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Does gender diversity in corporate boards and executive management teams influence carbon performance? Evidence from Europe

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Does gender diversity in corporate boards and executive management teams influence carbon performance? Evidence from Europe

ABSTRACT

We examine how gender diversity in both corporate boards and executive management teams influence both procedure-oriented carbon management performance (PCMP) and real carbon emission reduction performance (RCRP) of European listed firms. Drawing on multiple theoretical perspectives, our empirical models employ firm fixed-effects estimators to analyse a large dataset, consisting of 5,327 firm-year observations, covering a period of fifteen years. Our findings are three-fold. First, our primary evidence suggests that gender diversity in both corporate boards and executive management teams has a statistically significant positive association with PCMP and RCRP. Second, we provide robust evidence on the link between female directors' cognitive attributes and PCMP, as well as RCRP. Third, we find that board gender diversity reinforces the positive influence of gender-diverse executive management teams on PCMP and RCRP. Overall, our study results suggest that female directors and executives play complementary roles in influencing and shaping a company's response to global climate risk. Our results are generally robust to controlling for governance mechanisms, alternative measures/estimations and endogeneities. Our findings have implications for policies relating to gender-responsive governance reforms, as well as the integration of gender diversity into firm-level, country-specific and regional frameworks for climate change policies and reforms.

KEYWORDS: Board gender diversity; gender-diverse executive management teams; cognitive diversity; ethicality and socialisation theories; procedure-oriented carbon performance; GHG emissions; corporate sustainability.

JEL Classification: G34; J16; M14; M40; Q50

1. Introduction

"…*Recognising the important contributions of women as decision-makers, stakeholders, educators, carers and experts across sectors and at all levels can lead to successful, long-term solutions to climate change (IUCN, 2015, p. 1)."*

It has been argued that to achieve the critical targets contained in the 2016 Paris Climate-Change Agreement, governments and companies around the world will need to minimise the gap between long-term climate-related goals and short-term action plans, including committing to net zero targets with greater credibility and urgency (Agyei-Boapeah et al., 2023). Whilst this requires, among other things, developing and implementing overarching sustainable corporate policies/substantive actions of corporate boards/executive management teams, women's role as board members/corporate executives can be particularly crucial in developing/implementing sustainable/equitable solutions to climate risks (IUCN, 2015). Subsequently, the Conference of the Parties (COP25/2019) in Madrid agreed to integrate a gender perspective into climate policies/action plans (UNFCCC, 2020), considering women's contribution to strategic business decision-making (Al Hameli et al., 2023). Additionally, the literature points to the critical importance of examining the impact of specific board characteristics on corporate sustainability practices/disclosures (Michelon & Parbonetti, 2012)[2]. We, therefore, aim to contribute to this ongoing policy debate, as well as to the limited body of extant literature by examining how gender

[2]We note that the sustainability accounting and reporting literature of which carbon accounting and reporting is part of that this study seeks to contribute to also originates from the broader social and environmental accounting (SEA) literature, having a rich and long-standing history, with different perspectives, such as critical (e.g., Gray et al., 1995; Lehman, 1995, 2001), review (e.g., Deegan, 2002; Gray, 2002; Guthrie & Parker, 1989) and empirical (e.g., Adams, 2002; Arena et al., 2015; Deegan et al., 1995, 2002; Gray, 1992; Guthrie & Parker, 1990; Hogner, 1982; Jones, 2003; Lehman, 1999; Mallin & Michelon, 2011; Mallin et al., 2013; Michelon et al., 2013; Qian et al., 2024) studies. For detailed overview of the different strands of this early SEA literature, readers are referred to authoritative overviews by Bebbington (1997), Gray et al. (1995) and Parker (2005), amongst others.

diversity within corporate boards/executive management teams, and female directors' cognitive characteristics influence corporate carbon initiatives/performance.

The notion of integrating a gender perspective into the climate change framework is not just the concern of climate scientists/policymakers, but also a critical consideration for corporations, as a limited, but growing body of policy-oriented/academic literature recognises the significance of gender diversity in mitigating a firm's climate-related risks. This is further reinforced by mandatory/voluntary regulations to promote board gender diversity in many European countries, such as Spain, France, Italy, Netherlands, Belgium, Norway, Sweden, Germany, Austria and the UK (Clark et al., 2021). Accordingly, companies are increasingly promoting gender diversity in corporate boards/executive management teams as part of their effort to enhance corporate social/environmental reporting/performance, which in turn can improve firms' decision-making, governance and financial performance in the long-term.

Theoretically, gender socialisation and ethicality theories suggest that women board members tend to exhibit greater sensitivity towards ethical issues/greater societal challenges, such as climate change, and hence, they are more likely to adopt renewable energy-based solutions/reduce environmental violations than their male counterparts (Liu, 2018; Atif et al., 2021). Similarly, diversity theory suggests that cognitive/demographic diversity enhances board dynamics/promotes multiple perspectives, leading to an improvement in the quality of corporate decisions, as well as board monitoring, especially on critical issues of corporate sustainability/climate change (Post et al., 2011; Rao & Tilt, 2016). Likewise, the resource-based view (RBV) highlights that the human/relational capital and reputational attributes of a gender-diverse board can facilitate a firm's corporate sustainability initiatives and enhance corporate legitimacy (Hillman & Dalziel, 2003; Mallin & Michelon, 2011).

Despite the significance of gender diversity in promoting corporate sustainability initiatives, there seems to be a dearth of empirical literature on the likely influence of gender diversity in corporate boards/executive management teams on corporate carbon performance. Among others, Atif et al. (2021) examined the influence of board gender diversity on renewable energy consumption of S&P1500 firms. Similarly, Liu (2018) examined the influence of female board members/female chief executive officers/(CEOs) on corporate environmental violations in S&P1500 firms. Glass et al. (2016) also investigated how gender-diverse leadership teams (of boards/CEOs) influence environmental strategies of Fortune500 companies.

Evidently, the majority of these studies seem to focus on the US context and do not address actual greenhouse gas (GHG) emissions, whilst several studies use women on corporate boards rather than women in executive management teams. Crucially, existing studies have mainly focused on demographic characteristics of women rather than their cognitive attributes (Cormier et al., 2024). These limitations offer opportunities to make new/unique contributions to the extant literature on SEA/governance by examining the cognitive attributes of both executive and non-executive women directors on corporate process-oriented carbon management performance (PCMP) and real carbon emissions reduction performance (RCRP) (Rao & Tilt, 2016; Arena et al., 2015; Parker, 2005; Mallin et al., 2013; Qian et al., 2024). For example, Liu (2018) found that female board members/female CEOs play complementary roles in reducing corporate environmental violations, although Atif et al. (2021) found that female executive directors do not have any influence on renewable energy consumption.

Notably, and to the best of our knowledge, prior studies have not examined the influence of gender diversity within both corporate boards and executive management teams on both firms' PCMP and RCRP. This study goes beyond examining just the gender characteristic by considering

cognitive attributes, such as experience and qualifications of women on boards. Moreover, existing literature does not seem to address whether and how board gender diversity can moderate the effect of gender-diverse management teams on carbon performance. Therefore, we seek to address these limitations that are inherent in the following three research questions: (i) How does gender diversity in both corporate boards and executive management teams influence both PCMP and RCRP?; (ii) How do women board members' cognitive attributes, such as age, experience, qualifications and board committee membership influence PCMP and RCRP?; and (iii) Does board gender diversity moderate the influence of women in executive management teams on both PCMP and RCRP?

By addressing the above questions, this study seeks to make the following new/original contributions to the extant literature on gender diversity and SEA (Gray, 2002; Guthrie & Parker, 1989; Qian et al., 2024). *First*, we extend the existing limited, but steadily growing body of literature on governance, gender, SEA and performance (Adams, 2002; Deegan, 2002; Mallin & Michelon, 2011; Michelon et al., 2013; Mallin et al., 2013; Rao & Tilt, 2016) by examining how gender diversity within corporate boards/executive management teams individually and interactively influence both PCMP and RCRP. Unlike other studies, we consider the influence of gender-diverse executive management teams and investigate how the interplay between female board members and female managers can drive and shape a firm's response to climate change risks. By so doing, we argue that gender-diversity in executive teams matters and can reinforce the strategy/action plans of diverse boards towards carbon mitigation.

Second and contrary to the inconclusive findings of related studies (Prado-Lorenzo & Garcia-Sanchez, 2010; Xing et al., 2021), we find that board gender diversity positively influences PCMP and negatively influences actual GHG emissions, leading to an improved RCRP.

Importantly, our findings suggest a significant influence of female directors' cognitive characteristics on carbon performance. For instance, female directors' age, educational background in law and participation in audit and compliance committees of the board are positively associated with both PCMP and RCRP. Moreover, female presence on boards positively moderates the impact of gender-diverse executive management teams on both PCMP and RCRP. We also find that gender-diverse executive management teams positively influence both PCMP and RCRP.

Third, our study results imply that policymakers need to recognise that any gender-responsive corporate governance reforms should integrate gender diversity not just at the board level, but also at various levels of executive management to make a substantive/sustainable impact on corporate sustainability initiatives and their implementation. *Fourth*, with our study involving multidimensional relationships, we respond to the recent calls from the United Nations Framework Convention on Climate Change (UNFCCC) to integrate gender-diverse leadership and participation and gender-responsive action plans into micro- and macro-level carbon framework (UNFCCC, 2020), such as the UK's 2050 carbon plan towards Net Zero target and the EU's 2050 Carbon Neutrality Project.

Finally, our overall findings contribute to a limited, but emerging body of literature that draws insights from different theories, such as gender socialisation, ethicality, diversity, and resource-based view perspectives (Liu, 2018) to understand the influence of gender diversity within both corporate boards and executive management teams on corporate environmental performance, which is a multidimensional construct that requires greater consensus, substantive capacity-building and long-term commitments.

The rest of the paper is structured as follows. Section 2 critically reviews related theories, empirical literature and develops hypotheses. Section 3 explains research design issues, and section 4 presents and discusses our study results. Section 5 reports robustness analyses, whilst section 6 concludes the paper.

2. Theory, empirics and hypotheses development

2.1 Theory

2.1.1 Gender socialisation and ethicality theories

Gender socialisation and ethicality theories suggest that women consider the notions of morality and ethics differently than men, because of their personality traits, upbringing, and social interactions (Carlson, 1972; Gilligan, 1977; Oradi & E-Vahdati, 2021). Women exhibit greater sensitivity towards ethical issues, communities and wider societal challenges that have consequences in the long-term (Zalata et al., 2019a). According to this theory, women are less power-oriented than men and also show strong traits of tolerance, benevolence and universalism, hence, they care for the protection and welfare of nature and society (Adams & Funk, 2012; Zalata et al., 2019b).

Consequently, it has been argued that these characteristics enable women executives/board members to anticipate emerging societal challenges/climate-related risks of a firm and to initiate sustainable corporate practices to mitigate these risks (Adams & Funk, 2012). In addition, high ethical values, high universalism and low power-orientation traits would enable women directors/managers to minimise corporate environmental misconduct and to establish and manage stakeholder relationships more efficiently, leading to an improved corporate reputation (Liu, 2018).

2.1.2 Diversity theory

Whilst gender socialisation and ethicality theories explain why women board members/managers are more inclined to make positive contributions to society/environment, diversity theory appears to be appropriate for how gender-diverse board/executive management teams can influence corporate environmental policies, action plans and implementation (Post et al., 2011; Rao & Tilt, 2016). According to diversity theory, board gender diversity improves firm performance in two ways: *Firstly*, board gender diversity enhances the quality of board monitoring, improves board dynamics and decision-making quality, while enhancing frequent board meetings and attendance (Bear et al. 2010; Liu, 2018). *Secondly*, cognitive/demographic diversity (Rao & Tilt, 2016; Atif et al., 2021) improves board dynamics/board decision-making through: (i) better understanding/appreciation of multiple stakeholders' preferences, (ii) consideration of a wider range of perspectives/an assessment of more options to address wider societal concerns, leading to an optimal solution, (iii) assessment of more options to address wider societal concerns, and (iv) greater creativity and innovation.

2.1.3 Resource-based view (RBV)

Hillman and Dalziel (2003) proposed RBV to suggest that corporate board members can provide a firm with human/relational capital, such as legitimacy, advice, external collaboration, and access to resources to create a distinctive competitive advantage for a firm. Mallin and Michelon (2011) observed that several reputational attributes of corporate board members can enhance firms' corporate social responsibility (CSR) performance, and these include advice and counselling, consultations with influential stakeholders, and negotiations with the suppliers of materials,

technologies, and finance. Similarly, Beji et al. (2021) and Godfrey et al. (2020) argued that female board members tend to provide competencies, skills and external connections that can help firms improve SEA/CSR performance.

2.2 Empirical literature and hypotheses development

The literature examining the impact of board characteristics on SEA has expanded over time due to their prominence in improving strategic decision-making/enhancing the competitiveness of firms. Whilst some of these studies focus on the impact of board diversity on general SEA/CSR characteristics (Mallin & Michelon, 2011; Zhang et al., 2013), others focus on different aspects of SEA, with much emphasis on environmental factors. However, there is little emphasis on the impact of board diversity on carbon performance; an environmental issue that permeates most societies worldwide. Moreover, as Rao and Tilt (2016) observed, there has been limited research linking various board diversity characteristics, such as board gender, age, experience and background to CSR/CSR reporting. For Post et al. (2011), directors' experiences and backgrounds influence firms' strategic directions related to SEA strategies/commitments. Whilst female directors are mostly found to have a positive effect on SEA/CSR performance (Mallin et al., 2013; Zhang, 2012; Boulouta, 2013), most of the evidence tends to be from the US context. This study, therefore, investigates both gender and other cognitive diversity characteristics within the European context with the aim of contributing to the literature on corporate governance/SEA.

2.2.1 Gender diversity and carbon performance

We draw on gender socialisation theory to argue that women in corporate boards/executive management teams are more likely to recognise climate-related risks/opportunities and to convince

the entire board/executive management team to undertake long-term carbon abatement/energy-efficient projects. Women board members would also, as diversity theory suggests, facilitate efficient board decision-making on carbon-related strategies/innovative green solutions by bringing a wider range of perspectives, whilst addressing conflicts of interest among multiple stakeholders. Moreover, women board members' human/relational capital, such as relationship building, critical advice and resources can improve board decision-making on corporate environmental strategies (Mallin & Michelon, 2011) and provide efficient monitoring/support for a better implementation of climate adaptation/carbon mitigation projects.

Empirically, prior studies found a positive association between board gender diversity and CSR performance (Mallin & Michelon, 2011), climate-related disclosures (Ben-Amar et al., 2017; Liao et al., 2015; Hollindale et al.,2019), and biodiversity disclosures (Haque & Jones, 2020). Moreover Canil et al. (2021) and Glass et al. (2016) found that gender diversity in top management teams has a positive effect on corporate innovation/sustainability-oriented strategies. However, Prado-Lorenzo and Garcia-Sanchez (2010) and Haque (2017) found inconclusive evidence on the influence of gender-diverse boards on environmental disclosures/performance.

Overall, we build our arguments on these related theories that women's resource provisioning role, along with their socialisation and ethicality perspectives, as well as an improved decision-making/monitoring ability of the gender-diverse board/executive management teams, can be instrumental in driving corporate climate policies, strategies, action plans and implementations. We, therefore, expect a positive influence of women in corporate boards/executive management teams on firms' carbon performance and test the following hypothesis:

***H_1*:** *Ceteris paribus, firms with greater gender diversity within their corporate boards and executive management teams exhibit improved procedure-oriented carbon management performance (PCMP) and real carbon emission reduction performance (RCRP).*

Additionally, we explore the impact of female participation on board committees and various cognitive diversity attributes (Cormier et al., 2024) of female directors on carbon performance as follows:

2.2.2 Female on board committees and carbon performance

Extant literature provides evidence of a positive relationship between various committees, such as the environmental committee (Dixon-Fowler et al., 2017; Walls et al., 2012), governance committee (De Villiers et al., 2011), risk management committee (de Villers et al., 2022) and the environmental performance of firms. A few others like Rodrigue et al. (2013) find no effect of sustainability committees on environmental performance. Meanwhile, there is evidence of a stronger commitment by board committees towards environmental performance when there is higher female representation on such committees (Glass et al., 2016). The socialisation of women promotes long-term orientation with community focus and relationship building, which makes women pursue sustainability policies, including environmental performance more strongly (Glass et al., 2016). Thus, in line with socialisation and ethicality theories, we expect that board committee diversity will result in better carbon performance and we, therefore, test the following hypothesis:

> ***H_{1a}*: *Ceteris paribus, firms with females on their board committees exhibit improved procedure-oriented carbon management performance (PCMP) and real carbon emission reduction performance (RCRP).***

2.2.3 Age of female directors and carbon performance

Cognitive attributes like directors' age often signifies the level of exposure and experience that they may possess, with older directors having more experience. Younger directors tend to be more alert, energetic and technologically inclined, but may have less exposure, ceteris paribus (Handajani et al., 2014). Empirically, several studies found a positive association between

directors' age and CSR performance (Hafsi & Turgut, 2013; Post et al., 2011; Said et al., 2012; Fernandes et al., 2018). Even as females have ethicality and socialisation oriented towards social welfare, it is expected that older women will be more inclined to environmental policies and thus, we test the following hypothesis:

> ***H_{1b}:*** *Ceteris paribus, the age of female directors improves procedure-oriented carbon management performance (PCMP) and real carbon emission reduction performance (RCRP).*

2.2.4 Female board experience and carbon performance

From the RBV, board experience can help a firm to gain competitive advantage through better strategic decision-making. In the context of our study, female directors with longer board tenure are likely to offer a broader range of skills/experience to understand stakeholders' concerns and to accommodate conflicting needs of shareholders/stakeholders in board decision-making process. Accordingly, prior studies found a positive association between board experience and corporate social (Hafsi & Turgut, 2013; Melo, 2012)/environmental (De Villers et al., 2022) performance. Board experience is, therefore, expected to have a positive effect on carbon performance. We, therefore, test the following hypothesis:

> ***H_{1c}*:** *Ceteris paribus, the experience of female directors improves PCMP and RCRP.*

2.2.5 Education background/level of female directors and carbon performance

In light of the RBV, cognitive features like educational background/level determine the knowledge, skills and counsel that board members possess (Bogacki & Letmathe, 2021). Hence, education/knowledge about current issues on sustainability/environmental strategies are expected to increase the level of commitment of female executives to be supportive of environmental policies/ultimate performance. Previous studies show that diversity in educational

background/skills positively affects environmental performance (Rao & Tilt, 2016; Liao et al., 2015), although Post et al. (2011) found insignificant results on the linkage between board members' education and CSR performance. It has been argued that board members with finance background often tend to pay little attention to sustainability performance compared to others, hence, a negative effect of board skills on GHG reporting in the UK context (Al-Qahtani & Elgharbawy, 2020). Hence, a mixed result on this relationship is evident based on the predominant educational background of female executives/board members. We, therefore, test the following hypothesis:

> ***H_{1d}*:** *Ceteris paribus, firms that have female directors with diverse educational backgrounds exhibit improved PCMP and RCRP.*

2.2.6 Moderating effect of board gender diversity

Recent literature addresses the moderating effect of governance mechanisms (Arena et al., 2015; Rao & Tilt, 2016). Xing et al. (2021) referred to two opposing effects of the interaction between female top managers and board members. One the one hand, greater cooperation between women executives and women board members might constrain the independence/effective monitoring of the board, leading to poor firm performance. On the other hand, a close interaction between women executive managers and directors is likely to enhance cooperation/trust, as well as the resource provisioning role of the board in terms of expert knowledge/advise, and also facilitate the exchange of information, which in turn improves decision making/operational efficiency of a firm (Xing et al., 2021). Empirically, Liu (2018) found that female board members and CEOs play complementary roles in promoting corporate policies towards reducing corporate environmental violations in US firms, although Atif et al. (2021) found inconclusive evidence.

Based on the above-mentioned theoretical arguments, we expect women board members and managers to play complementary roles in undertaking corporate sustainability initiatives. Therefore, the following hypothesis is developed:

H_2*: *Ceteris paribus, board gender diversity positively moderates the influence that gender-diverse executive management teams have on firms' PCMP and RCRP.

3. Research design

3.1 Data and sample

Our empirical framework is based on an unbalanced panel dataset of 6,869 firm-year observations from European listed firms in 2005. We check the availability of carbon and diversity-related data in Refinitiv's Eikon database to determine our sample. Our sampled firms are listed on the main stock exchanges of the UK, Germany, Italy, Spain, Belgium, Denmark, Austria, Finland, Sweden, Netherlands, France, Switzerland and Norway. We then excluded 850 observations due to missing company-level data on carbon performance and a further 692 observations due to missing data on gender diversity. This leaves us with a final sample of 5,327 firm-year observations that capture data from 467 firms over 15 years from 2005 to 2019. We use Refinitiv's Eikon/BoardEx databases to collect governance and carbon-related data and the Worldscope database to collect data on financial control variables, with differing availabilities of governance data that explains variations in the number of observations across the different estimated models.

3.2 Regression models and variables

We follow Gallego-Alvarez et al. (2015) to develop/estimate the following empirical model to test *Hypothesis 1:*

$$Y_{it} = \beta_0 + \beta_1 * WOB_{it} + \beta_2 * WOM_{it} + \sum_{j=3}^{18} \beta_j * CONTROL_{jit} + \varepsilon \qquad (Eq.(1))$$

In Eq.(1), Y is *PCMP or RCRP; WOB* is a function of gender diversity within corporate boards; *WOM* is gender diversity in executive management teams; *CONTROL*: company-specific governance characteristics, financial indicators; and ε: the error term. Table 1 provides further details of all the variables.

Insert Table 1 about here

To investigate the impact of attributes of female board members on the environmental performance (*H1a* to *H1d*), we use the second models below:

$$Y_{it} = \beta_0 + \beta_1 * COM_{it} + \beta_2 * F.Dir\_Age_{it} + \beta_3 * F.Dir\_Experience_{it} + \sum_{k=4}^{8} \beta_k * EDU_{it} + \beta_9 * WOM_{it} + \sum_{j=10}^{25} \beta_j * CONTROL_{jit} + \varepsilon \qquad (Eq.(2))$$

In Eq.(2), Y is *PCMP or RCRP; COM*: the presence of female directors on board committees; *F.Dir_Age*: Age of female directors; *F.Dir_Experience*: Experience of female directors; *EDU*: Educational background/level of female directors; *WOM*: Gender diversity in executive management teams; *CONTROL*: company-specific governance characteristics, financial indicators; and ε: the error term.

To test *Hypothesis 2* on the moderating effect of a gender-diverse corporate board on gender-diverse executive management teams–carbon performance nexus, we follow, among

others, Morse et al. (2011) by estimating Eq.(1) for the two sub-samples of firms with and without a gender-diverse board.

3.2.1 Dependent variables

We follow Haque and Ntim (2020) in using two measures of carbon performance as dependent variables: (i) procedure-oriented carbon management performance (*PCMP*); and (ii) real carbon emission reduction performance (*RCRP*). *PCMP* is an index of 21 binary indicators that outlines company-specific policies, processes, initiatives, and disclosures relating to a company's climate-related initiatives to reduce carbon emissions, mitigate carbon-related risks/biodiversity loss, and build capacity /develop energy efficiency, sustainable supply chain management, and green building (***please see Appendix Table C1 for further details***). *PCMP* values range from 0 to 21, with a firm scoring higher value implying an improved procedure-oriented carbon management performance. We use the natural logarithm of the total of scope 1 and scope 2 emissions to measure real carbon emission reduction performance (*RCRP*), with lower emission implying better *RCRP* of a firm. We take the negative sign of GHG emissions to facilitate interpretations.

3.2.2 Explanatory variables

We use gender diversity in corporate boards (*WOB*) and gender diversity in executive management teams (*WOM*) as the two main explanatory variables. We use a commonly used measure of *WOB*, which is the percentage of women among the total board members. Unlike other studies, we use the percentage of women executives among the total managerial level employees (other than women board members) of the firm (*WOM*) to measure gender diversity in executive management teams. We also use three dummy variables indicating the presence of female directors on audit

committee (*F.AudCom_D*), compliance committee (*F.ComplCom_D*), and CSR committee (*F.CSRCom_D*). In addition, we use several cognitive diversity variables, such as age of female directors (*F.Dir_Age*) and experience of female directors (*F.Dir_Experience*), as well as the level/background of female directors, as measured by the percentage of female directors with a PhD (*F.Dir_PhD*), masters (*F.Dir_Masters*), business background (*F.Dir_business*), law background (*F.Dir_Law*) and accounting & finance background (*F.Dir_A&F*). As outlined in *Hypotheses 1, 1a-1d*, WOB, WOM, as well as board committees and cognitive diversity variables are expected to have positive associations with *PCMP* and *RCRP*. Finally, we use WOB_D as an alternative indicator to test *Hypothesis 2* on the moderating variable of a gender-diverse board (*WOB_D*). *WOB_D* is predicted to reinforce the positive influence of gender-diverse executive management teams on the *PCMP* and *RCRP* of a firm.

3.2.3 Control variables

Following past studies (de Villiers et al., 2011), our (i) ESG-related control variables include board size (*BS*), board independence (*IND*), separation of CEO from the board chairperson (*Sep*), the CSR committee of the board (*CSR*), board meeting (Meet), executive compensation (*Comp*), sustainable compensation policy (*ESG*), ISO14001 certification (*EMS*), and the number of employees (*Employees*), and (ii) financial control variables include Tobin's Q (*Q*), firm size (*Size*), profitability (*ROA*), leverage (*Lev*), liquidity (*Cash*), tangible assets (*PPE*), and sales growth (*Growth*).

4. Empirical results

4.1 Descriptive statistics and univariate analysis

Table 2 shows summary statistics of all the variables. Panel A of the Table shows that the procedure-oriented carbon management performance (*PCMP*) index has a mean value of 9.03 and a standard deviation of 4.62 on a scale of 0 to 21. A relatively high standard deviation suggests that the *PCMP* scores seem to be spreading out from the mean value reasonably well. The table also shows that the mean value of real carbon emission reduction performance (*RCRP*) is 12.86, with a standard deviation of 2.39, suggesting a higher concentration of GHG emissions among a group of sampled firms. Table 2 also shows around 18.34% representation of women board members in the sampled firms, with a standard deviation of 13.46. This suggests a greater variation in board gender diversity among the European listed firms. In addition, the percentage of women in executive management teams is around 11%, with a standard deviation of 12.42.

Insert Table 2 about here

Table 3 shows correlations among gender diversity, carbon performance and other variables. It is evident that women in corporate boards (*WOB*) have a moderate degree of positive correlation with *PCMP* and a weak negative correlation with *RCRP* indicators. Similarly, gender diversity in executive management (*WOM*) has a positive correlation with *PCMP* and a negative correlation with *RCRP*, although the degree of the relationship is relatively weak in both cases. Overall, correlation results are broadly consistent with our main hypotheses. Table 3 also shows that the relationships among the explanatory and control variables are moderate or weak, suggesting that we do not seem to have any serious concerns about the multicollinearity problem in our empirical estimations.

Insert Table 3 about here

4.2 Multivariate results and discussion

Our estimated results of the firm fixed-effects regressions are presented in Table 4. Columns 1 to 3 show the regression results of *PCMP* against two explanatory variables of *WOB* and *WOM* and other control variables related to governance/financial characteristics of the sampled firms. Columns 4 to 6 show the estimated results of a similar model with *RCRP*, as the dependent variable.

Column 1 of Table 4 shows the estimated results of Eq.(1) for the whole sample with *WOB* and *WOM* as the main explanatory variables. The results show both gender diversity variables having highly significant positive associations with *PCMP*. Columns 2 and 3 show the results of the sub-samples of firms with and without a gender-diverse board. It is evident that the relationship between *WOM* and *PCMP* is positive and highly significant at 1% level for the sub-sample of firms with a gender-diverse board, but this relationship is statistically insignificant for the sub-sample of firms without a gender-diverse board.

Insert Table 4 about here

Columns 4 to 6 show estimated results of the regression of *RCRP* against gender diversity and other control variables. Column 4 shows that both *WOB* and *WOM* are positively associated with *RCRP*. Columns 5 shows a positive and statistically significant relationship between *WOM* and *RCRP* for the sub-sample of firms with a gender-diverse board, whereas column 6 shows that *WOM* is statistically insignificant for the sub-sample of firms without a gender-diverse board. Among the control variables, board independence, CSR committee of the board, executive compensation, sustainable compensation policy and firm size show statistically significant positive

relationships with *PCMP*, although all of them are statistically insignificant in the regression of *RCRP*. Among the financial control variables, firm size and tangible assets show a positive relationship with *PCMP* and a negative relationship with *RCRP*, whereas sales growth shows a negative association with *PCMP* and *RCRP*.

Overall, our estimated results support *Hypothesis 1* in that gender diversity in corporate boards and executive management teams is positively associated with firms' *PCMB* and *RCRP*. This evidence is consistent with the findings of related studies (Glass et al., 2016; Liu, 2018) that showed a gender-diverse leadership team has a positive (negative) influence on corporate environmental strategies (violations), even though these studies have not tested actual carbon performance effect. However, this result is contrary to the evidence of related studies that show indecisive results on the influence of board gender diversity on environmental performance (Prado-Lorenzo & Garcia-Sanchez, 2010; Bui et al. 2020).

Insert Table 5 about here

Insert Table 6 about here

In support of the conjecture that gender diversity enhances carbon performance, Tables 5 and 6 present results on the extent to which female presence on board committees and some cognitive diversity characteristics of female board members affect *PCMP* and *RCRP*, respectively. Our results show that female presence on the compliance committee has a significant positive association with *PCMP* (see Columns 3 and 7), just as the age of female directors across all models in Table 5. Also, female directors with an educational background in business studies have a significant positive association with *PCMP* (see Column 5) and are insignificant in other Models

considered. Similarly, Table 6 shows that female presence on the audit (see Columns 2 and 6) and compliance (see Columns 3 and 7) committees is positively associated with *RCRP* and just as female directors' age as shown throughout the Columns. In Columns 5 to 8, educational background in law shows a significant positive association with *RCRP*, however, PhD education, and educational background in business, as well as the experience of female directors are negatively associated with *RCRP*.

Taken together, our results of a positive relationship between various board committees and environmental performance (Dixon-Fowler et al., 2017; Walls et al., 2012; de Villiers et al., 2022), and thus support *Hypothesis 1a*. More specifically, our results suggest that female directors' participation in audit/compliance committees of the board tend to facilitate not just the policy or procedure-oriented carbon performance, but also the implementation of those policies, as well as the compliance with sustainability-oriented laws/standards.

Moreover, our evidence provides support for *Hypothesis 1b*, suggesting that the age (the older the better, since they get more experienced) of female directors positively affects both *PCMP* and *RCRP*. This supports the findings of Said et al. (2012) and Fernandes et al. (2018) and contradicts the findings of Ibrahim and Hanefah (2016), who argued that younger people are rather more inclined to increase environmental performance. Nonetheless, our results contradict *Hypothesis 1c* and show that female board members' experience has a negative association with *RCRP*. This is contrary to the general findings of prior studies (García Martín & Herrero, 2020; Liao et al. 2015).

Finally, our results offer partial support *Hypothesis 1d* in that female directors' educational background in law appears to have a significant positive impact on firms' *RCRP*, although the PhD-level education shows an opposite effect. Moreover, female directors with business education

tend to focus on improving symbolic *PCMP*, rather than actual carbon performance. We find no significant effect of female board members with accounting and finance backgrounds on *PCMP* and *RCRP*, and thus support Al-Qahtani & Elgharbawy (2020). Hence, we provide evidence in line with the resource-based theory (Bogacki & Letmathe, 2021) that educational background of law might enable female directors to provide the executive management with critical advice about the long-term implications of a wide-range of sustainability standards/regulations at both national and international levels, together with a greater focus on compliance. This eventually improves firms' actual carbon performance in terms of reduced GHG emissions. This evidence validates our evidence that female participation in audit/compliance committees enables firms to focus on substantive carbon performance through greater compliance/implementation of carbon-related policies/action plans.

Our results are also consistent with *Hypothesis 2* in that a gender-diverse board positively moderates the influence of women in executive management teams on a firm's *PCMP* and *RCRP*. This evidence is consistent with the evidence of Liu (2018), but contradicts with Atif et al. (2021). Our findings are broadly consistent with the evidence of Ruiz-Jiménez et al. (2016), who found that a gender-diverse board positively reinforce the influence of knowledge combination capability on innovation performance in Spanish technology-based SMEs. Given that carbon abatement projects/green solutions require long-term monetary commitments, technology-oriented solutions/sustainable capacity building across different functional areas of a firm, it is imperative to have close coordination among the (women) board and the (women) management team to ensure greater harmonisation from the determination of climate-related policies to the development/co-ownership of carbon projects to an actual implementation of those projects.

Overall, these results support the predictions of the theories adopted. Firstly, as the gender socialisation and ethicality theories suggest, women's greater emphasis on ethical issues, universalism, communities, and wider societal challenges (Glass et al., 2016) makes women board members and managers to be more sensitive towards climate-related risks of a firm, as well as the consequence of a firm's actions on societies. Moreover, as women's ethical/helping behaviour centres around empathy, caring, and nurturing the communities/nature (Atif et al., 2021; Boulouta, 2013), women board members/managers are more likely to be proactive in driving a firm's climate-related agenda/action plans. Secondly, as the diversity theory suggests, women board members promote greater participation, open discussion, and conflict resolution to accommodate a wider range of perspectives. This can result in greater consensus/more efficient decision-making on long-term carbon strategies/innovative green solutions.

Thirdly, women board members' resource provisioning role in the forms of critical advice/support, access to resources, and efficient monitoring is likely to facilitate capacity building/effective implementation of carbon abatement/energy efficient projects. This is supportive of the arguments of the resource-based view that a gender-diverse top management team, with a heterogeneous knowledge base, social skills, and professional trajectories, can enhance creativity/innovation performance (Ruiz-Jiménez et al., 2016), especially in areas of sustainable climate mitigation projects/green solutions.

Finally, women managers tend to lead the process of actual implementation of these projects through innovative/efficient ground-level solutions, effective coordination, compliance, control, and reporting (Liu, 2018). This eventually leads to an improvement in both carbon-related policies and processes, as well as a decline in actual GHG emissions. Altogether, women board members/managers play complementary roles in influencing a firm's powerful

management/shareholders towards shaping a firm's climate-related agenda from policymaking to a substantive and target-oriented implementation.

5. Robustness tests, identification and further analysis

5.1 Robustness tests

We undertake several tests to check the robustness of our estimation results. *First*, we estimate Eq.(1) with the first, second and third lags of the main explanatory variables *WOB* and *WOM*. The results (shown in Table 7) suggest similar estimation results for gender-diverse boards and gender-diverse executive management teams. *Second*, to examine the robustness of our estimation results for *RCRP*, we re-estimate Eq.(2) by replacing our dependent variable of logarithmic measure of GHG emission with an alternative measure of carbon intensity, which is measured by dividing total GHG emissions with total assets. Our findings (partly shown in Table 8) seem to remain unchanged in relation to the influence of both gender diversity variables on *RCRP*. *Third*, we check the robustness of our findings by re-estimating all the specifications after winsorizing at 1% and 99% levels. The results (***reported in Table A1 in the appendix***) are broadly similar to the reported results.

Insert Table 7 about here

Insert Table 8 about here

Fourth, we follow Atif et al. (2021) and re-estimate Eq. (1) by using firm fixed-effects regression with industry-adjusted carbon performance measures as dependent variables against industry-adjusted measures of the gender-diverse board and gender-diverse executive

management, alongside all other control variables. Our estimation results (***reported in Table A2 in the appendix***) are similar to the reported findings.

5.2 Identification

We adopt the following three approaches to address potential endogeneity concerns: (i) the instrumental variable approach, (ii) propensity score matching (*PSM*), and (iii) difference-in-difference estimations.

5.2.1 Instrumental variable approach

We use the instrumental variable (*IV*) approach and estimate the regressions using two-stage least squares (*2SLS*) to address the concerns on endogeneity. We follow Atif et al. (2021) in using country-level female-to-male workforce participation ratio (female-to-male) as an exogenous instrument for *WOB* and *WOM*. Table 9 presents *2SLS* regression results. The first-stage regression and diagnostic test results shown in Columns 1, 3, 5 and 7 suggest the validity of our instruments.

Insert Table 9 about here

The second-stage regression results shown in Columns 2, 4, 6 and 8 of Table 9 suggest that the fitted values of *WOB* and *WOM* are positive and statistically significant against both *PCMP* and *RCRP*, conforming to our reported results[3].

[3]We also undertake additional 2SLS regressions using two alternative instrumental variables, such as gender equality index and percentage of women in parliament. Our results, as presented ***Tables A3 and A4 in the appendix***, suggest no qualitative difference with our reported findings.

5.2.2 Propensity score matching

We follow, among others, Atif et al. (2021) and Palma et al. (2022) in using propensity score matching to eliminate the differences in company-specific characteristics. We identify treatment firms (with at least one female board member) and control firms (without any female board member) and use the nearest neighbour approach to match firm-year observation with the closest predicted propensity score by using a calliper distance of 1% (Atif et al., 2021). We present the *t-test* results for the matched sample in ***Table A5 in the appendix*.** Overall, our results suggest that the differences in most of the company-specific characteristics between the treatment and control firms are largely insignificant, indicating that our estimation results are not affected by the differences in observable characteristics of the sampled firms. We also estimate Eq. (1) for the matched sample of 892 firm-year observations. The estimation results (shown in Table 10) suggest that both *WOB* and *WOM* are positively associated with *PCMP* and *RCRP*, and thus confirm our reported results.

Insert Table 10 about here

5.2.3 Difference-in-difference analysis

We carry out difference-in-difference (DiD) analysis by using the implementation of mandatory quota provision in European countries as a policy instrument. We estimate the following model to implement DiD analysis:

$$PCMP_{it} \text{ or } RCRP_{it} = \beta_0 + \beta_1 * WOB\_D + \beta_2 * Post\_Gender\_Quota + \beta_3 * (WOB\_D \times Post\_Gender\_Quota) + \beta_4 * Controls + \beta_5 * Country\ Dummies + \beta_6 * Industry\ dummies + \beta_7 * Year\ dummies\ + \epsilon \quad (3)$$

where *WOB_D* is a dummy variable that equals one if the firm is in the treatment group, and zero if the firm is in the control group. *Post_Gender_Quota* is a dummy variable indicating the period after the implementation of board gender quota provision. We follow the same process of propensity score matching (as explained in section 5.2.2) to determine the treatment and control groups of 892 firm-year observations. Table 11 presents our DiD estimation results for the matched sample. Column 1 of the Table shows that our main variable of interest (*WOB_D* × *Post_Gender_Quota*) is positive and statistically significant at 5% level, as expected. However, our results show mixed evidence in the regression of *RCRP*. Whilst the coefficient of *WOB_D* is positive and significant, as expected, the coefficient of the interaction term is negative and significant at 5% level[4]. This result indicates that firms with a gender-diverse board tend to have lower GHG emissions, and thus partly confirms our reported results, even though this decline in emission might not necessarily be an outcome of the implementation of gender quota.

One likely reason of this inconclusive results for *RCRP* might be that the use of quota provision as a policy instrument (treatment) might be inappropriate in our DiD framework in a cross-country analysis, as this gender-based governance reform (approved in the EU Parliament in November 2013, with the implementation deadline of 2018) allowed greater flexibility to European countries to adopt mandatory or voluntary provision on board gender diversity depending on country-specific priorities. There has also been a greater divergence between the dates of enactment of laws/regulations and the implementation deadlines among the European countries. Therefore, we argue that it might be appropriate to examine the effectiveness of the gender quota provisions in European countries in a single-country setting rather than in a cross-country analysis.

[4]We also use alternative measures of gender quota provision, such as post-enactment of mandatory quota provision, post-implementation of mandatory/voluntary quota provision, and found roughly similar results.

Insert Table 11 about here

5.3. Further analysis

We undertake several additional analyses to enhance our contribution to the extant literature. These include (i) analysis of critical mass, (ii) analysis of the impact of board connections, experience and cultural diversity, and (iii) analysis of board diversity and financial performance. We include these analyses/estimation results in ***Online Appendix B*** to conserve space.

6. Conclusion

We have examined how women within both corporate boards and executive management teams influence both procedure-oriented carbon management performance (*PCMP*) and real carbon emission reduction performance (*RCRP*) of European listed firms. Our analysis is based on a firm-fixed-effects estimator to examine data from a sample of 5,327 firm-year observations, covering a longer time horizon of fifteen years. Overall, our estimated results suggest that gender diversity within both corporate boards and executive management teams has a positive relationship with *PCMP* and *RCRP*. We also find that the female directors' participation in audit/compliance committees of the board, as well as the female directors' age and educational background of law have a substantive positive impact on carbon performance. We also find evidence in support of a complementary role of women board members and women in executive management teams in that a gender-diverse board positively moderates the influence of a gender-diverse executive management team on both *PCMP* and *RCRP*.

Taken together, our study results suggest that women board members and women in executive management teams show greater concern for communities, morality and ethics, and

societal well-being, hence, they play a more active role in driving and shaping a firm's response to the eminent climate crisis from corporate policymaking on mitigating climate risks to efficient decision-making on long-term carbon abatement strategies/projects to a meaningful and target-oriented implementation of energy-efficient solutions. Our results suggest that women within corporate boards tend to reinforce not just the carbon reduction initiatives, but also the implementation of those initiatives by facilitating effective policies/decisions on climate-related projects and offering critical advice, support, and access to external resources to implement those projects. This eventually encourages women in executive management teams to take ownership of climate abatement projects and to play a more active role in operational matters, such as implementation, coordination, control, and reporting. Overall, our evidence is consistent with the arguments of our integrated theoretical framework of gender socialisation and ethicality perspectives, resource-based view and diversity theory.

Our study results have several policy implications. First, our evidence suggests the significance of promoting gender diversity in addressing the global climate crisis and the need to integrate gender diversity with a country-specific, regional, and global framework of climate change, such as the UK's carbon budget towards Net Zero target and the EU's Carbon Neutrality Project 2050. Second, this evidence also substantiates the recommendations of global institutions, such as the UNFCCC to promote gender-diverse leadership/knowledge sharing and gender-responsive action plans to mitigate climate change risks, and the subsequent 5-year Gender Action Plan (GAP) of the COP25/2019 parties to integrate gender equality, women's leadership and participation into climate policies/projects. Third, our results suggest that women board members and managers play complementary roles in shaping a firm's carbon-related policies, action plans and actual implementations. Therefore, any gender-responsive corporate governance reform ought

to promote gender diversity both within the board and the executive management team of a company so that there is a shared goal and joint ownership of the complex and capital-intensive climate-related projects from their initial phases to the final implementation. Moreover, our evidence in support of critical mass theory implies that climate-centred governance reform initiatives need to ensure a critical mass of women board members to make significant influence on board decision-making of corporate climate strategies and to enhance monitoring of actual implementation. This eventually enhances not just *PCMP*, but also reduces the *RCRP*, as evident from our study.

Although our results are important and robust, they have limitations that also have implications for future research. First, although we found a highly significant positive influence of gender-diverse management on PCMP and RCRP, our empirical results tend to be constrained by a lack of availability of data on important governance characteristics, such as independent and executive women board members, as well as ownership. Therefore, future studies can address this topic by looking into alternative data sources to examine how ownership (block, director, institutional and state ownership), as well as independent and executive women board members influence carbon performance Second, given our inconclusive evidence from DiD framework, future researchers can adopt similar methodology to conduct a comprehensive country-specific analysis of the effect of board gender diversity on carbon performance after the implementation of mandatory quota provision on corporate board. Third, one potential limitation of our study is that we have not fully examined the financial implication for corporate climate engagement of a firm. Therefore, further studies can investigate whether and how gender diversity and improved carbon performance influence financial performance. Fourth, one potential area of future research is to examine how institutional characteristics, such as governance and climate-related regulations

interact with gender-diverse boards and women in executive management teams in influencing carbon performance. Fifth, our proxies for carbon performance, governance and financial indicators may/may not reflect actual. Our dichotomous measure for *PCMP*, for example, may result in measurement errors/corporate misreporting/greenwashing. Future studies can use in-depth case studies to explore how the interplay among shareholders, gender-diverse boards and gender-diverse executive management teams at various levels shape corporate sustainability initiatives and carbon performance. Finally, future researchers can address this issue by undertaking a comparative study between European countries and other largest GHG emitters, such as China, the US, India, and Russia.

Data availability statement:

The data that support the findings of this study are available from Refinitiv's Eikon, BoardEx and Worldscope databases. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the authors with the permission of Refinitiv's Eikon, BoardEx and Worldscope.

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Tables

Table 1. Variable definitions.

Variables	*Symbols*	*Definitions*
Test variables		
Procedure-oriented carbon management performance	PCMP	A composite index comprising 21 dummy variables relating to policies, procedures and initiatives to address climate related risks, reduce carbon emissions and develop capacity building and energy efficiency. This index ranges from 0 to 21, with a company scoring a higher index value demonstrating superior process-oriented carbon performance (**a *list of these dummy variables is added in the Appendix Table C1***).
Actual carbon emission reduction performance	RCRP	Ln of the total of scope 1 and scope 2 emissions. A negative sign of GHG emissions is taken, implying that firms with low GHG emissions show improved actual carbon performance.
Explanatory variables		
Gender diversity in board	WOB	Women board members as a percentage of total board members.
Gender diversity in executive management	WOM	Women executive managers as a percentage of total managers of the firm.
Gender-diverse board	WOB_D	A binary variable that takes the value of 1 if the firm has at least one female board member.
Female on Audit Committee	F.AudCom_D	A binary variable that takes the value of 1 if the audit committee has at least one female board member.
Female on Compliance Committee	F.ComplCom_D	A binary variable that takes the value of 1 if the compliance committee has at least one female board member.
Female on CSR Committee	F.CSRCom_D	A binary variable that takes the value of 1 if the CSR committee has at least one female board member.
Age of female directors	F.Dir_Age	Ln of average age of female directors.
Experience of female directors	F.Dir_Experience	Ln of number of years as female directors.
Female directors with PhD	F.Dir_PhD	Percentage female directors holding a PhD.
Female directors with Masters	F.Dir_Masters	Percentage female directors holding a Masters.
Female directors with business background	F.Dir_business	Percentage female directors with business background.
Female directors with law background	F.Dir_Law	Percentage female directors with law background.
Female directors with Accounting & Finance background	F.Dir_A&F	Percentage female directors with accounting & finance background.
Control variables		
Board size	BS	Ln of the total members on the board.
Independence of the board	IND	Independent board members as a percentage of total board members.
Separation of CEO and Chair	Sep	A binary variable that takes the value of 1 if there is separation between the roles of CEO and chairperson, and 0 otherwise.

CSR committee	CSR	A binary variable that takes the value of 1 if the firm has a board CSR committee, and 0 otherwise.
Board meeting	Meet	Average overall attendance percentage of board meetings.
Executive compensation	Comp	Ln of total compensation of all senior executives as reported by the firm.
Sustainable compensation policy	ESG	A binary variable that takes the value of 1 if the company adopts sustainable (e.g., ESG) compensation policy, and 0 otherwise.
ISO14001 certification	EMS	A binary variable that takes the value of 1 if the firm complies with the ISO14001 certification requirements, and 0 otherwise.
Tobin's Q	Q	The ratio of market value of equity minus book value of equity plus total assets to total assets.
Firm size	Size	Ln of total assets.
Profitability	ROA	The ratio of net income to total assets.
Leverage	Lev	The ratio of total debt to total assets.
Liquidity	Cash	The ratio of cash and cash equivalents to total assets.
Tangible assets	PPE	The ratio of plants, properties and equipment to total assets.
Growth	Growth	5-year average sales growth.
Employees	Employee	Ln of total number of employees.

Table 2. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
PCMP	5,327	9.03	4.62	0	21
RCRP	4,296	12.86	2.39	5.23	19.29
WOB	5,327	18.34	13.46	0	66.67
WOM	5,327	10.73	12.44	0	100
BS	5,327	2.32	0.95	0.69	3.26
F.AudCom_D	2,795	0.19	0.39	0	1
F.ComplCom_D	2,795	0.03	0.16	0	1
F.CSRCom_D	2,795	0.06	0.24	0	1
F.Dir_Age	2,143	52.07	12.19	0	84
F.Dir_Experience	2,143	6.02	3.07	0	18
F.Dir_PhD	2,795	9.93	12.24	0	60
F.Dir_Masters	2,795	32.95	19.21	0	100
F.Dir_business	2,795	39.47	18.91	0	100
F.Dir_Law	2,795	3.62	6.59	0	44.44
F.Dir_A&F	2,795	22.01	14.86	0	80
IND	5,327	93.42	45.10	1	187
Sep	5,327	0.20	0.40	0	1
CSR	5,327	0.68	0.47	0	1
Meet	5,327	36.18	17.71	2	50
Comp	5,327	15.63	1.29	6.37	23.72
ESG	5,327	0.35	0.48	0	1
EMS	5,327	0.72	0.45	0	1
Q	5,327	1.90	2.88	0.28	91.20
ROA	5,327	6.91	11.04	-107.68	259.48
Size	5,327	15.54	1.63	7.44	20.09
Lev	5,327	24.49	16.48	0	133.09
Cash	5,327	0.12	0.11	0	0.99
PPE	5,327	0.60	0.46	0	8.46
Growth	5,327	6.64	20.16	-100	482.55
Employee	5,327	8.26	1.00	2.77	9.26

Note: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively.

Table 3. Correlation matrix.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
(1) PCMP	1																
(2) RCRP	0.430	1															
(3) WOB	0.344	-0.008	1														
(4) WOM	0.116	-0.158	0.344	1													
(5) BS	-0.246	-0.191	-0.096	-0.007	1												
(6) IND	0.152	0.055	0.114	0.108	-0.063	1											
(7) Sep	0.068	0.070	0.020	-0.047	-0.046	-0.074	1										
(8) CSR	0.555	0.224	0.251	0.127	-0.119	0.185	0.010	1									
(9) EMS	0.391	0.310	0.054	-0.085	-0.122	0.042	0.051	0.244	1								
(10) Q	-0.084	-0.199	0.054	0.154	0.034	0.000	-0.011	-0.083	-0.144	1							
(11) ROA	-0.006	-0.162	0.054	0.116	-0.011	0.042	0.005	-0.029	-0.072	0.612	1						
(12) Size	0.567	0.720	0.151	-0.061	-0.349	0.099	0.115	0.332	0.346	-0.236	-0.070	1					
(13) Lev	0.133	0.210	0.047	-0.044	-0.065	0.001	0.044	0.110	0.093	0.253	0.182	-0.045	1				
(14) Cash	-0.215	-0.128	-0.107	0.069	0.107	-0.082	0.008	-0.148	-0.195	0.208	0.051	-0.308	0.064	1			
(15) PPE	0.102	0.376	0.041	-0.002	-0.002	-0.022	-0.052	0.057	0.068	-0.083	-0.039	0.069	0.054	-0.195	1		
(16) Growth	-0.125	-0.049	-0.058	-0.008	0.003	0.011	0.021	-0.074	-0.082	0.036	-0.058	-0.057	-0.111	0.028	-0.117	1	
(17) Employee	-0.001	0.004	0.037	0.022	-0.031	0.006	-0.021	0.007	0.016	0.035	0.012	-0.015	-0.002	0.007	0.022	0.005	1

Note: Variable descriptions are shown in Table 1.

Table 4. Fixed-effect regression of procedure-oriented carbon management performance (PCMP) and real carbon emission reduction performance (RCRP) against board diversity.

	Dep Var: PCMP			Dep Var: RCRP		
	1	2	3	4	5	6
Ind. Variables	Whole sample	Firms with gender-diverse board	Firms without gender-diverse board	Whole sample	Firms with gender-diverse board	Firms without gender-diverse board
WOB	0.0345***			0.00287***		
	(0.00437)			(0.000821)		
WOM	0.0102**	0.0200***	-0.00514	0.00219***	0.00276***	0.00151
	(0.00401)	(0.00392)	(0.0136)	(0.000835)	(0.000804)	(0.00409)
BS	-0.109**	-0.0872*	0.238*	-0.00600	-0.00660	-0.0493
	(0.0506)	(0.0519)	(0.134)	(0.0105)	(0.0108)	(0.0398)
IND	0.00230**	0.00366***	0.00706***	0.000142	0.000221	-2.52e-07
	(0.00113)	(0.00114)	(0.00252)	(0.000233)	(0.000240)	(0.000830)
Sep	-0.169	-0.106	-0.246	-0.0401	-0.0296	-0.173
	(0.159)	(0.163)	(0.376)	(0.0327)	(0.0350)	(0.125)
CSR	2.614***	2.786***	3.039***	-0.00163	0.0129	0.0631
	(0.116)	(0.118)	(0.250)	(0.0237)	(0.0256)	(0.0697)
Meet	0.196	0.246	0.964***	0.0177	0.00768	-0.0638
	(0.150)	(0.153)	(0.370)	(0.0312)	(0.0320)	(0.110)
Comp	0.308***	0.285***	0.668***	0.0152*	0.0124	-0.0286
	(0.0391)	(0.0400)	(0.116)	(0.00831)	(0.00817)	(0.0346)
ESG	1.111***	1.298***	1.059***	-0.0415*	0.00782	-0.248***
	(0.104)	(0.104)	(0.315)	(0.0216)	(0.0216)	(0.0890)
EMS	0.764***	0.797***	1.659***	-0.0347	0.00756	0.207
	(0.153)	(0.156)	(0.368)	(0.0328)	(0.0340)	(0.131)
Q	-0.00161	0.0146	-0.0449	-0.00627	-0.00396	0.0732
	(0.0295)	(0.0302)	(0.121)	(0.00940)	(0.00917)	(0.0668)
ROA	-0.00756	-0.0104	-0.0219	0.00195	0.00134	0.00817
	(0.00787)	(0.00807)	(0.0155)	(0.00191)	(0.00196)	(0.00889)
Size	1.321***	1.631***	1.477***	-0.690***	-0.623***	-0.731***
	(0.136)	(0.136)	(0.293)	(0.0283)	(0.0293)	(0.107)
Lev	0.0138***	0.0107**	-0.0175*	0.00220**	0.00157	0.000425
	(0.00481)	(0.00492)	(0.00954)	(0.000959)	(0.00102)	(0.00342)
Cash	-0.917	-0.758	2.336*	0.0502	-0.0334	0.343
	(0.655)	(0.671)	(1.322)	(0.133)	(0.139)	(0.473)
PPE	0.658***	0.829***	-0.508	-0.281***	-0.188***	-0.397**
	(0.177)	(0.180)	(0.451)	(0.0357)	(0.0363)	(0.164)
Growth	-0.00592***	-0.00712***	-0.0288***	-0.00220***	-0.00276***	0.00164

	(0.00215)	(0.00219)	(0.00765)	(0.000579)	(0.000570)	(0.00295)
Employee	-0.0292	-0.0236	0.158	-0.00440	0.00760	-0.0537
	(0.0425)	(0.0435)	(0.117)	(0.00873)	(0.00903)	(0.0367)
Constant	-20.25***	-24.75***	-32.52***	-2.100***	-3.256***	-0.300
	(2.199)	(2.214)	(4.758)	(0.463)	(0.483)	(1.776)
Observations	3,942	3,961	932	3,991	3,476	537
R-squared	0.326	0.326	0.427	0.168	0.154	0.221
N. of firm	441	442	234	429	420	172

Notes: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Table 5: Woman board members' characteristics and procedure-oriented carbon performance (PCMP).

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
F.AudCom_D		-0.0305				-0.0169		
		(0.196)				(0.198)		
F.ComplCom_D			1.617***				1.542***	
			(0.590)				(0.595)	
F.CSRCom_D				0.235				0.257
				(0.303)				(0.305)
F.Dir_Age	1.164***	1.172***	1.212***	1.125***		1.085***	1.124***	1.036***
	(0.341)	(0.345)	(0.341)	(0.344)		(0.347)	(0.343)	(0.347)
F.Dir_Experience	-0.00306	-0.0130	0.0190	0.0267		-0.00551	0.0193	0.0324
	(0.146)	(0.159)	(0.146)	(0.151)		(0.160)	(0.146)	(0.151)
F.Dir_PhD					-0.00571	-0.0128	-0.0105	-0.0124
					(0.00715)	(0.00865)	(0.00868)	(0.00866)
F.Dir_Masters					0.000137	0.00322	0.00264	0.00318
					(0.00474)	(0.00567)	(0.00566)	(0.00566)
F.Dir_business					0.0167***	0.00378	0.00369	0.00376
					(0.00600)	(0.00724)	(0.00720)	(0.00721)
F.Dir_Law					0.00483	-0.0120	-0.0135	-0.0133
					(0.0105)	(0.0124)	(0.0124)	(0.0125)
F.Dir_A&F					0.00557	0.00775	0.00826	0.00788
					(0.00713)	(0.00878)	(0.00872)	(0.00873)
WOM	0.0236***	0.0236***	0.0232***	0.0234***	0.0281***	0.0228***	0.0225***	0.0226***
	(0.00491)	(0.00493)	(0.00491)	(0.00492)	(0.00438)	(0.00493)	(0.00491)	(0.00492)
All Control variables	Y	Y	Y	Y	Y	Y	Y	Y
Constant	-24.23***	-24.26***	-24.17***	-24.17***	-22.45***	-24.29***	-24.22***	-24.21***
	(3.112)	(3.121)	(3.107)	(3.113)	(2.253)	(3.138)	(3.126)	(3.132)
Observations	2,030	2,030	2,030	2,030	2,795	2,030	2,030	2,030
R-squared	0.208	0.208	0.212	0.209	0.275	0.212	0.215	0.213
N. of firm	234	234	234	234	261	234	234	234

Note: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively.

Table 6: Woman board members' characteristics and actual carbon emission reduction performance (RCRP).

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
F.AudCom_D		+0.178***				+0.182***		
		(0.0358)				(0.0357)		
F.ComplCom_D			+0.321***				+0.265**	
			(0.108)				(0.108)	
F.CSRCom_D				+0.0832				+0.0531
				(0.0539)				(0.0539)
F.Dir_Age	+0.147**	+0.0931	+0.152**	+0.131**		+0.132**	+0.191***	+0.176***
	(0.0609)	(0.0614)	(0.0608)	(0.0617)		(0.0614)	(0.0609)	(0.0618)
F.Dir_Experience	-0.0693**	-0.00264	-0.0669**	-0.0576**		+0.00887	-0.0580**	-0.0520*
	(0.0276)	(0.0305)	(0.0276)	(0.0286)		(0.0304)	(0.0274)	(0.0285)
F.Dir_PhD					-0.00336**	-0.00619***	-0.00566***	-0.00603***
					(0.00145)	(0.00156)	(0.00158)	(0.00157)
F.Dir_Masters					+0.000832	-0.000615	-0.000814	-0.000737
					(0.000939)	(0.00102)	(0.00103)	(0.00103)
F.Dir_business					-0.00286**	-0.00226*	-0.00157	-0.00159
					(0.00121)	(0.00132)	(0.00132)	(0.00132)
F.Dir_Law					+0.00509**	+0.00620***	+0.00591***	+0.00586***
					(0.00205)	(0.00221)	(0.00223)	(0.00225)
F.Dir_A&F					+0.000167	-0.00181	-0.00274*	-0.00273*
					(0.00145)	(0.00159)	(0.00159)	(0.00159)
WOM	+0.00244***	+0.00214**	+0.00235***	+0.00239***	+0.00290***	+0.00214**	+0.00238***	+0.00241***
	(0.000908)	(0.000903)	(0.000906)	(0.000908)	(0.000875)	(0.000896)	(0.000900)	(0.000902)
All Control variables	Y	Y	Y	Y	Y	Y	Y	Y
Constant	3.303***	3.096***	3.292***	3.277***	2.058***	2.999***	3.181***	3.169***
	(0.609)	(0.606)	(0.608)	(0.609)	(0.525)	(0.603)	(0.606)	(0.607)
Observations	1,805	1,805	1,805	1,805	2,314	1,805	1,805	1,805
R-squared	0.194	0.206	0.198	0.195	0.197	0.225	0.215	0.212
N. of firm	225	225	225	225	250	225	225	225

Note: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively.

Table 7. Robustness tests: Fixed-effect regressions with lagged independent variables.

Ind.	Dep. Var: PCMP						Dep. Var: RCRP					
Variables	1	2	3	4	5	6	7	8	9	10	11	12
$WOB_{(t-1)}$	0.0422***						0.00472***					
	(0.00354)						(0.000798)					
$WOM_{(t-1)}$		0.0321***						0.00529***				
		(0.00328)						(0.000816)				
$WOB_{(t-2)}$			0.0249***						0.00639***			
			(0.00332)						(0.000837)			
$WOM_{(t-2)}$				0.0173***						0.00352***		
				(0.00368)						(0.000812)		
$WOB_{(t-3)}$					0.0114***						0.00208**	
					(0.00332)						(0.000822)	
$WOM_{(t-3)}$						0.00861***						0.00117
						(0.00331)						(0.000832)
All Control variables	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4,581	4,302	3,972	4,600	4,323	3,999	3,863	3,698	3,479	3,876	3,709	3,494
R-squared	0.294	0.205	0.134	0.275	0.189	0.123	0.177	0.180	0.185	0.172	0.170	0.169
N. of firms	447	446	444	447	446	444	425	425	424	425	425	424

Notes: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Table 8. Robustness tests: Fixed-effect regressions carbon intensity as a relative carbon performance measure.

	Dep. Var: RCRP			
	1	2	3	4
Ind. Variables	Whole sample	Whole sample	Firms with gender-diverse board	Firms without gender-diverse board
WOB	0.00133***			
	(0.000472)			
WOM		0.00113**	0.00225***	0.000695
		(0.000478)	(0.000716)	(0.00111)
All Control variables	Y	Y	Y	Y
Observations	3,993	4,002	3,476	537
R-squared	0.033	0.033	0.026	0.265
N. of firms	429	429	420	172

Notes: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard.

Table 9. Two-stage least square regression of PCMP and RCRP against gender-diverse board (WOB) and gender-diverse executive management (WOM).

	(1) First-stage	(2) Second-stage	(3) First-stage	(4) Second-stage	(5) First-stage	(6) Second-stage	(7) First-stage	(8) Second-stage
Dep. Variables	WOB	PCMP	WOM	PCMP	WOB	RCRP	WOM	RCRP
Ind. Variables								
Female-to-Male	3.305***		1.518***		0.877***		0.556***	
	(0.0847)		(0.0947)		(0.0485)		(0.0548)	
WOB_Fitted		0.106***				0.0403***		
		(0.00783)				(0.00715)		
WOM_Fitted				0.238***				0.0641***
				(0.0218)				(0.0120)
All Control variables	Y	Y	Y	Y	Y	Y	Y	Y
Constant	-276.5***	-16.38***	-133.8***	-14.90***	-85.48***	6.441***	-47.13***	6.010***
	(7.878)	(0.998)	(8.773)	(1.279)	(5.264)	(0.473)	(5.945)	(0.492)
Country dummies	Y	Y	Y	Y	Y	Y	Y	Y
Industry dummies	Y	Y	Y	Y	Y	Y	Y	Y
Year dummies	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4,857	4,857	4,874	4,874	3,993	3,993	4,002	4,002
R-squared		0.558		0.272		0.695		0.651
F-statistic	157.93***		96.16***		228.97***		200.83***	
Cragg-Donald Wald F statistic	1520.88		257.21		326.87		102.93	
Stock-Yogo weak ID test critical values: 10% maximal IV size	16.38		16.38		16.38		16.38	

Notes: This table presents 2SLS regressions using Female-to-Male (the ratio of female of male in workforce participation) as an instrumental variable. Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Table 10. Propensity score matching - Regression results for the matched sample.

	(1)	(2)
Dep. Variables	PCMP	RCRP
Ind. Variables		
WOB	0.0364***	0.00758**
	(0.00708)	(0.00343)
WOM	0.0142**	0.00646**
	(0.00630)	(0.00301)
All Control variables	Y	Y
Country effects	Y	Y
Industry effects	Y	Y
Year effects	Y	Y
Observations	892	892
R-squared	0.256	0.697

Notes: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Table 11. Difference-in-difference estimations.

	(1)	(2)
Dep. Variables	PCMP	RCRP
Ind. Variables		
WOB_D	1.075***	0.170*
	(0.214)	(0.0883)
Post_Gender_Quota	-2.160*	0.725*
	(1.239)	(0.438)
WOB_D* Post_Gender_Quota	3.112**	-1.139**
	(1.304)	(0.573)
All Control variables	Y	Y
Country effects	Y	Y
Industry effects	Y	Y
Year effects	Y	Y
Observations	892	892
R-squared	0.532	0.733

Notes: Table 12 presents results of difference-in-difference estimations. Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

ONLINE APPENDICES

Appendix A. Robustness tests

Appendix A presents the results of the robustness tests and identification strategies (e.g., propensity score matching) that were discussed in Sections 5.1 and 5.2, respectively, in the main paper.

Table A1. Robustness tests: Fixed-effect regression of procedure-oriented carbon management performance (PCMP) and real carbon emission reduction performance (RCRP) against board diversity (*after winsorizing at 1% and 99% levels*).

	Dep. Var: Industry adjusted PCMP			Dep. Var: Industry adjusted RCRP		
Ind. Var.	(1)	(2)	(3)	(4)	(5)	(6)
WOB	0.0614***		0.0562***	0.00211***		0.00141*
	(0.00352)		(0.00370)	(0.000752)		(0.000789)
WOM		0.0375***	0.0179***		0.00297***	0.00251***
		(0.00396)	(0.00407)		(0.000813)	0.00141*
All Control variables	Y	Y	Y	Y	Y	Y
Observations	5,082	5,082	5,082	4,159	4,159	4,159
R-squared	0.352	0.322	0.354	0.154	0.156	0.156
N. of firm	465	465	465	438	438	438

Notes: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Table A2. Robustness tests: Fixed-effect regression of industry-adjusted carbon performance measures against industry-adjusted board and executive management.

	Dep. Var: Industry adjusted PCMP			Dep. Var: Industry adjusted RCRP		
Ind. Var.	(1)	(2)	(3)	(4)	(5)	(6)
WOB	0.0461***		0.0440***	0.00354***		0.00287***
	(0.00358)		(0.00376)	(0.000781)		(0.000821)
WOM		0.0209***	0.00711*		0.00306***	0.00219***
		(0.00375)	(0.00384)		(0.000793)	(0.000835)
All Control variables	Y	Y	Y	Y	Y	Y
Observations	4,857	4,874	4,855	3,993	4,002	3,991
R-squared	0.378	0.365	0.379	0.166	0.164	0.168
N. of firm	456	456	456	429	429	429

Notes: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Table A3. Robustness tests: Two-stage least square regression of PCMP and RCRP against gender-diverse board (WOB) and gender-diverse executive management (WOM).

	(1) First-stage	(2) Second-stage	(3) First-stage	(4) Second-stage	(5) First-stage	(6) Second-stage	(7) First-stage	(8) Second-stage
Dep. Variables	WOB	PCMP	WOM	PCMP	WOB	RCRP	WOM	RCRP
Ind. Variables								
Gen_Equal	-242.7***		-110.9***		-250.0***		-107.4***	
	(6.182)		(7.020)		(6.954)		(8.050)	
WOB_Fitted		0.0958***				+0.0199***		
		(0.00774)				(0.00353)		
WOM_Fitted				0.210***				+0.0463***
				(0.0209)				(0.00861)
All Control variables	Y	Y	Y	Y	Y	Y	Y	Y
Constant	17.74***	-16.22***	1.838	-14.91***	23.59***	-5.709***	3.600	-6.011***
	(3.352)	(1.013)	(3.806)	(1.252)	(3.662)	(0.467)	(4.238)	(0.486)
Country dummies	Y	Y	Y	Y	Y	Y	Y	Y
Industry dummies	Y	Y	Y	Y	Y	Y	Y	Y
Year dummies	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4,678	4,678	4,678	4,678	3,887	3,887	3,887	3,887
R-squared		0.560		0.331		0.728		0.701
F-statistic	151.26***		99.50***		266.32***		242.23***	
Cragg-Donald Wald F statistic	1540.512		249.463		1292.569		177.997	
Stock-Yogo weak ID test critical values: 10% maximal IV size	16.38		16.38		16.38		16.38	

Notes: This table presents 2SLS regressions using Gen_Equal (e.g., Gender Equality Index) as an instrumental variable. Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Table A4. Robustness tests: Two-stage least square regression of PCMP and RCRP against gender-diverse board (WOB) and gender-diverse executive management (WOM).

	(1) First-stage	(2) Second-stage	(3) First-stage	(4) Second-stage	(5) First-stage	(6) Second-stage	(7) First-stage	(8) Second-stage
Dep. Variables	WOB	PCMP	WOM	PCMP	WOB	RCRP	WOM	RCRP
Ind. Variables								
W_Parliament	1.162***		0.468***		1.144***		0.422***	
	(0.0348)		(0.0385)		(0.0378)		(0.0425)	
WOB_Fitted		0.0893***				+0.0153***		
		(0.00875)				(0.00402)		
WOM_Fitted				0.221***				+0.0415***
				(0.0274)				(0.0113)
Constant	-38.85***	-16.20***	-21.74***	-14.85***	-30.93***	-5.779***	-17.02***	-6.012***
	(3.680)	(1.010)	(4.075)	(1.281)	(4.094)	(0.465)	(4.607)	(0.479)
All Control variables	Y	Y	Y	Y	Y	Y	Y	Y
Country dummies	Y	Y	Y	Y	Y	Y	Y	Y
Industry dummies	Y	Y	Y	Y	Y	Y	Y	Y
Year dummies	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4,678	4,678	4,678	4,678	3,887	3,887	3,887	3,887
R-squared		0.562		0.302		0.730		0.709
F-statistic	151.26***		99.50***		266.32***		242.23***	
Cragg-Donald Wald F statistic	1540.512		249.463		1292.569		177.997	
Stock-Yogo weak ID test critical values: 10% maximal IV size	16.38		16.38		16.38		16.38	

Notes: This table presents 2SLS regressions using W_Parliament (e.g., % of Women in Parliament) as an instrumental variable. Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Table A5. Propensity score matching: Mean difference between the firms with and without gender diversity for the matched sample.

	Matched sample (n = 892)			
Variables	Treatment (Firms with gender diversity)	Control (Firms without gender diversity)	Mean difference	t-stat
BS	2.466	2.569	0.103	1.52
IND	88.335	90.212	1.876	0.70
Sep	0.188	0.172	-0.016	-0.66
CSR	0.629	0.643	0.014	0.46
Meet	35.012	35.651	0.639	0.319
Com	15.332	15.256	0.076	1.247
ESG	0.235	0.268	-0.033	-1.396*
EMS	0.716	0.690	-0.025	-1.21
Q	1.584	1.579	-0.005	-0.10
ROA	6.707	6.151	-0.556	-1.59
Size	15.419	15.307	-0.112	-1.79*
Lev	24.511	23.526	-0.986	-0.97
Cash	0.110	0.109	-0.001	-0.20
PPE	0.626	0.642	0.016	0.52
Growth	7.475	7.332	-0.152	-0.16
Employee	8.336	8.258	-0.078	-1.30

Notes: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Appendix B. Further analysis

Appendix B presents several additional analyses that we briefly mentioned in Section 5.3 of the main paper. These include, (i) analysis of critical mass, (ii) analysis of the impact of board connections, experience and cultural diversity, and (iii) analysis of board diversity and financial performance.

5.3.1B. Analysis of critical mass

We address the theory of critical mass by replacing *WOB* with three alternative binary test variables for board gender diversity such as *WOB_D* (indicating the presence of at least one female board member), *WOB3_D* (indicating the presence of three or more women board members) and *WOBM_D* (indicating the proportion of female board members being above or equal to the value sample median) as our main test variables. The results, shown in Table A5, suggest that a critical mass of at least three women board members is required to influence the substantive aspect of corporate carbon performance in terms of reduction of GHG emission, even though this does not seem to matter for symbolic or procedure-oriented carbon performance.

Table B1. Additional analysis (Gender critical mass): Fixed-effect regression of procedure-oriented carbon management performance (PCMP) and real carbon emission reduction performance (RCRP) against alternative measures of gender-diverse board based on dummy variables.

Ind.	Dep Var: PCMP			Dep Var: RCRP		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
WOB_D	1.008***			0.0455*		
	(0.112)			(0.0263)		
WOB3_D		0.650***			0.0528***	
		(0.100)			(0.0205)	
WOBM_D			0.862***			0.0378**
			(0.0862)			(0.0187)
WOM	0.0159***	0.0164***	0.0130***	0.00327***	0.00266***	0.00275***
	(0.00372)	(0.00376)	(0.00376)	(0.000801)	(0.000806)	(0.000812)

All Control variables	Y	Y	Y	Y	Y	Y
Observations	4,855	4,860	4,855	3,991	3,995	3,991
R-squared	0.371	0.367	0.373	0.166	0.166	0.166
N. of firms	456	456	456	429	429	429

Notes: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

5.3.2B. Analysis of board connections, experience and cultural diversity

We carry out additional tests to examine the impact of other board diversity characteristics of the entire board such as board connections (*B.Aff*), board experience (*B.Exp*) and cultural diversity (*Culture.div*)of board members. The estimation results shown in Appendix A4 shows the results suggest that *B.Exp* and *Culture.div* have a positive relationship with *PCMP*, as expected. In addition, *B.Aff* shows a negative association with *RCRP*, as expected, although *Culture.div* shows an opposite impact. Overall, our results suggest that board connections tend to enable firms to get access to external resources to implement carbon-related projects, leading to a decline in GHG emissions, even though cultural diversity or the presence of foreign nationals on corporate board tends to play a symbolic role in terms improving procedure-oriented carbon performance.

Table B2. Additional analysis: Fixed-effect regression of procedure-oriented carbon management performance (PCMP) and real carbon emission reduction performance (RCRP) against board connections, experience and cultural diversity.

	Dep Var: PCMP	Dep Var: RCRP
Ind. Variables	4	8
WOB	0.0423***	+0.00233**
	(0.00459)	(0.00108)
WOM	0.0125**	+0.00559***
	(0.00552)	(0.00128)
B.Aff	-0.0346	+0.0804***
	(0.0947)	(0.0248)
B.Exp	0.307***	+0.0123
	(0.101)	(0.0250)
Culture_Div	0.00676***	-0.00139**
	(0.00261)	(0.000606)
Constant	-4.836	-2.855***
	(3.067)	(0.772)
All Control variables	Y	Y

Observations	2,248	2,039
R-squared	0.234	0.196
N. of firm	317	297

Notes: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

5.3.3B. Analysis of board diversity and financial performance

We undertake additional analysis to examine the impact of WOB and WOM on firm profitability (ROA) and market value (Tobin's Q). Our results shown in Appendix A5 suggest that WOB and WOM show positive association with market-based financial performance, as expected, although WOB is found to have an inverse association with profitability. Overall, this evidence imply that markets tend to respond favourably towards corporate effort to promote diversity in board and executive managements teams.

Table B3. Additional analysis: Regression of profitability and firm value against board diversity and carbon performance

				Profitability (ROA)		Market Value (Q)		
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
WOB		-0.0493***	-0.0394***	-0.0243**		0.0108***	0.0103***	0.00568***
		(0.0115)	(0.0118)	(0.0113)		(0.00195)	(0.00200)	(0.00134)
WOM	-0.00542	0.0116	0.0138	0.00311	0.0104***	0.00662***	0.00650***	-0.000866
	(0.0119)	(0.0125)	(0.0125)	(0.0121)	(0.00201)	(0.00212)	(0.00212)	(0.00144)
PCMP			-0.166***				0.00889	
			(0.0466)				(0.00793)	
RCRP				+0.538**				-0.0200
				(0.236)				(0.0281)
Constant	-13.05**	-18.31***	-21.02***	13.89**	7.940***	9.054***	9.199***	7.818***
	(5.588)	(5.712)	(5.755)	(6.486)	(0.942)	(0.960)	(0.969)	(0.762)
All Control variables	Y	Y	Y	Y	Y	Y	Y	Y
Observations	5,115	5,115	5,115	4,177	5,115	5,115	5,115	4,177
R-squared	0.260	0.263	0.265	0.166	0.199	0.205	0.205	0.073
Number of Firms	466	466	466	438	466	466	466	438

Note: Variable descriptions are shown in Table 1. ***, ** and * imply statistically significant results at 1%, 5% and 10% levels, respectively. The heteroskedasticity-adjusted robust standard errors are shown in the parentheses.

Appendix C: Measurement of Procedure-oriented Carbon Management Performance (PCMP)

Table C1. Individual Items for Procedure-oriented Carbon Management Performance (PCMP)

The following binary variables (Yes= 1 and No = 0) are taken from the Refinitiv's Eikon database to measure PCMP. All of the individual scores for these 21 questions are added up to get an overall PCMP score of a firm.

1	Does the company make use of renewable energy?
2	Does the company have a policy to improve its energy efficiency?
3	Does the company have a policy to improve its water efficiency?
4	Does the company use environmental criterion the selection process of its suppliers or sourcing partners?
5	Does the company report or show to be ready to end a partnership with a sourcing partner, if environmental criteria are not met?
6	Does the company report on its impact on biodiversity or on activities to reduce its impact on the native ecosystems and species, as well as the biodiversity of protected and sensitive areas?
7	Does the company evaluate the commercial risks and/or opportunities in relation to climate change?
8	Does the company report on initiatives to reduce, reuse, substitute or phase out toxic chemicals or substances?
9	Does the company report on initiatives to recycle, reduce, reuse, substitute, treat or phase out total waste?
10	Does the company report about environmentally friendly or green sites or offices?
11	Does the company report on initiatives to reduce the environmental impact on land owned, leased or managed for production activities or extractive use?
12	Does the company have a policy to improve emission reduction?
13	Has the company set targets or objectives to be achieved on emission reduction?
14	Does the financial company have a public commitment to divest from fossil fuel?
15	Does the company develop products or technologies for use in the clean, renewable energy?
16	Has the company set targets or objectives to be achieved on energy efficiency?
17	Does the company develop products or technologies that are used for water treatment, purification or that improve water use efficiency?
18	Has the company set targets or objectives to be achieved on water efficiency?
19	Does the company have a policy for reducing the use of natural resources or to lessen the environmental impact of its supply chain?
20	Does the company set specific objectives to be achieved on resource efficiency?
21	Does the company report on initiatives to recycle, reduce, reuse, substitute, treat or phase out e-waste?