EInno),* which is our moderating variable, is much higher for carbon-intensive firms (61.61%) than non-carbon-intensive firms (58.41%). Furthermore, the average values of most of the control variables apart from *Growth* and *ROI* are not significantly different for the two intensity subsamples.

Table 4 shows the pairwise correlations of the main variables in this study using Pearson correlations. The correlation matrix further shows a negative linear relationship between board gender diversity and carbon emissions. A similar negative coefficient is recorded for *Growth*, slack and *ROI*, whereas the correlation coefficient for the other variables is positive.

Table 4: Pairwise Correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) GHG	1.00									
(2) FEM%	-0.06	1.00								
(3) EInno	0.08	-0.02	1.00							
(4) Growth	-0.07	-0.07	-0.04	1.00						
(5) FSize	0.55	0.07	0.12	0.02	1.00					
(6) ETrain	0.13	-0.01	0.15	-0.11	0.15	1.00				
(7) CSR	0.02	0.08	0.10	-0.08	0.12	0.18	1.00			
(8) Slack	-0.31	-0.08	-0.02	0.12	-0.13	-0.02	-0.03	1.00		
(9) ROI	-0.11	0.01	0.08	0.22	-0.04	-0.05	0.03	0.04	1.00	
(10) BSize	0.21	0.08	0.07	-0.02	0.32	0.05	0.07	-0.16	-0.03	1.00

None of the correlation coefficients among the independent variables is up to 0.80, which is an acceptable threshold as argued by Gujarati (1995) and as such the issue of multicollinearity is not applicable in this analysis. Further to this, the variance inflation factors (VIF)[1] in all regressions are less than 10.

5.1.2. Multivariate analysis

Prior to running any regression models, we explored the normality of the data using the Shapiro-Wilk test to transform highly skewed data. We further eliminated outliers by winsorising all variables at 1 and 99 percentiles. After running Hausman test which showed

[1] The VIF estimations have been excluded because the values were significantly lesser than 10 with the mean VIF=1.19.

that there is a systematic difference (prob>chi2>1.53) between fixed and random effect, fixed effects model appeared to be more appropriate to obtain efficient and consistent estimates. The fixed effects results are shown in Table 5 from model 1 through to model 4. Contrary to H1, FEM% and GHG are positively related but not statistically significant in model 1. Following the critical mass theory (Ben-Amar et al., 2017), we also employed dummy variables for the number of females on board as proxies in the regression. Model 2 shows that there is an insignificant yet positive relationship between 1_FEM and GHG. 2_FEM and 3-FEM, on the other hand, had a negative association with GHG though statistically insignificant.

Table 5: Fixed Effects and Two-Stage Least Squares

	Fixed Effects				**2SLS**			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Growth	-0.002**	-0.002**	-0.002**	-0.002**	-0.008***	-0.007***	-0.011	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.018)	(0.002)
FSize	0.518***	0.522***	0.520***	0.522***	0.939***	0.926***	0.746	0.915***
	(0.086)	(0.085)	(0.085)	(0.085)	(0.033)	(0.035)	(0.654)	(0.040)
ETrain	0.170***	0.168***	0.166***	0.168***	0.299***	0.349***	0.093	0.379***
	(0.061)	(0.060)	(0.060)	(0.060)	(0.080)	(0.086)	(0.952)	(0.097)
CSR	-0.036	-0.037	-0.035	-0.038	-0.208**	-0.202**	0.368	-0.218**
	(0.051)	(0.052)	(0.051)	(0.052)	(0.092)	(0.099)	(2.060)	(0.103)
Slack	-0.053**	-0.052**	-0.053**	-0.052**	-0.358***	-0.345***	-0.614	-0.368***
	(0.022)	(0.023)	(0.022)	(0.022)	(0.031)	(0.044)	(0.922)	(0.052)
ROI	0.002	0.002	0.002	0.002	-0.001	-0.002	-0.009	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.026)	(0.003)
BSize	-0.004	-0.004	-0.004	-0.004	0.034*	0.029	0.001	0.030
	(0.010)	(0.010)	(0.010)	(0.010)	(0.018)	(0.019)	(0.123)	(0.020)
FEM%	0.002				-0.022***			
	(0.002)				(0.005)			
1_FEM		0.018				0.273		
		(0.045)				(0.309)		
2_FEM			-0.053				-0.914	
			(0.037)				(.175)	
3_FEM				-0.005				-1.307
				(0.039)				(1.351)
Adj. R^2	0.17	0.17	0.17	0.17	0.53	0.52	0.46	0.47
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	199	1992	1992	1992	1651	1651	1651	1651

GHG represents the natural logarithm of the absolute greenhouse gas emission; *FEM%* stands for the percentage of board gender diversity; *EInno* is the percentage of firm environmental innovation; *Growth* represents 1 year lagged sales growth; *Fsize* is the firm size; *ETrain* stands for firm environmental training; *CSR* represents corporate social responsibility committee; *Slack* stands for firm financial slack; *ROI* is the 1 year lagged return on investments; *BSize* represents corporate board size. *1_FEM* is the dummy variable for one female on board; *2_FEM* is the dummy variable for two females on board and *3_FEM* is the dummy for three females on board. Instrumental variables used are *L.FEM%* (i.e., lagged diversity) and *C.G. Cttee*, which is the corporate governance committee. Robust standard errors are in parenthesis *** p<0.01, ** p<0.05, * p<0.1

Due to endogeneity issues postulated to exist in a relationship like that of *FEM%* and *GHG* (Adams, 2016; Gould *et al*., 2018), we took an instrumental variable approach. Consistent with Gould *et al*. (2018) we adopt the two-stage least squares (2SLS) method as the suitable estimation approach to address the endogeneity issues, which could emanate from reverse causality, omitted variables, and measurement errors. In our 2SLS estimation, we first specified corporate governance committee (*C.G. Cttee*) as our first instrumental variable to capture the potential influence of the existence of CG committee on board gender diversity. Also, we took advantage of the panel data structure and used the lagged values of diversity (*L.FEM%*) as our additional instrumental variable.

Using two instrumental variables in a fixed-effect model resulted in overidentification of instruments which allowed us to test for the validity of the instruments. After the inclusion of the instruments, we tested for Wu-Hausman (p=0.5205) and Durbin (p=0.5113), which both do not reject that *FEM%* is exogenous at all significance levels. This outcome of the two tests of endogeneity indicates that 2SLS estimates are consistent compared to OLS. We further tested for overidentification of instruments. To ensure that the instruments used are not weak, we run the Stock & Yogo (2005) test on our sets of instruments. We found that F statistic=882.72 for the joint significance of our instruments with prob>F=0.0000. Thus, our additional instruments are significant for *FEM%*. Furthermore, we checked the Cragg and Donald (1993) minimum eigenvalue statistics which showed that the test statistic exceeds the critical values. We also run the overidentification test of our instruments using both Sargan and Basmann's tests. Sargan's test resulted in chi2=.884 (p=0.3471) and Basmann's test resulted in chi2=.879 (p=0.348). The estimation results for 2SLS in model 5 shows a statistically significant negative relationship between *FEM%* and *GHG* as expected in H1. As such, we do not reject the null hypothesis that board gender diversity reduces GHG emissions. Even though we failed to find a significant impact of the number of females (i.e., *1_FEM%*, *2_FEM%* and *3_FEM%)* on board following the critical mass theory, it was discovered that the presence of two and three females is negatively associates with GHG emissions.

To test H2 and H3, we included the interaction of gender diversity and environmental innovation (*FEM%* x *EInno*) in model 2 in Table 6. It was found that *FEM%* x *EInno* reduces *GHG* by 13.6% (exp (0.128)-1) compared to *FEM%* which only reduces emissions by 4.10% (exp (0.04)-1), a difference of 9.5% further reduction with the interaction effect. We do not reject our null hypothesis (H2) that the negative relationship between *FEM%* and *GHG*

increases when interacted environmental innovation. We continued to H3 that such moderation effect is more pronounced for carbon-intensive firms than non-intensive firms. Our findings, as shown in models 3 and 4 in Table 6, support our assertion that indeed GHG emissions reduce much further in carbon-intensive firms by 8.3%.

Table 6: Moderation effect of environmental innovation

		Interaction	**Carbon Intensity**	
	Base Model (1)	**Full sample (2)**	**Non-Intensive (3)**	**Intensive (4)**
Growth	-0.008***	-0.007***	-0.010***	-0.007
	(0.002)	(0.002)	(0.004)	(0.004)
FSize	0.939***	0.934***	0.811***	1.118***
	(0.033)	(0.035)	(0.037)	(0.071)
ETrain	0.299***	0.306***	0.384***	0.110
	(0.080)	(0.086)	(0.095)	(0.143)
CSR	-0.208**	-0.221**	-0.255*	0.046
	(0.092)	(0.099)	(0.144)	(0.198)
Slack	-0.358***	-0.351***	-0.182***	-0.435***
	(0.031)	(0.045)	(0.039)	(0.131)
ROI	-0.001	-0.001	0.009***	0.009
	(0.003)	(0.003)	(0.003)	(0.007)
BSize	0.034*	0.030	0.012	0.095
	(0.018)	(0.018)	(0.020)	(0.072)
FEM%	-0.022***	0.070***	-0.032	-0.093**
	(0.005)	(0.044)	(0.036)	(0.038)
EInno		-0.160***	-0.215	-0.187***
		(0.070)	(0.028)	(0.063)
FEM% x EInno		-0.128***	0.070	-0.141***
		(0.082)	(0.014)	(0.030)
Adj. R^2	0.53	0.54	0.49	0.32
Industry Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
N	1651	1651	681	969

GHG represents the natural logarithm of the absolute greenhouse gas emission; *FEM%* stands for the percentage of board gender diversity; *EInno* is the percentage of firm environmental innovation; FEM% x EInno represents the interaction effect between gender diversity and environmental innovation; Growth represents 1 year lagged sales growth; *Fsize* is the firm size; *ETrain* stands for firm environmental training; *CSR* represents corporate social responsibility committee; *Slack* stands for firm financial slack; *ROI* is the 1 year lagged return on investments; *BSize* represents corporate board size. Instrumental variables used are *L.FEM%* (i.e., lagged diversity) and *C.G. Cttee*, which is the corporate governance committee. Robust standard errors are in parenthesis **** p<0.01, ** p<0.05, * p<0.1*

5.1.3. Additional analysis

We conduct several additional tests and analysis to ensure that the robustness of our baseline results using 2SLS in Table 5 is consistent and efficient. Specifically, two subsamples, alternative measures and model specifications and a propensity score matching approach are further employed.

Table 7: Robustness Tests Results

	Mandatory Reporting (2010- 2012 excluded)		**Financial Crisis (2007-2009 excluded)**		**Scope 1 GHG**		**Scope 2 GHG**	
	Before	**After**	**Before**	**After**				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Growth	-0.006*	-0.008**	-0.011	-0.008***	-0.009***	-0.009**	-0.006**	-0.006**
	(0.003)	(0.003)	(0.007)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
FSize	0.889***	0.934***	0.764***	0.937***	1.056***	1.044***	0.761***	0.756***
	(0.057)	(0.043)	(0.130)	(0.039)	(0.055)	(0.055)	(0.031)	(0.030)
ETrain	0.244*	0.436***	0.146	0.371***	0.477***	0.530***	0.167**	0.190**
	(0.128)	(0.121)	(0.210)	(0.107)	(0.132)	(0.133)	(0.082)	(0.081)
CSR	0.133	-0.316**	0.013	-0.281**	-0.374**	-0.474***	-0.072	-0.093
	(0.144)	(0.153)	(0.221)	(0.142)	(0.160)	(0.160)	(0.099)	(0.100)
Slack	-0.542***	-0.289***	-0.848***	-0.308***	-0.552***	-0.551***	-0.277***	-0.273***
	(0.076)	(0.049)	(0.097)	(0.045)	(0.051)	(0.052)	(0.042)	(0.042)
ROI	-0.010**	0.004	0.022*	0.001	-0.007	-0.007	0.006**	0.006**
	(0.005)	(0.004)	(0.013)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
BSize	0.026	0.027	0.065	0.029	0.076***	0.073***	0.010	0.009
	(0.028)	(0.024)	(0.059)	(0.021)	(0.027)	(0.027)	(0.017)	(0.017)
FEM%	0.198	-0.024*	0.449*	-0.065**				
	(0.071)	(0.055)	(0.163)	(0.049)				
Exec_FEM%					-0.012***		-0.007**	
					(0.003)		(0.003)	
Res_FEM%						-0.020***		0.000
						(0.006)		(0.006)
Adj. R^2	0.58	0.51	0.69	0.50	0.47	0.46	0.44	0.44
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	622	1029	117	1311	1447	1447	1406	1406

GHG represents the natural logarithm of the absolute greenhouse gas emission; *Exec_FEM%* stands for the percentage of executive females on board; *Res_FEM%* is the residual female directors on board; Growth represents 1 year lagged sales growth; *Fsize* is the firm size; *ETrain* stands for firm environmental training; *CSR* represents corporate social responsibility committee; *Slack* stands for firm financial slack; *ROI* is the 1 year lagged return on investments; *BSize* represents corporate board size. Instrumental variables used are *L.FEM%* (i.e., lagged diversity) and *C.G. Cttee*, which is the corporate governance committee. Robust standard errors are in parenthesis *** *p<0.01*, ** *p<0.05*, * *p<0.1*

In the first robustness test, we explore the subsamples in the board gender diversity – GHG relationship. The sample is divided into firm-year observations prior to mandatory GHG reporting in 2010 and post-2012. As reported in Table 7, the percentage of women on board significantly contributes to reducing GHG emissions after the mandatory reporting requirement when compared to the pre-mandatory period. We further examine the effect of the financial crisis on the *GHG-FEM%* relationship by looking at the periods before and after. It was found that gender diversity did not reduce emissions pre-financial crisis. However, there was a significant reduction in emissions after the financial crisis with gender diversity. These results demonstrate the robustness of the findings after accounting for endogeneity.

To alleviate the potential concern that our proxies for both independent and dependent variables might affect the baseline regression outcome, we also use alternative measures in the analysis. Scope 1 and Scope 2 GHG emissions proxies are employed as dependent variables, whereas female executive directors and residual female directors are used as independent variables. As shown in Table 7, female executive directors significantly contribute towards the reduction of both Scopes of emissions. The coefficient of the residual number of female directors is only negative and significantly associated with scope 1 emissions and not scope 2. These results corroborate the baseline findings (see Table 5).

We also address the potential of self-selection bias by using propensity score matching (PSM) approach to eliminate confounding factors that may affect board gender diversity and GHG emissions simultaneously. The PSM compares the average GHG emissions of firms with at least one female director on board to a matched average of GHG emissions with no female director on board, thus, representing the treatment and control groups, respectively.

Table 8: Propensity Score Matching Results

Variable	Treated	Control	p>|t|
Growth	5.8409	5.8809	0.743
FSize	16.604	16.652	0.163
ETrain	.73166	.73761	0.705
CSR	.74633	.79609	0.171
BSize	11.057	11.119	0.237
Slack	1.3681	1.3405	0.814

Table 8 shows that the covariates for treatment and control groups are not significantly different from each other, and therefore the matching criteria is met (Kyaw et al., 2017). We went ahead to calculate the average treatment effect on the treated (ATT) using the kernel matching approach and found statistically significant estimates (-0.1920) representing emissions reduction of 21% (exp (-.1920)-1). This result supports our baseline findings that firms with at least one female on board perform better in their emissions reduction than those with no female directors on board.

6. Discussion

Reduction in GHG emission is not currently considered as a major performance indicator for only governments but corporations as well because of the mandatory GHG emissions requirements for larger firms in many jurisdictions. The significant negative relationship between gender diversity and GHG emissions reflect the ideologies of upper echelon theorists that BOD characteristics affect strategic choices and performance (Carpenter *et al*., 2004). The results point the fact that women, who are more receptive to innovations and new ideas, are likely to accept the introduction of environmental reduction measures than men. Our arguments and findings are also supported by the conclusions of Bear *et al*. (2010) who reported that women on board impact firm's CSR rating, including GHG emissions. Supporting the views expressed by Bear *et al*. (2010) and Tingbani *et al*. (2020) we assert that the traits of women on BOD such as higher qualification and experience (Hillman *et al*., 2002; Singh *et al*., 2008), charitable in nature (Williams, 2003) and participative communication style (Eagly *et al*., 2003) are attributes linked to a higher level of CSR, such as a reduction in GHG emission.

The findings are also in line with Ben-Amar *et al*. (2017), who report that the voluntary climate change disclosure is more dominant for firms with a high percentage of women on board. It is contended that females are more sensitive to environmental issues (Rose, 2007). Therefore, it is expected that when the percentage of females on board is increased, decision making regarding reduction in GHG emissions will also be enhanced and consequently result in lower GHG. To buttress our argument, whereas Ciocirlan and Pettersson (2012) discovered that gender diversity has a significant and positive impact on climate change commitment, Boulouta (2013) explained that the presence of female directors on board reduces harmful practices. This is due to the emphatic, caring nature of female directors.

More female on corporate board also puts pressure on firms to show higher support for environmental practices. Arguing from stakeholder and resource dependency theories, to obtain support from influential stakeholders and to gain access to critical resources, females on corporate board can increase pressure on board to purse sustainable environmental practices. This argument has also been supported by empirical finding, where using a dataset from China, it was reported that female directors have a positive impact on overall corporate environmental performance (Elmagrhi *et al*., 2018). Similarly, the study also provides support to our theoretical argument that increase females on board can enhance board effectiveness through diverse ideas, experience, and knowledge.

The findings indicate that mixed gender governance approach is likely to meet the demands of stakeholders and obtain legitimacy for green practices (Tingbani *et al*., 2020). The board skills are mostly high when women are part of the board. This is because women brings diverse skills to the board room, which are feminine related. Eagly *et al*. (2003) indicated that women exhibit communal attributes such as being nurturing, helpful, sympathetic, sensitive, more collaborative, and cooperative and exploit the opportunities to enhance shareholders' wealth. Therefore, women will embrace GHG emission measures which require a collaborative effort with various stakeholders, helpful to society and sensitive to corporations and governments. In support of this argument, Bernardi and Threadgill (2011) explained that increased female representation on board enhance organisational practices relating to CSR, improve environmental performance and also restrain disreputable practices such as pollution (Bear *et al*., 2010; Zhang, 2012).

Empirical support from Kyaw *et al*., (2017) also confirms that board-gender diversity improves environmental practices and prevalent across industries. Thus, board-gender diversity promotes environmental practices irrespective of the industry. It has also been reiterated that the greater female representation on board, the lesser the organisation are sued for environmental-related violation (Liu, 2018). Similarly, it has been suggested that women are mostly concern with stakeholder welfare and thus likely to take actions against harmful environmental practices such as GHG emissions that impact negatively on the community (Adams *et al*., 2011). Women executives and directors are regarded less confident and as such are likely to obtain expert advice than male, a trait which is likely to alleviate an organisation's exposure to environmental risk (Levi *et al*., 2015).

While the findings of this study confirm our hypothesis 2 that the extent of a negative association between the proportion of female on board increases with environmental innovations, it is also in line with the recent studies and the upper echelon theory which form the basis of our study. Arena *et al*. (2018) established that CEO hubris reinforces innovative green projects. Women have higher extraversion and agreeableness personality traits than men (Weisberg *et al*., 2011). Thus, if women are found to be more outgoing, friendly and confident than men, then they are more likely to embrace environmental innovation, hence increase in a negative association between gender diversity and GHG emissions.

Similarly, based on gender role theory, Rosener (1995) contended that the flexibility associated with females results in a greater ability to deal with complex situations, such as environmental innovations that is unlikely to be embraced by all management team. However, it is expected that the females on board may use their unique feminine attributes such as flexibility, sympathy, gentility, and effective communications skills to influence other members of the board to accept environmentally friendly technologies. Hence, an increase in a negative relationship between gender diversity and GHG emissions when moderated by environmental innovations. Our assertion is in line with findings of Chen *et al*. (2018) who reported that female board representation is linked with greater innovation success as firms with more female directors tend to invest more in innovations, research and development. The innovation attitude of female directors has been attributed to the fact that risky innovations may cost mangers their jobs if they fail, and therefore most managers are innovation averse. However, we emphasise that female directors obtain more information about mangers abilities and capabilities, and skilful managers are encouraged to pursue innovation-driven activities that will enhance GHG reduction (Chen *et al*., 2018). Additionally, women usually are considered wiser and diligence in the boardroom (Huse and Solberg, 2006) and may bring different values, expertise and knowledge and thus impact positively on innovation (Hillman *et al*., 2002; Eagly *et al*., 2003; Bilimoria and Wheeler, 2012).

In our hypothesis 3, we found that the impact of innovation on gender diversity and GHG emission is more significant in carbon-intensive sectors than less-intensive sectors. Liao *et al*. (2015) found that gender diversity has a significant positive relationship with GHG emission control in less-carbon-intensive industries than carbon-intensive industries. Arguing from a regulatory point of view, they indicated that regulatory institutions that are responsible for the control of GHG emissions are likely to be more substantial, constraining, and strict in carbon-

intensive industries than less-carbon-intensive industries. However, our results showed a contrary view. We found that gender diversity, coupled with innovation is more effective in reducing GHG emissions in carbon-intensive industries than in less-carbon-intensive industries. We argue that less carbon-intensive firms may already be efficient and therefore, gender diversity moderated by environmental innovation will not have any significant impact on already efficient firms (Busch and Hoffmann, 2011). Gender diversity moderated by environmental innovation in carbon-intensive industries is likely to have a substantial effect on GHG emissions. This is because there are many areas in such sectors where the deployment of innovative pollution abatement strategies might result in considerable GHG impact.

In contrast, it is difficult for less-carbon-intensive industries to achieve the same improvements from environmental innovativeness. The reason is that unlike the carbon-intensive firms which have "low hanging fruits" which can be picked easily, less-carbon-intensive firms do not (Darnall and Carolina, 2005). Also, arguing from a regulatory point of view because regulators are likely to be stricter on carbon sensitive industries, they are likely to adopt efficient, innovative practices to avoid fines and penalties. Females on board in such sensitive environmental industries use their assertiveness to influence the BOD to employ innovative environmental practices that enhance GHG emission reduction practices to avoid the likelihood of fines and penalties, and also reduce harmful effect on the community to avoid questioning of the firms' legitimacy. Liu (2018) emphasised that where there is a critical mass of females on board, the lesser the organisations are sued for issues related to the environmental violation. Therefore, we assert that innovative measures that require women involvement from the boardroom to reduce environmental penalties are more sensitive in carbon-intensive firms than less-carbon-intensive firms.

7. Conclusions and Implications

This study examines the impact of gender diversity on corporate carbon emission. It also investigates whether the link between gender diversity and emissions is reinforced by environmental innovation and whether the effect is more significant in carbon-intensive or less-carbon-intensive industries. Using multi-theoretical approach including stakeholder, resource dependency, and upper echelon theory we discover that female gender diversity reduces GHG emission and the effect is more significant when moderated by environmental innovation. Drawing lessons from the upper echelon theory and in line with recent study by Tingbani *et al*. (2020), we explained that as women are more accommodating, assertive, and communal in

nature, they are more likely to accept innovative environmental practices that reduce harmful effect on the environment than men. We also discover that the impact of environmental innovation on gender diversity and GHG is more beneficial in carbon-intensive industries than less-carbon-intensive industries. Following the argument offered by Liu (2018), we assert that where there is a critical mass of females on board, their influence on environmental innovation on GHG is higher in carbon-intensive industries than less-carbon-intensive industries.

The study has important social, theoretical, practical and policy implications. *Socially*, even though existing empirical studies have examined the effect of board gender diversity on firm financial performance (Carter *et al*., 2010, Sarhan *et al*., 2018) and GHG disclosure (Liao et al., 2015; Tingbani *et al*., 2020), the effect of board gender diversity on GHS emission has received very little attention. This study contributes to filling such a knowledge gap by providing evidence of the effect of board gender diversity on GHG emission. It revealed that women could resolve some of the social problems such as GHG emissions through their influences in the board decisions. This finding is also consistent with the suggestion that the beneficial effect of board gender diversity is reducing the harmful effect of the organisation's activities. Thus, females with strong beliefs about CSR will promote the broader stakeholder community's interest using their dynamic personality, expertise, and communication style to resolve social menace like GHG emissions.

Theoretically, our results are in line with the upper echelons theory, which stipulates that collective cognition, capability, and interaction of the entire BOD significantly affect organisational performance. The study's findings aside, confirming that gender diversity impact on emissions also revealed that gender diversity, coupled with innovation, also significantly impacts GHG emissions, particularly in carbon-intensive industries. Thus, based on the upper echelon theory's tenets, women employ unique values such as assertiveness, flexibility, and cooperative behaviour to influence the board decision on innovative environmental practices to reduce GHG emissions. Thus, the study enhances our understanding of the positive effect of board diversity. The study's findings are also in line with the resource dependency theory. It suggests that the gender differences in the board room provide different skills, perspective, and influence on issues to the benefit of the firm (Hillman *et al*., 2007). These attributes of women, unique resources become more revealing when dealing with high polluting industries. Women are generally concerned with stakeholder welfare than men and would use their unique resource to pursue actions that reduce harmful effects on stakeholders such as GHG emissions.

Practically, one key implication is the pertinence of environmental innovation for organisations that intend to improve their carbon performance through board gender diversity. It shows that women on board encourage innovations, and innovative practices, particularly environmental innovations, positively reduce GHG emissions. Our results also indicate that carbon-intensive firms need to invest persistently in environmental innovation to significantly reduce their carbon emissions. Thus, it provides a useful guide to management on the extent to which environmental innovation can influence the reduction of GHG emissions. Also, there is increasing pressure on organisations to increase females in the boardroom from civil groups and government. However, one question demanding an answer is whether females in the boardroom advance corporate performance (Cook and Glass, 2018). It is therefore important to understand the influence of females in the boardroom and on firm performance. The study's findings have clearly demonstrated that women can influence corporate performance, especially in areas of GHG emissions.

One key *policy* implication of the study is that it helps advance the females in the boardroom agenda. The study revealed that board gender diversity reduces GHG emissions of the firm, and the increasing number of females positively impacts GHG emissions. This is expected to provide practitioners and policymakers with empirical evidence to back the theoretical argument(s) supporting the female boardroom advocacy. Thus, we provide empirical evidence to enhance our understanding of the role of BOD gender diversity as a CG mechanism and environmental innovation that should be useful for public-policymakers who are concerned with the impact of governance structure on emissions-control targets. Business executives can benefit from the evidence regarding the extent to which governance characteristics can influence GHG performance.

Despite these contributions and implications, our analysis is not without *limitations*. The study concentrated on only one measure of environmental performance indicator, GHG. However, Boakye *et al*. (2020) using multiple measures of sustainable environmental indices, argued that they offer broader perspective than just a single measure of environmental performance indicator. Thus, it is expected future studies on gender, and environmental innovation will capture other environmental performance metrics, as indicated by *Boakye et al*. (2020). Data limitation relating to executive and independent female directors did not allow for analysis of the impact of the two types of directors on the GHG emission. This could further provide valuable insight and help focus on which type of female directors' firms should be

encouraged to appoint to the boardroom. Future studies may look at the impact of this segregation on firm performance in general and GHG. Results are limited to only U.S. listed companies. Future studies could investigate this study from other developed or emerging economies. Also, using secondary data does not help us capture the moral aspect of the association. Therefore, future research could rely on alternative methodologies such as surveys and interviews to consider how moral values or belief systems of female versus male BOD members may influence the environmental innovation and GHG emissions reduction. Yet, future research could explicitly explore whether variation in the moral values or belief among BOD members affects environmental innovation and GHG emissions more generally.

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