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RESEARCH ARTICLE

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Board gender diversity and carbon emissions: European evidence on curvilinear relationships and critical mass

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Abstract

The role of European businesses in addressing environmental issues and climate change has taken center stage with the European Green Deal. With increasing attention to the effect of board gender diversity (BGD) on firms' environmental performance, the question arises whether BGD has any influence on carbon emissions. Based on legitimacy and critical mass theory, this study empirically investigates the impact of BGD on firms' carbon performance (CP), based on total carbon emissions intensity. The paper relies on two-stage least squares (2SLS) regressions with instrumental variable (IV) and a two-step generalized method of moments (GMM) system approach to analyze a cross-country sample of 3123 observations from non-financial firms in the European STOXX600 index over the 2009–2018 period. Our findings add to the growing empirical evidence twofold: (1) there is a robust linear and positive relationship between BGD and CP, whereas some indication of a U-shaped relationship is found; and (2) we find that a critical mass of at least two women directors needs to be reached to increase CP. Our research results contribute to the current discussion on sustainable corporate governance, especially in the European capital market, and have implications for researchers, business practice, and regulatory issues alike.

KEYWORDS

carbon emissions, carbon performance, climate change, corporate governance, critical mass, gender diversity

1 | INTRODUCTION

The Paris Agreement is associated with rapid reductions in greenhouse gas (GHG) emissions (Rogelj et al., 2018). There is increasing social, economic, and regulatory pressure on firms to improve corporate governance (CG) effectiveness to reduce GHG emissions (Luo, Lan, & Tang, 2012). In response, a growing number of companies have started to establish mitigation strategies and release their carbon disclosure (Gallego-Álvarez, Segura, & Martíinez-Ferrero, 2015). Carbon disclosure is regarded as the voluntary or mandatory reporting of GHG emissions and other quantitative and qualitative information using common frameworks from the Carbon Disclosure Project (CDP), Climate Disclosure Standards Board (CDSB), and the Task Force on Climate-related Financial Disclosures (TCFD) (Goloshchapova Poon, Pritchard, & Reed, 2019). Differently, carbon performance (CP) describes the actual

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or outcome-oriented GHG emissions of a company. CP is more directly linked to the carbon intensity of underlying assets and the resulting transition risk, which is increasingly priced with a risk premium (Clark, 2019).

At an organizational level, improving CP through corporate decision-making originates among boards and may be shaped by board composition. Not surprisingly, researchers and business practitioners increasingly try to identify and improve these CG mechanisms to successfully improve CP. In previous years, an increasing interest in the subject area of sustainable accounting has produced theoretical and empirical studies analyzing possible board composition drivers of corporate carbon disclosure and performance (Hahn, Reimsbach, & Schiemann, 2015). Theoretical support for a relationship between board characteristics and CP derives from legitimacy theory (Dowling & Pfeffer, 1975). Empirical studies use a wide range of board variables while using either CP (Qian & Schaltegger, 2017) or carbon disclosure (Liao, Luo, & Tang, 2015). Although some studies find an insignificant or even a negative relationship between board effectiveness and carbon disclosure (Krishnamurti & Velayutham, 2018; Li, Huang, Ren, Chen, & Ning, 2018), most find positive associations (García Martín & Herrero, 2020; Haque, 2017; Liao et al., 2015; Tingbani, Chithambo, Tauringana, & Papanikolaou, 2020). Contrarily, very few studies show an association between board composition and actual GHG emissions, that is, CP (García Martín & Herrero, 2020; Haque, 2017).

During recent years, a growing number of researchers include specific sustainable CG variables in their empirical–quantitative research design and analyze possible impacts on sustainability performance and CP. In view of the extensive discussion from a regulatory and business practice perspective, board gender diversity (BGD) represents the most important sustainable CG proxy since the 2008/2009 financial crisis. BGD can be defined as the equitable or fair representation of men and women on corporate boards. This is commonly measured as the percentage or total number of women directors, the existence of a specific number of women on the board or diversity proxies such as the Blau index (e.g., Ben-Amar, Chang, & McIlkenny, 2017). Literature reviews on the link between BGD and sustainability (Dawar & Singh, 2016; Velte, 2017) state an overall positive relationship. Byron and Post (2016) conduct a meta-analysis on 87 studies and find an overall positive impact of BGD on sustainability performance. Women are assumed to care more about the needs of other stakeholders than shareholders and to show greater sensitivity towards environmental and social topics (Liu, 2018). Boards that lack diversity may be less incline to consider sustainability risks and especially environmental risks (Bord & O'Connor, 1997). In view of the increased climate change debate (e.g., Fridays for Future), some researchers explicitly focus on the impact of BGD on environmental outputs (Birindelli, Iannuzzi, & Savioli, 2019; Cordeiro, Profumo, & Tutore, 2020; García Martín & Herrero, 2020; Haque & Jones, 2020; Post, Rahman, & Rubow, 2011) and carbon issues (Ben-Amar et al., 2017; García Martín & Herrero, 2020; Kılıç & Kuzey, 2019; Liao et al., 2015; Prado-Lorenzo & Garcia-Sanchez, 2010; Tingbani et al., 2020). With regard to carbon disclosure, Tingbani et al. (2020), Ben-Amar et al. (2017), and Liao et al. (2015) find a positive influence of the percentage of female directors. García Martín and Herrero (2020) present the only study that includes carbon emissions as an inverse measure of CP; the authors state a positive association between BGD and CP.

In contrast to prior research on the impact of BGD on environmental performance and disclosure (Birindelli et al., 2019; Cordeiro et al., 2020; Post et al., 2011), related studies on CP and disclosure assume a linear relationship and neglect that female directors might need to form a critical mass to significantly influence carbon strategies in line with critical mass theory (Kanter, 1977; Konrad, Kramer, & Erkut, 2008) and social identity theory (Tajfel, 1978). Birindelli et al. (2019), Cordeiro et al. (2020), and Post et al. (2011) include a critical mass of at least one, two, and three female directors as a BGD proxy and state a positive impact on environmental performance and disclosure. Ben-Amar et al. (2017) provide the only study with a focus on both carbon issues and critical mass theory. The authors state that the representation of at least two women directors on the board increases CDP participation. Based on critical mass theory and previous empirical studies, it is assumed that BGD has to form a critical mass in order to have a positive impact on CP.

The majority of prior research assumes a linear relationship between BGD and environmental outputs and neglects a possible curvilinear link. As a proportional relationship between female directors and environmental outputs might be unrealistic, researchers explicitly recommend analyzing nonlinear relationships in strategic management (e.g., Haans, Pieters, & He, 2016). Two studies on our research topic already address this research gap (Ben-Amar et al., 2017; Birindelli et al., 2019). Birindelli et al. (2019) find a U-shaped relationship for female CEOs and environmental performance. In contrast to this, Ben-Amar et al. (2017) stress that their regression models on curvilinear relationships between BGD and CDP participation are insignificant.

The inconsistency in prior research on critical mass and nonlinearity might be based on multiple factors such as the use of different econometric models and proxies, endogeneity problems, or a focus on different legal and CG regimes. Schultz, Tan, and Walsh. (2010) show that apparently significant relations uncovered by common methods such as ordinary least squares (OLS) or fixed effects are the results of spurious correlations. To solve these inconsistencies, we employ advanced methods (two-stage least squares [2SLS] regressions and the generalized method of moments [GMM] in connection with instrumental variables [IVs]) and include critical mass theory, social identity theory, and the "too-little-of-a-good-thing" (TLGT) effect. With regard to the increased relevance of climate change policy on the European capital market, we include actual carbon emissions intensity as key performance indicators for the first time, as a major contribution to prior research outputs. Thus, this study addresses the following research question:

Is there a specific connection between BGD and CP for listed European firms in terms of a curvilinear (U-shaped) relationship, and does BGD need to form a critical mass to have a positive impact on CP?

In addressing this research question, the paper makes a fruitful contribution to the literature (e.g., Ben-Amar et al., 2017; Birindelli et al., 2019; García Martín & Herrero, 2020). First, we include a "theory mix" (legitimacy theory, critical mass theory, social identify theory, and the TLGT effect) and analyze a more realistic relationship between BGD and CP within business practice. As the recognition of critical mass can be linked to lower greenwashing risks and more substantive BGD and carbon strategies, our research design is also relevant from a practical and regulatory perspective. Second, as prior research only addresses broader environmental outputs, carbon disclosure, and CDP participation as dummy variables, we are interested in actual carbon emissions as one of the key performance subpillars of environmental performance and CP. Third, in order to account for endogeneity concerns in our research design, we include advanced econometric models. Finally, we are mainly interested in the European capital market, as the European Union (EU) regulators have introduced several reforms aimed at pushing companies to fulfill stakeholder expectations with regard to climate change, including the EU Emission Trading Scheme (ETS) in 2005, the implementation of the Non-financial Reporting Directive (NFRD), and, most recently, the "European Green Deal" project with major sustainable finance legislation. Moreover, many European corporations voluntarily disclose their carbon emissions in line with international frameworks, for example, the CDP, Global Reporting Initiative (GRI), or TCFD (Goloshchapova et al., 2019).

The final sample of this paper consists of 3123 firm-year observations of (non-)financial data from the European STOXX600 for 2009–2018. In line with previous research (Ben-Amar et al., 2017; García Martín & Herrero, 2020; Haque, 2017; Joecks, Pull, & Vetter, 2013), we use the percentage of female directors, Blau index for gender diversity, and different numbers of women directors for critical mass as independent variables for BGD. Our dependent variable is carbon emissions intensity as an inverse proxy for CP, measured as total GHG emissions divided by total sales.

The paper is structured as follows: Section 2 provides a theoretical background on and a literature review of the link between BGD and CP and the European market. Then, based on critical mass theory, social identity theory, legitimacy theory, and past literature, our two main hypotheses are developed. Section 3 provides a description of the data, variables, and econometric model. Thereafter, the results are presented (Section 4), followed by a discussion of the findings and selected recommendations (Section 5). Finally, Section 6 will conclude the paper and provide limitations.

2 | THEORETICAL BACKGROUND, LITERATURE REVIEW, AND HYPOTHESES DEVELOPMENT

2.1 | The link between board effectiveness and CP according to legitimacy theory

In line with increasing physical and transitional climate-related risks, a growing number of studies focus on the drivers of carbon outputs (disclosure and performance) in various countries and industries. Most studies rely on carbon disclosure scores and participation from Bloomberg, the carbon disclosure index, or the CDP (Hahn et al., 2015; Velte, Stawinoga, & Lueg, 2020), whereas others use CP (i.e., outcome-oriented GHG emissions) (Haque, 2017; Qian & Schaltegger, 2017). Moreover, prior research investigates various governance drivers of carbon disclosure and performance, such as country-specific governance factors (Peng, Sun, & Luo, 2015), whereas others use CG factors (e.g., board characteristics, ownership, and stakeholder pressure) (Haque, 2017).

Although different theories have been used (e.g., principal agent theory, stakeholder theory, and resource dependence theory), legitimacy theory (Dowling & Pfeffer, 1975) is the most widely used theoretical underpinning of the CG–CP link (e.g., Kılıç & Kuzey, 2019; Qian & Schaltegger, 2017). Legitimacy theory proposes the concept of a "social contract" that exist between organizations and society and assumes that "legitimacy is a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995, p. 574). In situations in which organizations act against societal norms, they are rigorously sanctioned by society. Thus, organizations must increase board effectiveness in carbon-related aspects to gain legitimacy and ultimately respond to societal expectations with regard to reducing GHG emissions. Therefore, legitimacy theory suggests that enhancing board effectiveness to increase CP should align organizations' activities with societal expectations and ultimately favor their legitimacy (Suchman, 1995). Moreover, societal expectations are not permanent, but rather change over time, requiring organizations to be responsive to the environment in which they operate (Deegan, 2002). Thus, with increasing societal pressure to act on climate change, organizations must improve CP to retain their legitimacy. However, most studies considering legitimacy theory find that organizations with poorer environmental performance are more likely to engage in disclosure because they find it easier to manage their image than to make actual changes to performance (Cho, Guidry, Hageman, & Patten, 2012). This raises the question of whether board effectiveness leads to symbolic actions to secure legitimacy or is followed by subsequent substantial environmental management activities and improved CP.

Different assumptions about the relationship between board composition and CP can be found in the literature. On the one hand, investment in board members aiming to promote environmental protection can be seen as an economic diversion that shifts valuable resources away from investment in green technology (Margolis & Walsh, 2003). On the other hand, a firm with improved board composition is likely to set more ambitious GHG controls and is therefore expected to have better CP (de Villiers, Naiker, & van Staden, 2011; Post et al., 2011).

2.2 | The European regulatory environment

The adoption of the Kyoto Protocol is often named as a main driver of corporate activities to mitigate climate change (Jaggi, Allini, Macchioni, & Zagaria, 2018; Kılıç & Kuzey, 2019). Particularly within the EU, climate change policy has taken center stage. In 2005, the EU introduced an ETS for certain high-polluting corporations. Since the business year 2017, the NFRD requires selected public interest entities to publish a non-financial declaration. As part of the European Green Deal 2020, the European Commission (EC) recently announced a review of the NFRD and a renewed sustainable finance strategy. The goal of the European standard setter is to increase the quality of climate-related disclosures for listed corporations. As a first step, the Commission published a nonbinding guideline on climate change reporting in 2019 in line with the recommendations of the TCFD. As carbon disclosure and performance have many interactions, a high-qualified carbon report may have a positive impact on CP and vice versa (Qian & Schaltegger, 2017). Additionally, to decrease voluntary carbon disclosure problems, such as greenwashing and information overload, many European firms engage in voluntary carbon disclosure standards, including the CDP, CDSB, and TCFD (Goloshchapova et al., 2019), environmental management systems, or the external assurance of environmental disclosure. In July 2020, the EU was advised to act on BGD, for example, by introducing a new EU directive on board composition (EY, 2020). Thus, this study argues in line with García Martín and Herrero (2020) that the European capital market is of special interest for empirical–quantitative carbon research. García Martín and Herrero (2020) test the effect of eight different board characteristics (including BGD) on seven environmental performance proxies (including total carbon emissions). The authors find a positive association between board effectiveness (as well as BGD) and environmental performance (resp. a negative influence on carbon emissions).

2.3 | BGD and the effect on environmental outcomes

Whereas we note an increased complexity of board composition variables in prior research, literature states that BGD represents the most popular proxy (Byron & Post, 2016; Velte, 2017). In this context, many researchers assume that BGD strengthens not only a firm's total corporate social responsibility (CSR) scores (e.g., Dienes & Velte, 2016; Velte, 2016) but also environmental policies and ultimately leads to a reduction in carbon emissions (e.g., García Martín & Herrero, 2020; Kılıç & Kuzey, 2019; Tingbani et al., 2020). We decide to focus on BGD in view of great discussion on that topic within the European market since the 2008/2009 financial crisis. Although female quotas on the boards of directors have been regulated in many EU member states, a European regulation has not yet been realized. The EC proposed a directive on fixed gender quotas (40%) for nonexecutive directors in 2012, but the draft was rejected by the European council in 2015. Thus, as comparability within the European capital market is rather low, the focus on BGD and on European listed corporations offers an interesting and relevant research design.

Literature indicates that women and men have different views on sustainability issues as a result of early experiences through social interactions (Liu, 2018). It is assumed that women are more aware of and care more about of the needs of other stakeholders and show greater sensitivity towards environmental and social topics (Liu, 2018). Within boards of directors, female directors bring different ethical values and traits to decision-making. As a consequence, female leaders show greater concern for stakeholders beyond shareholders. Empirical studies show that women on the board of directors perceive environmental risks differently from men (Bord & O'Connor, 1997). As female directors are assumed to be more active in stakeholder relations, environmental concerns and especially climate change policies will be promoted by BGD and should lead to lower carbon emissions in line with our legitimacy theoretical framework.

In view of environmental *disclosure* items, a positive significant impact of female directors can be found for total environmental issues (Baalouch, Ayadi, & Hussainey, 2019; Rao, Tilt, & Lester, 2012), environmental lawsuits (Liu, 2018), biodiversity (Haque & Jones, 2020), carbon emissions (Elsayih, Tang, & Lan, 2018; Liao et al., 2015; Tingbani et al., 2020), green product innovation (patents) (He & Jiang, 2019), and CDP participation (Ben-Amar et al., 2017; Liao et al., 2015). Few studies indicate no impact of female directors on environmental outputs (Birindelli et al., 2019) or on carbon issues in particular (Kılıç & Kuzey, 2019; Prado-Lorenzo & Garcia-Sanchez, 2010).

Referring to environmental *performance*, Burkhardt, Nguyen, and Poincelot (2020) and Galia, Zenou, and Ingham (2015) state a positive impact of BGD in France. These positive results are supported for the Chinese (Elmagrhi, Ntim, Elamer, & Zhang, 2019) and the US-American capital market (Cordeiro et al., 2020; Kassinis, Panayiotou, Dimou, & Katsifaraki, 2016; Li et al., 2017; Lu & Herremans, 2019). According to Glass, Cook, and Ingersoll (2016), only board interlocks of female directors, as opposed to the percentage of female directors, increase environmental performance.

We only identify two studies with a focus on the link between BGD and *CP* (García Martín & Herrero, 2020; Haque, 2017). Haque (2017) concentrates on a UK setting and differentiates between a carbon reduction initiatives index and carbon emissions as alternative CP proxies. The author stresses that BGD increases the carbon reduction initiatives index, but there is no impact on actual carbon emissions. Referring to a sample of 644 EU-based firms, García Martín and Herrero (2020) find a significant negative effect of BGD on carbon emissions.

Table 1 summarizes prior research on the relationship between BGD, carbon, and environmental outputs. In total, the empirical evidence on the link between female representation on the board and CP is controversial. This ambiguity of findings and theories might be explained by the data stemming from various regimes (with different CG and economic development), different time periods, or heterogeneous proxies and regression methods. But this controversial discussion might also be based on assumptions regarding the significant contribution of one female director within the board and of a linear relationship. Experiences from business practice suggest that the association between BGD and CP might be more complex.

2.4 | BGD and the TLGT effect on carbon emissions

Although engaging in BGD strategies might have positive or negative effects on CP, it is not realistic that the link between these two

TABLE 1 Literature review on empirical–quantitative research on BGD, carbon, and environmental outputs

Year of publication	Author(s)	Journal	Country Sample size Time frame	Dependent variable(s)	Independent variable(s)	Results
BGD and carbon outputs (performance and disclosure)						
2020	Garcia Martin and Herrero	Corporate Social Responsibility and Environmental Management	Cross-country (EU) 644 EU-based firms 2002–2017	Carbon emissions	• Percentage of female directors	• –
2020	Tingbani et al.	Business Strategy and the Environment	UK 215 firms 2011–2014	Carbon emission disclosure (score)	• Percentage of female directors • Unexplained percentage of female directors	• +
2019	Hollindale , Kent, Routledge, and Chapple	Accounting and Finance	Australia 2059 firms 2007	Carbon disclosure dummy; quality (score)	• Presence of a female director • Presence of at least two women • Moderator: multiple appointments	• +/– • Critical mass: + • Moderator: + (only by at least two women)
2019	Kilic and Kuzey	International Journal of Climate Change Strategies and Management	Turkey 2011–2015	CDP participation (dummy) Carbon emission disclosure (score)	• Percentage of female directors • Blau index	• +/–
2018	Elsayih et al.	Accounting Research Journal	Australia 203 firm-year observations 2009–2012	Carbon disclosure quality (score; index)	• Percentage of female directors	• +
2017	Ben-Amar et al.	Journal of Business Ethics	Canada 541 firm-year observations 2008–2014	Participation in CDP (dummy)	• Presence of a female director • At least three women	• Linear: + • Critical mass: + • Curvilinear: +/–
2017	Haque	British Accounting Review	UK 256 firms 2002–2014	Carbon performance (carbon reduction initiatives index; GHG emissions)	• Percentage of female directors	• + (carbon reduction initiatives index) • +/– (carbon emissions)
2015	Liao et al.	The British Accounting Review	UK 329 firms 2011	CDP participation Greenhouse gas disclosure (score)	• Percentage of female directors • Moderator: carbon intensive sector	• + • Moderator: non-carbon-intensive sector: +
2010	Prado-Lorenzo and Garcia-Sanchez	Journal of Business Ethics	Cross-country 283 firms from FTSE Global Equity Index 2007	Carbon disclosure score (CDP)	• Percentage of female directors • Moderators: firm's litigation risk regarding environmental behavior, institutional macro-context of country of origin	• +/–
BGD and environmental outputs (performance and disclosure)						
2020	Burkhardt et al.	Corporate Social Responsibility and Environmental Management	France 817 firm-year observations 2006–2017	Environmental performance (Asset4 database)	• Percentage of female directors • Blau index • More than 10% female directors • Moderator: growth opportunities	• + • + • Critical mass: +

(Continues)

TABLE 1 (Continued)

Year of publication	Author(s)	Journal	Country Sample size Time frame	Dependent variable(s)	Independent variable(s)	Results
2020	Garcia Martin and Herrero	Corporate Social Responsibility and Environmental Management	Cross-country (EU) 644 EU-based firms 2002–2017	Environmental performance (Asset4 database)	• Percentage of female directors	• +
2020	Haque and Jones	The British Accounting Review	Cross-country (Europe) 4013 firm-year observations 2002–2016	Biodiversity initiatives disclosure (score) Biodiversity impact assessment (dummy)	• Percentage of female directors • Moderators: inclusion of the GRI framework, EU 2020 biodiversity strategy (dummies)	• + • Moderators: +
2019	Baalouch et al.	Journal of Management and Governance	France 570 firm-year observations 2009–2014	Environmental disclosure (score)	• Percentage of female directors • Moderator: environmentally sensitive industry	• + • Moderator: +
2019	Birindelli et al.	Corporate Social Responsibility and Environmental Management	Cross-country (Europe, Middle East, Africa) 96 listed banks 2011–2016	Environmental performance (Asset4 database)	• Percentage of female directors • Existence of female CEO • At least three women • Interaction between at least three women and percentage of female directors	• Linear: +/– • Critical mass: + (threshold around 30% if there is a female CEO) • Curvilinear: + (U-shape only by female CEO)
2019	Cordeiro et al.	Business Strategy and the Environment	USA 2755 firm-year observations 2010–2015	Environmental performance (CSRHub environment category ranking)	• Percentage of female directors • At least three women • Moderator: family and dual-class majority ownership	• + • Moderator: + • Critical mass: + (only by including moderators)
2019	Elmagrhi et al.	Business Strategy and the Environment	China 383 firms 2011–2015	Environmental performance (RKS ratings)	• Percentage of female directors	• +
2019	He and Jiang	Business Strategy and the Environment	China 1585 firms 2010–2015	Green product innovation (patents) Green process innovation (ISO 14001)	• Percentage of female directors • At least one women • At least two women • At least three women	• + (only product innovation) • Critical mass: + (at least two women)
2019	Lu and Herremans	Business Strategy and the Environment	USA 837 firms 2009–2015	Environmental performance	• Blau index • Moderator: environmental sensitive industry	• + • +
2018	Liu	Journal of Corporate Finance	USA 16,360 firm-year observations 2000–2015	Environmental lawsuits (number)	• Percentage of female directors • Female CEO • Interaction of female CEO and percentage • At least three women	• – • +/– • – (only in firms with low percentage of female directors) • Critical mass: +

(Continues)

TABLE 1 (Continued)

Year of publication	Author(s)	Journal	Country Sample size Time frame	Dependent variable(s)	Independent variable(s)	Results
2017	Li et al.	Business Strategy and the Environment	USA 865 firms NA	Environmental performance (KLD)	• Percentage of female directors • Moderator: environmental sensitive industry	• +
2016	Glass et al.	Business Strategy and the Environment	USA 473 firms 2001–2010	Environmental performance (KLD database)	• Percentage of female directors • Female CEO • Interlinks of female directors • Interaction of female CEO and percentage of female directors	• +/– • +/– • + • +/–
2016	Kassinis et al.	Corporate Social Responsibility and Environmental Management	USA 296 firms 2008–2012	Environmental Consciousness Index (Asset4)	• Percentage of female directors • Gender Consciousness Index	• +
2015	Galia et al.	International Journal of Entrepreneurship and Small Business	France 142 firms 2008	Environmental performance (CIS database)	• Percentage of female directors	• +
2012	Rao et al.	Corporate Governance	Australia 96 firms 2008	Environmental disclosure (score)	• Percentage of female directors	• +
2011	Post et al.	Business & Society	USA 78 firms 2007	Environmental disclosure (score) Environmental performance (KLD database)	• At least three women	• Critical mass: + (only environmental strengths)

Abbreviations: BGD, board gender diversity; CDP, Carbon Disclosure Project; EU, European Union; GHG, greenhouse gas; GRI, Global Reporting Initiative; NA, not applicable.

variables is always linear, assuming a proportional increase in female directors leads to a proportional effect on carbon emissions. The impact of BGD on CP in a quadratic curvilinear form may either be convex (U-shaped) or concave (inversely U-shaped). The U-shaped form can be classified as a TLGT effect (Barnett & Salomon, 2012). It can be argued that an initial negative relationship, forming a downward slope and therefore negative impact of BGD on CP, may be explained by using increased social performance through BGD as a substitute for decreased resources for carbon-related innovations. According to Joecks et al. (2013), a U-shaped link would support Kanter's theory that a critical mass must be reached before an effect can be observed. In contrast to this, an *inverted U-shaped* relationship indicates a "too-much-of-a-good-thing" (TMGT) effect (Pierce & Aguinis, 2013; Trumpp & Guenther, 2017), which is based on the law of diminishing marginal returns. With regard to the TMGT effect, the predicted inverted U-shaped function has a maximum CP that can be achieved from BGD strategies, after which more female board directors lower CP.

Except for Birindelli et al. (2019) and Ben-Amar et al. (2017), all prior research on BGD and carbon and environmental outputs assumes a *linear* relationship and does not test for a curvilinear link. This low research intensity also relates to nonlinear analyses between BGD and financial performance (Ali, Kulik, & Metz, 2011; Ali, Ng, & Kulik, 2014; Strydom, Yong, & Rankin, 2017; Wiley & Monllor-Tormos, 2018). A nonlinear relationship has not been yet tested for *CP*. Whereas Ben-Amar et al. (2017) does not state any significant results for a nonlinear relationship between CDP participation and BGD, Birindelli et al. (2019) find a nonlinear relationship between BGD and banks' environmental performance. When the number of female directors exceeds the critical mass, environmental performance does not correlate with the percentage of women on the board or eventually declines (inverted U-shaped relationship). The authors do not find support for critical mass theory, which posits the opposite relationship. However, when banks are led by a female CEO, a U-shaped relationship seems to emerge. There is a positive impact on environmental performance for an increasing percentage of female board members that exceed an estimated threshold of 30%. Therefore, we hypothesize the following:

Hypothesis 1. BGD and CP have a curvilinear, U-shaped relationship.

2.5 | Critical mass of BGD and the effect on carbon emissions

Legitimacy theory suggests that enhancing BGD to increase CP should align organizations' activities with societal expectations (Suchman, 1995). But the question remains what level or mass of BGD must be reached before improving CP to ultimately favor legitimacy. As a consequence, we complete our legitimacy theoretical framework with critical mass theory (Kanter, 1977) and social identity theory (Tajfel, 1978). Kanter (1977) constructs four different categories of groups according to their composition: uniform groups, skewed groups, tilted groups, and balanced groups. With regard to our research topic, uniform groups are those within which the board of directors has no female director. Skewed groups include up to 20% of "token women." Tilted groups refer to male-dominated boards of directors, where the percentage of women is 40% maximum. Finally, balanced groups refer to those with 40%–60% of female directors. In a skewed group, the tendency is that innovative ideas (e.g., new strategies for climate change policies) may either not be adequately expressed by the female tokens or not spotted by the dominant males (Joecks et al., 2013). In tilted or balanced groups, the mixture of female and male attributes will likely induce successful discussions and will hence positively affect group performance (Joecks et al., 2013). Thus, critical mass theory suggests that having an unbalanced board of directors impairs innovative decision-making (Konrad et al., 2008; Kramer, Konrad, & Erkut, 2006) as social pressures encourage minority group members to adopt or conform to the majority's opinions (Nemeth, 1986).

According to the social identity theory (Tajfel, 1978) as a complement to critical mass theory, individuals use demographic attributes, for example, gender, race, or age, to classify themselves, as well as others, into various social categories (e.g., feminine and masculine), and they possess a social identity based on belonging to those groups or categories (Amorelli & Garcia-Sanchez, 2020). By defining themselves in terms of group memberships, the behavior of individuals is linked to the social categories with which they identify. As a consequence, female directors act in line with their female stereotype, according to which they are more sustainability oriented, emotional, and empathic than men, contributing different points of view and heterogeneity to the decision-making process (Amorelli & Garcia-Sanchez, 2020). However, when minorities form a critical mass, interpersonal interactions are improved and greenwashing behavior and information overload risks should be decreased. Thus, until a certain threshold or "critical mass" of female directors within the board is not realized, there is a high probability that innovative perspectives, for example, carbon reduction initiatives, of females will not be focused on by the board.

During recent years, several researchers have analyzed whether female directors form a critical mass in order to increase both *financial* (Joecks et al., 2013; Konrad et al., 2008; Torchia, Calabro, & Huse, 2011) and *CSR* outputs (Amorelli & Garcia-Sanchez, 2020; Cabeza-Garcia, Fernandez-Gago, & Nieto, 2018; Fernandez-Feijoo, Romero, & Ruiz-Blanco, 2014; Jia & Zhang, 2013; Manita, Bruna, Dang, & Houanti, 2018; Post et al., 2011; Wieland & Flavel, 2015; Zaichkowsky, 2014). A few studies have also been conducted to measure a possible critical mass of female directors in order to influence *environmental* (Birindelli et al., 2019; Burkhardt et al., 2020; Cordeiro et al., 2020; He & Jiang, 2019; Liu, 2018; Post et al., 2011) and *carbon* outputs (Ben-Amar et al., 2017; Hollindale et al., 2019). However, a critical mass of BGD has not been analyzed for *CP*. Different *thresholds* for the critical mass of female directors have already been included, both in terms of absolute numbers (one, two, and three: Ben-Amar et al., 2017; He & Jiang, 2019; two: Hollindale et al., 2019; and three: Birindelli et al., 2019; Cordeiro et al., 2020; Liu, 2018; Post et al., 2011) and relative figures (more than 10%: Burkhardt et al., 2020). All the related studies find clear indications for a critical mass of female directors in order to increase *environmental* performance (Birindelli et al., 2019; Burkhardt et al., 2020; Cordeiro et al., 2020) and disclosure (Post et al., 2011), green innovation (He & Jiang, 2019), and the prevention of environmental lawsuits (Liu, 2018). Furthermore, both carbon disclosure (Hollindale et al., 2019) and CDP participation (Ben-Amar et al., 2017) can be significantly increased through a critical mass of female directors.

Based on critical mass theory, social identity theory, and previous empirical studies, we assume that BGD will need to reach a critical mass before being effective at decreasing carbon emissions:

Hypothesis 2. BGD needs to form a critical mass in order to increase CP.

3 | METHODOLOGY

3.1 | Dataset description

The original dataset consists of 6000 firm-year observations from the European index STOXX600 for the years 2009–2018. The index includes 600 listed companies from 17 European countries (EU and non-EU), covering approximately 90% of the free-float market capitalization of the European stock market. We use a 10 year time frame starting at the end of the 2007/2008 financial market crisis. The primary data were obtained from the Thomson Reuters Datastream database and the World Economic Forum in August 2020. In line with previous research, all financial service firms were removed from the analysis due to their specific capital structure and regulatory requirements (Cornett, Erhemjamts, & Tehranian, 2016). Additionally, missing (non-)financial datapoints lead to a decrease in firm-year observations. Table 2 summarizes the year-wise final sample consisting of 3123 firm-year observations.

3.2 | Variables of the study

The main analysis of this study focuses on an outcome-based inverse measure of CP scaled to firms' sales as the dependent variable: *total GHG intensity*, that is, the sum of direct Scope 1 and indirect Scope 2 GHG emissions divided by total sales in thousands of US dollars. Total GHG emissions are an overall indicator of CP because both

TABLE 2 Final sample

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Listed European companies in the STOXX Europe 600	600	600	600	600	600	600	600	600	600	600
Less										
Financial service firms	131	131	131	131	131	131	131	131	131	131
Observations with missing firm-level data on Thomson Reuters Datastream database	261	195	176	156	147	154	139	137	106	96
Final sample (base regression)	208	274	293	313	322	315	330	332	363	373

Scope 1 and Scope 2 emissions are under the influence of a company's management and are considered to be part of corporate carbon responsibility (Qian & Schaltegger, 2017). Carbon emissions may heavily depend on the size of a firm, and the board may influence the *carbon intensity* of its business rather than the sheer size of emissions. Therefore, this study scales GHG emissions to sales in thousands of US dollars at the end of the year to obtain carbon emission intensity. This is in accordance with common practice (e.g., Cho & Patten, 2007; Clarkson, Li, Richardson, & Vasvari, 2008; Patten, 2002; Qian & Schaltegger, 2017). Scope 3 emissions have not been considered due to a low number of observations and a wide discrepancy in the inclusion of emission sources (Downie & Stubbs, 2013).

The main independent variables are two proxies for *BGD* (e.g., Ben-Amar et al., 2017; García Martín & Herrero, 2020; Haque, 2017; Nadeem, Gyapong, & Ahmed 2020). First, we use the percentage of women directors on the board. Second, to test the effect of critical mass, we include four binary variables indicating at least one, two, three, or four female directors.

Furthermore, controls include *CG variables*, *other firm characteristics*, and *country-specific governance factors* consistent with prior research (Haque, 2017; Liao et al., 2015). With regard to *CG variables*, according to de Villiers et al. (2011), board independence (*B. Independence*) may improve effective monitoring, reduce agency costs, and support long-term green investment. We also include multiple directorships (*B.Affiliations*) as the average number of board seats held by directors of an organization, which is assumed to have a positive influence on board experience and perspectives in line with prior literature (García Martín & Herrero, 2020; Haque, 2017). The existence of a sustainability committee (*Sust. Com*) potentially addresses specific environmental opportunities and risks better (Jaggi et al., 2018; Liao et al., 2015). Board size (*B.Size*) and the number of board meetings (*B.Meetings*) as formal variables linked to carbon disclosures were included (Tingbani et al., 2020). CEO duality (*Duality*) may cause agency issues, reduce the effectiveness of the monitoring role of the board, and reduce the likelihood of approving long-term capital investment in environmental projects, leading to a decline in environmental performance (de Villiers et al., 2011; Haque, 2017). To measure the effect of compensation, a dummy variable indicating a firm's adoption of an Environmental, Social, and Governance (ESG) compensation policy (*ESG.Comp*) and the natural logarithm of total executive compensation (*Exec.Comp*) is used (Haque, 2017).

Regarding *other firm characteristics*, to capture the effect of carbon pricing for different sectors under the EU ETS, a dummy variable (*ETS*) is incorporated. Because CP might be affected by financial performance (Qian & Schaltegger, 2017), various firm performance measures are added to the model. The study uses return on assets (*ROA*) as an accounting-based measure and *Tobin's Q* as a market-based measure for financial performance (He, Tang, & Wang, 2013; Nuber, Velte, & Hörisch, 2020). Following Haque (2017), capital intensity (*Cap.In*) is included and calculated as capital expenditures divided by beginning-of-the-year total assets. Cash flow (*CF*) is incorporated as net cash flow divided by sales (Nuber et al., 2020). The debt ratio (*Debt*) is used as a proxy for idiosyncratic firm risk and is measured as total debt divided by total assets (Liao et al., 2015). Finally, in models using 2SLS (or OLS and random effects [RE] in our robustness tests), we account for industry- and country-related governance effects. The industry in which a company operates can have profound effects on its carbon emissions. Thus, the Thomson Reuters general industry classification (*IND*) is used to differentiate between (1) industrials, (2) utility, and (3) transportation.

Concerning *country governance variables*, separation between case (common) or code (civil) law was included by Grauel and Gotthardt (2016) and Luo et al. (2012). Thus, we control for the legal system (*Civil.Law*) using a dummy variable where 1 indicates civil law systems. Grauel and Gotthardt (2016) and Zhou, Simnett, and Green (2016) show that legal enforcement influences CDP participation and the choice of carbon assurance provider, respectively. Therefore, environmental enforcement (*Env.Enforce)* is included using data from the World Economic Forum. The enforcement of environmental regulation score ranges from 1 (*very lax*) to 7 (*very rigorous*) and is assessed through an executive opinion survey. Table 3 summarizes all the variables.

3.3 | Empirical methods

To measure the impact of BGD on CP considering all control variables, the base regression model states:

$$\begin{aligned} CP_{it} = {} & \alpha_0 + \beta_1\, BGD_{it} + \beta_2\, B.Affiliations_{it} + \beta_3\, B.Independence_{it} \\ & + \beta_4 Sust.Com_{it} + \beta_5\, B.Size_{it} + \beta_6\, B.Meetings_{it} + \beta_7\, Duality_{it} \\ & + \beta_8\, ESG.Comp_{it} + \beta_9\, Exec.Comp_{it} + \beta_{10}\, ETS_{it} + \beta_{11}\, ROA_{it} \\ & + \beta_{12}\, CF_{it} + \beta_{13}\, Cap.Int_{it} + \beta_{14}\, Debt_{it} + \beta_{15}\, TobinsQ_{it} \\ & + \beta_{16}\, IND_{it} + \beta_{17}\, Env.Enforce_{it} + \beta_{18}\, Civil.Law_{it} + \varepsilon_{it} \end{aligned}$$

TABLE 3 Variables of the study

Variables	Explanation and measurement
Dependent variables	
Total GHG intensity	(Scope 1 GHG emissions + Scope 2 GHG emissions)/Total sales in thousands of US dollars
Scope 1 intensity	Scope 1 GHG emissions/Total sales in thousands of US dollars (used in robustness test)
Independent variables	
B.Female	Percentage of females on the board = (female board members)/(total number of board members)*100
One woman; two women; three women; four women	Four binary variables, where (1) indicates at least one woman, two women, three women, or four women on the board of directors, and (0) otherwise
B.Blau.Gender	Board gender diversity index that ranges from 0 (*complete homogeneity*) to 0.5 (*complete heterogeneity*, i.e., 50/50) (used in robustness test)
Control variables	
Corporate governance variables	
B.Affiliations	Average number of corporate affiliations or multiple directorships of board members
B.Independence	(independent board members/total number of board members)*100
Sust.Com	Dummy variable for (1) existence of a sustainability committee and (0) otherwise
B.Size	Number of board members
B.Meetings	Number of board meetings
Duality	Dummy variable for (1) CEO is (ex-)board chair and (0) otherwise
ESG.Comp	Dummy variable for (1) existence of ESG-linked management compensation and (0) otherwise
Exec.Comp	Natural logarithm of total executive compensation
Other firm characteristics	
ETS	Dummy variable for (1) part of EU ETS and (0) otherwise
ROA	Return on assets = (net income before preferred dividends + ((interest expense on debt-interest capitalized)*(1 − tax rate)))/average of last year's and current year's total assets*100
CF	(net cash flow/sales)*100
Cap.In	Capital expenditures/beginning-of-the-year total assets
Debt	Total debt/total assets
Tobin's Q	(market value of equity + liabilities)/(book values of equity + liabilities)
IND	Dummy for industries using Thomson Reuters general industry classification index, where (1) industrials, (2) utility, and (3) transportation
Country-related governance variables	
Env.Enforce	Environmental enforcement in country (WEF Executive questionnaire)
Civil.Law	Dummy variable for (1) civil law and (0) case law

Abbreviations: ESG, Environmental, Social, and Governance; EU ETS, European Union Emission Trading Scheme; GHG, greenhouse gas; WEF, World Economic Forum.

where the subscripts of i and t refer to firm and year, respectively, and ε_{it} is a random disturbance term. However, one major concern regarding our research topic is linked with the endogeneity between BGD and CP because the selection of directors may not be an exogenous process but rather endogenously determined by firms according to their needs (Lahouel, Gaies, Zaied, & Jahmane, 2019; Wintoki, Linck, & Netter, 2012). Our research may be subject to different types of endogeneity bias. The BGD proxies might be endogenous (influenced by other variables; omitted variables) or jointly determined with the CP variable (reversed causality). There is a risk that the CP's error terms are correlated with the BGD proxies, which may cause inconsistent estimates and potentially leads to wrong inferences, misleading significant results, interpretations, and incorrect theoretical interpretations. Literature assumes that almost 90% of papers published in premier journals have not adequately addressed endogeneity bias (Ullah, Jiang, Shahab, Li, & Xu, 2020). Papers suggesting apparently significant relations uncovered by OLS or fixed effects are results of spurious correlations (Schultz et al., 2010). To address these concerns, prior literature proposes the use of advanced regression models (e.g., Wintoki et al., 2012; Zahid, Rahman, Khan, Ali, & Shad, 2020), such as 2SLS with IVs and dynamic panel GMM estimators, instead of classical OLS or fixed effects methods (Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998).

The 2SLS estimator requires valid instruments (i.e., variables that have a significant relationship with the independent variable but are uncorrelated to the error term). In our 2SLS approach, we follow

Larcker and Rusticus's (2010) suggestions to provide increased transparency in 2SLS models because some previous accounting literature does not provide enough information to assess the quality of IV estimates. In the context of our research, this means that we need to find IVs that are (strongly) correlated with BGD but (nearly) uncorrelated with the error term. Many CG variables (e.g., multiple directorships, board independence, and board size) and firm performance variables (e.g., ROA) are likely to be correlated with BGD. However, only variables that are considered to be external to the firm or more time invariant and not directly influenced by management may be (nearly) uncorrelated to the error term. In our search for instruments, we first exclude firm performance measures, because these are very likely to be correlated with the error term and other performance measures. Furthermore, external firm variables with a possible association with gender diversity (e.g., the introduction of a mandatory gender quota) were not found for a European sample. Other commonly used instruments, such as industry averages or ranked endogenous regressors, are highly unlikely to be adequate IVs (Larcker & Rusticus, 2010). GC variables, such as multiple directorships, are expected to be positively correlated with BGD but may change according to the composition of the board itself and are therefore not an adequate instrument. Thus, more time-invariant governance and firm variables were suggested in previous research, such as board size, employee retirement, and CSR policy variables (e.g., Ben-Amar et al., 2017; Birindelli et al., 2019). However, the inclusion of a large number of CSR policies may lead to overidentifying instruments and are expected to have little explanatory power. Differently, board size is a CG variable that is expected to have a significant positive association with the appointment of women directors (Campbell & Minguez-Vera, 2008). Like most firm variables, board size may not be completely exogenous. However, board size is relatively stable over time and may be far less impacted by firm performance than other governance variables. Furthermore, board size may well be influenced by external factors, such as the legal system or company size. We control for both by using a dummy variable for a country's legal system and scale the dependent variable to sales. Thus, we use board size as an instrument. A company's approach to its employees' retirement is also expected to be positively correlated with BGD because higher average pensions may lead to a higher directorship turnover, attract more women, and result in a higher number of female appointments to boards (Ben-Amar et al., 2017). Therefore, as second instrument, we use total pensions scaled to the number of employees. We control for factors that may correlate with average pensions such as industry, company size, or firm performance. Thus, we use board size and retirement as exogenous instruments to predict the percentage of women directors. Adopting an IV approach by performing a 2SLS estimation yields the following:

$$BGD_{it} = \alpha_0 + \gamma_1\ B.Size_{it} + \gamma_2\ Retirement_{it} + \partial\ CONTROLS_{it} + Year_t + \varepsilon_{it}\ \text{(first stage)}$$

$$CP_{it} = \alpha_0 + \hat{\gamma}_1\ BGD_{it} + \partial\ CONTROLS_{it} + Year_t + \varepsilon_{it}\ \text{(second stage)}$$

where *CONTROLS* are a set of control variables and $Year_t$ represent year dummies used in the first and second stages. First, we regress our instruments and controls to get fitted values of the endogenous independent variables. In the second stage, the modified version of the regression model replaces the endogenous variable using the fitted value from the first stage regression. For models investigating a nonlinear impact, a quadratic term BGD_{it}^2 is added to the second stage of the equation.

A firm's past performance can also determine the future of CP and BGD making our baseline model dynamic in nature. Additionally, 2SLS cannot easily be applied to critical mass because it does not allow for an endogenous (independent) dummy variable since the associated first stage is most likely of nonlinear nature (Angrist, 2009). Instead, Wintoki et al. (2012) stressed that the GMM allows for firm fixed effects to be included to account for (fixed) unobservable heterogeneity that current CG will be influenced by previous realizations of, or shocks to, past firm performance and that GMM estimators assume that the underlying economic process itself is dynamic. GMM approaches provide two types of transformation methods including first-difference transformation (one-step GMM) and second-order transformation (two-step GMM). However, one-step GMM is somewhat limited in its approach. For example, if a variable's recent value is missing, first-difference transformation may lead to loss of observations (Roodman, 2009). On the contrary, the second-order transformation (two-step) variant uses residuals from the one-step estimates, which can prevent unnecessary data loss, and is asymptotically more efficient and consistent than the one-step estimate (Arellano & Bover, 1995; Roodman, 2009). Furthermore, system GMM (SGMM) corrects standard errors, accounts for small-sample adjustments, and employs orthogonal deviations, which is considered as a prime estimator for addressing endogeneity due to at least two reasons (Blundell & Bond, 1998; Windmeijer, 2005): first, SGMM does not rely on external instruments but instead makes use of a firm's past history, accounting for endogeneity issues. Second, it accounts for the dynamic relationship by including the lags of the dependent variable as repressors in the equation. Therefore, following Wintoki et al. (2012), we employ a two-step SGMM.

$$\begin{aligned} CP_{it} = {} & \beta_1\ CP_{it-k} + \beta_2\ BGD_{it} + \beta_3\ B.Affiliations_{it} + \beta_4\ B.Independence_{it} \\ & + \beta_5\ Sust.Com_{it} + \beta_6\ B.Size_{it} + \beta_7\ B.Meetings_{it} + \beta_8\ Duality_{it} \\ & + \beta_9\ ESG.Comp_{it} + \beta_{10}\ Exec.Comp_{it} + \beta_{11}\ ETS_{it} + \beta_{12}\ ROA_{it} \\ & + \beta_{13}\ CF_{it} + \beta_{14}\ Cap.Int_{it} + \beta_{15}\ Debt_{it} + \beta_{16}\ TobinsQ_{it} + Year_t \\ & + \eta_i + \varepsilon_{it}{}^{1} \end{aligned}$$

where CP_{it-k} represents the lags of the dependent variable, $Year_t$ represents year dummies, and η_i represents unobserved time-invariant characteristics of the firm. Here, it is important to determine how many lags of *CP* should be included in the model because if too many lags are included, then it may lead to the overidentifying of instruments, and if too few are included, then it may not capture the impact

[1]For models testing a nonlinear impact, a quadratic term BGD_{it}^2 is added to the equation.

of past performance (Wintoki et al., 2012). In line with previous literature, we run models with one, two, and three lags, controlling for all other variables as in our baseline model to identify that the first two lags are significant in all models (e.g., Nadeem et al., 2020; Ullah et al., 2020; Wiley & Monllor-Tormos, 2018). Therefore, we include the first (CP_{it-1}) and second (CP_{it-2}) lag of *CP* in our model. All the explanatory variables except year dummies and firm effects are included in the regressions as endogenous variables (Schultz et al., 2010; Wintoki et al., 2012).

4 | RESULTS

4.1 | Descriptive statistics

Figure 1 shows a decreasing trend for GHG intensity (*total GHG intensity* and *Scope 1 intensity*) over the observed period. The maximum *total GHG intensity* can be observed in 2009, then decreases until 2012, stays almost flat until 2016, and decreases again until 2018. *Scope 1 intensity* follows a similar trend, although it increases slightly from 2012 to 2016. For BGD, a steady rising trend for the percentage of women on the board can be observed. In 2009, the average percentage of women on the board was around 12%, which almost linearly increased to just over 30% in 2018.

Table 4 summarizes the descriptive statistics, including the number of observations, means, SDs, minimums, medians, and maximums. Total GHG intensity has a mean of 0.30 and SD of 0.84. On average, there are 23.27% women on corporate boards (SD of 12.64) whereas the maximum is only 63.64%. This indicates that the sample is highly skewed and that few boards with high percentages of female directors or a female majority exist. Table 5 shows pairwise Pearson correlations for all variables. A relatively weak but highly significant negative correlation (−0.08) of BGD and GHG intensity can be observed. This correlation confirms the trends depicted in Figure 1. Interestingly, CEO duality is also negatively significantly correlated with GHG intensity. On the other hand, board independence, board size, the existence of a sustainability committee and an ESG compensation policy have a positive and significant association with GHG intensity. As expected, companies under the EU ETS are positively associated with higher GHG intensity. Interestingly, firm performance measures ROA and Tobin's Q are negatively associated with GHG intensity. On the contrary, companies with higher cash flow, capital intensity, and debt ratio also have a higher GHG intensity. Surprisingly, country governance variables are not significantly correlated with CP. Furthermore, companies with higher BGD tend to also have higher average multiple directorships, higher board independence, more board meetings, larger boards, and an ESG compensation policy. Companies in sectors covered by the EU ETS tend to have significantly less BGD. Moreover, BGD is positively associated with firm performance measures including ROA, Tobin's Q, and cash flow. Interestingly, countries with a civil law system tend to have higher BGD, which may be based on their more stakeholder-oriented legal system.

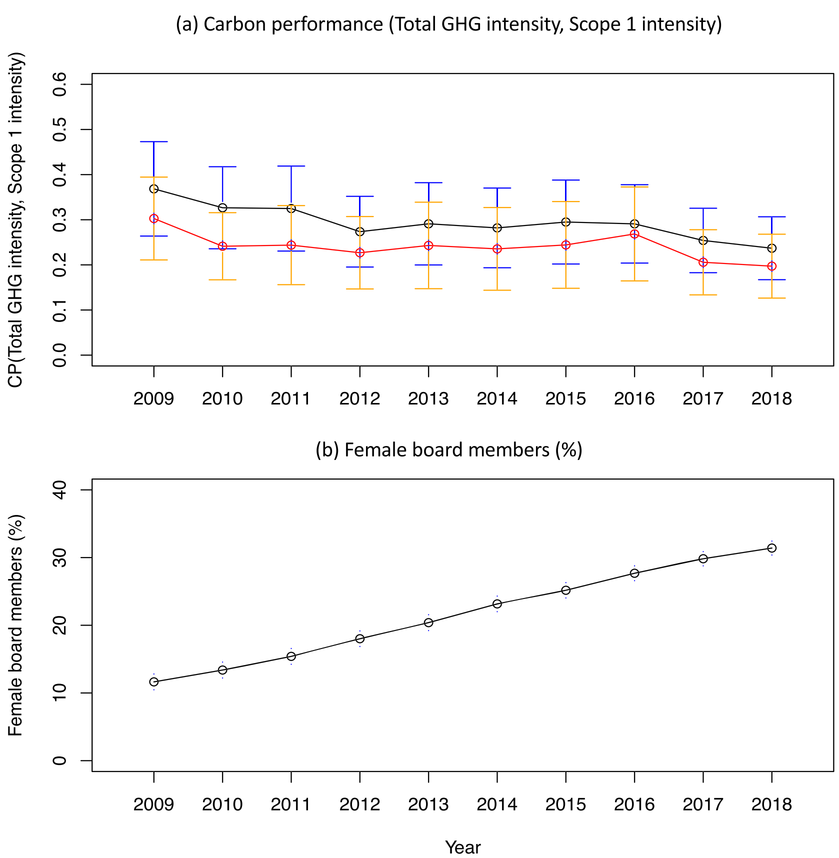

FIGURE 1 Trends of average values of (a) total GHG intensity and Scope 1 intensity and (b) percentage of female board members over the observed period from 2009 to 2018. The vertical lines indicate error bars at the 5% level. CP, carbon performance; GHG, greenhouse gas [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 4 Descriptive statistics

Variables	N	Mean	SD	Min	Median	Max
CP (total GHG intensity)	3123	0.30	0.84	0.0000	0.04	10.36
B.Blau.Gender	3123	0.33	0.14	0.00	0.36	0.50
B.Female	3123	23.27	12.64	0.00	23.08	63.64
B.Independence	3123	1.16	0.69	0.00	1.08	6.00
B.Affiliations	3123	59.80	22.55	0.00	60.00	100.00
Sust.Com	3123	0.88	0.33	0	1	1
B.Size	3123	11.53	3.77	2	11	26
B.Meetings	3123	8.68	3.36	1	8	43
Duality	3123	0.22	0.42	0	0	1
ESG.Comp	3123	0.45	0.50	0	0	1
Exec.Comp	3123	16.07	1.31	5.70	16.08	23.30
ETS	3123	0.35	0.48	0	0	1
ROA	3123	7.79	13.03	−24.54	6.11	269.11
Tobin's Q	3123	2.03	3.32	0.58	1.54	91.20
CF	3123	15.73	11.62	−33.01	13.10	89.84
Cap.In	3123	0.04	0.03	0.00	0.04	0.31
Debt	3123	0.59	0.17	0.04	0.59	1.44
Env.Enforce	3123	5.50	0.65	3.40	5.40	6.40
Civil.Law	3123	0.68	0.47	0	1	1
IND	3123	1.18	0.46	1	1	3

Note. This table reports descriptive statistics for variables of the study. Table 3 summarizes all variables used in the analysis.

4.2 | Regression results

Table 6 reports 2SLS regressions relating to the linear and curvilinear relationship of BGD and CP (Hypothesis 1). To test the shape of the relationship, we run two separate models (1) for a linear relationship with single power *B.Female* and (2) adding a quadratic term *B.Female*^{2}. We start by estimating the first stage regression that shows promising highly significant coefficients for our instruments of moderate magnitude. Due to the relatively low magnitude of the coefficients, we test our model for weak instruments following Larcker and Rusticus's (2010) recommendations. First, a simple way to detect the presence of weak instruments is by running a partial *F* test (or weak instrument test) in the first stage. If the *F* statistic is low or insignificant, this implies that the selected instruments are weak. However, the weak instrument tests are highly significant, with observed *F* statistics of 23.82 and 35.85, far exceeding the critical value of 11.59 for two instruments (Larcker & Rusticus, 2010; Stock, Wright, & Yogo, 2002). Second, the adj. R^2 of the first stage models is 33.4%. However, this overstates the true explanatory power of the instruments as the control variables also contribute to this adj. R^2. After removing the contribution of the control variables, we estimate the partial R^2 as approximately 1.79%, which indicates a satisfactory explanatory power of our instruments (Larcker & Rusticus, 2010). Based on the positive results of the first stage, we run the second stage. In the second stage, our results show a significant ($p < 0.05$) and negative coefficient for *B.Female* (−0.027) in the linear model. In the quadratic model, no significant coefficients can be observed for our independent variable. This indicates that an increase in BGD leads to a linear decrease in total GHG intensity, that is, improved CP. To test our second stage, we again follow Larcker and Rusticus (2010), who say that previous accounting research mostly relies on the classic Hausman (1978) test for endogeneity but mostly neglects reporting the overidentification restriction test. This is necessary to assess the validity of IV application where the number of instruments exceeds the number of endogenous regressors (which is the case in our study). Therefore, we report results for both, the Hausman test and overidentification restriction test. For the linear model, the Wu–Hausman test is significant, and the overidentification restriction test insignificant, indicating the appropriateness of our IV estimation.

On the contrary, in the quadratic model, the tests indicate an insignificant Wu–Hausman test and possible overidentification, somewhat challenging the appropriateness of the nonlinear 2SLS model.[2]

In a next step, Table 7 reports the results based on a two-step SGMM for testing Hypothesis 1. Again, we run a linear and quadratic model separately. Because the SGMM model controls for endogeneity, includes lagged values, and applies internal transformation processes, the results reported may be significantly different from those produced by other methods (e.g., Schultz et al., 2010). Our results show that the coefficient for *B.Female* is significant ($p < 0.05$) in the linear model. For the quadratic models, the coefficients for *B.*

[2]Untabulated results for OLS and RE regressions are briefly discussed in Section 4.3.

TABLE 5 Pearson correlation matrix

Variables		1	2	3	4	5	6	7	8	9
1	*CP (total GHG intensity)*									
2	*B.Blau.Gender*	−0.08***								
3	*B.Female*	−0.08***	0.96***							
4	*B.Affiliations*	0.02	0.10***	0.09***						
5	*B.Independence*	0.06**	0.21***	0.19***	0.24***					
6	*Sust.Com*	0.05*	0.02	0.01	0.08***	0.02				
7	*B.Size*	0.06***	0.05**	0.03	−0.05**	−0.33***	0.20***			
8	*B.Meetings*	0.01	0.09***	0.10***	0.06***	0.16***	0.04*	−0.08***		
9	*Duality*	−0.05**	0.03	0.06***	0.03	−0.10***	0.01	0.13***	−0.06***	
10	*ESG.Comp*	0.06***	0.13***	0.12***	0.16***	0.13***	0.14***	0.07***	0.06**	−0.09***
11	*Exec.Comp*	0.01	0.00	0.01	0.10***	0.01	0.10***	0.14***	0.02	−0.08***
12	*ETS*	0.20***	−0.09***	−0.11***	0.04*	0.01	0.16***	0.28***	0.00	0.02
13	*ROA*	−0.07***	0.05**	0.06***	0.02	0.01	−0.18***	−0.15***	−0.05**	−0.05**
14	*Tobin's Q*	−0.07***	0.06**	0.06***	0.02	0.02	−0.17***	−0.12***	−0.05**	0.03
15	*CF*	0.06***	0.04*	0.05*	0.02	0.01	−0.08***	−0.07***	0.04*	0.03
16	*Cap.In*	0.15***	0.00	0.01	0.01	0.00	0.02	0.04*	0.04*	0.03
17	*Debt*	0.04*	0.03	0.01	0.06**	0.03	0.12***	0.25***	0.06***	0.03
18	*Env.Enforce*	0.01	0.03	0.00	0.01	0.12***	−0.05**	−0.18***	−0.11***	−0.18***
19	*Civil.Law*	0.03	0.11***	0.15***	−0.15***	−0.08***	0.06***	0.31***	0.06**	0.26***
20	*IND*	0.16***	0.02	0.03	0.02	−0.05*	0.01	0.14***	0.12***	0.02

Note. This table reports Pearson correlations. Table 3 summarizes all variables used in the analysis.
*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.

TABLE 5 (Continued)

Variables	10	11	12	13	14	15	16	17	18	19
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11	0.03									
12	0.11***	0.10***								
13	−0.07***	0.03	−0.11***							
14	−0.07***	0.01	−0.12***	0.89***						
15	0.04*	−0.04*	−0.07***	0.31***	0.27***					
16	0.01	−0.05*	0.10***	0.01	0.02	0.23***				
17	0.08***	0.02	0.13***	−0.09***	0.01	−0.05**	0.00			
18	−0.08***	0.20***	−0.04*	0.07***	0.05**	−0.06**	0.00	−0.16***		
19	−0.16***	0.05**	0.11***	−0.12***	−0.10***	−0.08***	0.05**	0.00	0.11***	
20	0.08***	−0.07***	0.15***	−0.07***	−0.07***	0.19***	0.23***	0.18***	−0.10***	0.04*

Note. This table reports Pearson correlations. Table 3 summarizes all variables used in the analysis.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

TABLE 6 2SLS regression results for testing Hypothesis 1

	2SLS		
	First stage	Second stage	
	BGD (*B.Female*)	CP (*total GHG intensity*)	
B.Female		−0.027**	−0.004
B.Female^2			0.000
Control variables			
B.Affiliations	1.289***	−0.039	−0.069**
B.Independence	0.065***	0.003***	0.002**
Sust.Com	1.039	0.089	0.058
B.Meetings	0.203***	−0.007	−0.012**
Duality	0.040	−0.053	−0.05
ESG.Comp	1.221***	0.052	0.017
Exec.Comp	0.165	0.004	0.002
ETS	−2.618***	0.219***	0.264***
ROA	0.113***	−0.0004	−0.003
CF	0.019	0.004**	0.004**
Cap.In	8.857	3.368***	3.081***
Debt	1.354	−0.085	−0.139
Tobin's Q	0.301	−0.082***	−0.085***
Env.Enforce	−1.250***	0.0001	0.027
Civil.Law	3.988***	0.019	−0.088**
IND (2)	0.628	0.328***	0.311***
IND (3)	−3.823***	−0.03	0.064
Instruments			
B.Size	5.082		
Retirement	0.014***		
Constant	0.461	0.335	0.254
Year	Y	Y	Y
Observations	2727	2727	2727
Adj. R^2	0.334		
Partial R^2	0.0179		
Weak instruments test		23.817 (p < 0.01)	35.847 (p < 0.01)
Wu–Hausman test		3.335 (p = 0.0679*)	0.072 (p = 0.7882)
Overidentifying restrictions test		2.676 (p = 0.1019)	6.482 (p = 0.0109**)
Wald test		9.961 (p < 0.01)	10.44 (p < 0.01)

Note. The table presents results of two-stage least squares (2SLS) with instrumental variable (IV) regressions for the independent board gender diversity (BGD) variable *B.Female* and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, country-related governance, industry, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports adj. R^2 to describe the explanatory power of the first stage regressions and the values for the specification tests: the test for weak instruments, test of overidentifying restrictions, and the Hausman test. Finally, Wald statistic for the robust test on the 2SLS coefficient on CP is presented.
*p < 0.1. **p < 0.05. ***p < 0.01.

Female are significant, and the coefficients for single power *B.Female* are positive and negative for quadratic coefficients. Remembering that *total GHG intensity* is an inverse measure of CP, this implies an inverted U-shaped relationship between percentage of women directors and CP. Following Ullah, Akhtar, and Zaefarian (2018), we run post-estimation tests to check for the appropriateness of our estimates. First, insignificant Sargan tests imply that the instruments are exogenous, which is a critical assumption for the validity of GMM estimates. Second, an insignificant Arellano–Bond second-order autocorrelation (AR2) shows that the lagged variables are not

TABLE 7 GMM regression results for testing Hypothesis 1

	System GMM	
	Model 1	Model 2
	CP (*total GHG intensity*)	
B.Female	−0.0003**	−0.001**
B.Female²		0.00001*
B.Affiliations	−0.0004	−0.0003
B.Independence	−0.00003	−0.00002
Sust.Com	−0.006	−0.006
B.Size	0.001**	0.001**
B.Meetings	0.001	0.001
Duality	−0.006	−0.006*
ESG.Comp	0.001	0.001
Exec.Comp	−0.001	−0.001
ETS	0.013***	0.013***
ROA	−0.001**	−0.001**
CF	0.0003*	0.0003*
Cap.In	0.213***	0.202**
Debt	−0.004	−0.005
Tobin's Q	0.001	0.001
Lag I total GHG intensity	0.728***	0.730***
Lag II total GHG intensity	0.160***	0.159***
Year	Y	Y
Firm	Y	Y
Observations	3123	3123
Number of instruments	35	36
Sargan test statistic	49.62 (p = 0.0518)	50.14 (p = 0.0589)
AR2	−0.8547 (p = 0.3927)	−0.8512 (p = 0.3946)
Wald test for coefficients	120,199.2 (p < 0.01)	119,870.9 (p < 0.01)
Wald test for time dummies	27.7527 (p < 0.01)	28.3574 (p < 0.01)

Note. The table presents results of two-step system generalized method of moments (GMM) regressions for the independent board gender diversity (BGD) variable *B.Female* and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of instruments, Sargan test of overidentification, and Arellano–Bond test for second-order autocorrelation (AR2). Finally, Wald statistics for the coefficients of variables on CP and year dummies are presented.
*p < 0.1. **p < 0.05. ***p < 0.01.

correlated with the error term, which confirms the validity of the model used in our estimation process. Wald statistics for coefficients and time dummies further confirm our model choice and use of time dummies.

Table 8 reports results regarding the testing of Hypothesis 2 using a two-step SGMM. We run four regressions with binary variables and controls for at least one, two, three, and four women directors. The coefficient of the "at least one woman" variable is insignificant. The coefficients in models with at least two, three, and four women on the board are highly statistically significant (p < 0.01) and negative. These results indicate that the presence of at least two women directors decreases *total GHG intensity* (i.e., increases CP). Interestingly, the magnitude of coefficients for at least two (−0.013), three (−0.011), and four (−0.012) women directors stays relatively stable. Again, we perform two post-estimation tests to determine the appropriateness of our model (Ullah et al., 2018). The insignificant Sargan tests for all models show that our instruments are valid. This is also confirmed by the insignificant AR2 tests, consistent with the requirements of the SGMM estimator. Significant Wald statistics again support the model choice and the use of time dummies.

4.3 | Robustness checks

Various robustness tests are performed to challenge our chosen econometric model and variables. First, as commonly performed in

TABLE 8 GMM regression results for testing Hypothesis 2

	System GMM			
	Model 1	Model 2	Model 3	Model 4
	CP (*total GHG intensity*)			
One woman	0.001			
Two women		−0.013***		
Three women			−0.011***	
Four women				−0.012***
B.Affiliations	−0.002	−0.002	−0.001	−0.002
B.Independence	0.00003	0.00000	0.00002	−0.00001
Sust.Com	−0.008	−0.008	−0.007	−0.007
B.Size	0.002**	0.002**	0.002**	0.002***
B.Meetings	0.001	0.001	0.0005	0.001*
Duality	−0.007	−0.007*	−0.005	−0.005
ESG.Comp	0.0003**	0.002	0.0001	0.002
Exec.Comp	−0.001	−0.001	−0.001	−0.001
ETS	0.016***	0.014***	0.016***	0.014***
ROA	−0.001***	−0.001***	−0.001**	−0.001***
CF	0.0004**	0.0004**	0.0003*	0.0004**
Cap.In	0.214***	0.219***	0.236***	0.206***
Debt	−0.003	−0.001	−0.002	−0.004
Tobin's Q	0.002	0.001	0.001	0.001
Lag I total GHG intensity	0.731***	0.735***	0.723***	0.733***
Lag II total GHG intensity	0.155***	0.151***	0.162***	0.154***
Year	Y	Y	Y	Y
Firm	Y	Y	Y	Y
Observations	3123	3123	3123	3123
Number of instruments	35	35	35	35
Sargan test statistic	43.94 (p = 0.1428)	44.12 (p = 0.1388)	43.73 (p = 0.1478)	42.97 (p = 0.1667)
AR2	−0.8101 (p = 0.4179)	−0.81209 (p = 0.4167)	−0.8562 (p = 0.3919)	−0.7997 (p = 0.4239)
Wald test for coefficients	116,416.7 (p < 0.01)	119,455.6 (p < 0.01)	123,010.3 (p < 0.01)	123,179.2 (p < 0.01)
Wald test for time dummies	28.0181 (p < 0.01)	32.4547 (p < 0.01)	28.6411 (p < 0.01)	33.7582 (p < 0.01)

Note. The table presents results of two-step system generalized method of moments (GMM) regressions for the independent variables at least one, two, three, and four women on the board and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of instruments, Sargan test of overidentification, and Arellano–Bond test for second-order autocorrelation (AR2). Finally, Wald statistics for the coefficients of variables on CP and year dummies are presented.
*p < 0.1. **p < 0.05. ***p < 0.01.

(sustainability) accounting research, we estimate variance inflation factors (VIFs), testing for possible multicollinearity problems. The maximum VIFs obtained are 5.14 for Tobin's Q and 4.98 for ROA; hence, the critical value of 10 is clearly not exceeded (Fox & Monette, 1992). Second, we apply the same 2SLS and two-step SGMM estimation with the same instruments and specification models but using alternative proxies for BGD and CP. For BGD, we rely on the Blau (1977) index of heterogeneity as a high number of women on the board can lead to gender homogeneity, a percentage number may not be sufficient as a gender diversity proxy (Ben-Amar et al., 2017; Lu & Herremans, 2019; Nadeem et al., 2020). The Blau index ranges from 0 (*complete homogeneity*) to 0.5 (*complete heterogeneity*, i.e., 50/50 men and women directors) and is calculated as follows: $H = 1 - \sum_i^k Ip_i^2$, where I is the number of gender categories (i.e., female and male) and p_i denotes the proportion of group members (i.e., the percentage of men and women directors) (Blau, 1977). The Blau index rises with increasing female board representation and reaches its maximum for gender parity. For boards with a female majority, the index decreases again. Thus, gender diversity would return a low value for boards with more (or exclusively) female directors. Furthermore, the presence of female directors is still mostly relatively low, and it is difficult to find boards with a female majority, limiting interpretability of the Blau index. Thus, the Blau index is used as a complementary measure of board diversity in order to add robustness and increase comparability with other studies (e.g., Abad, Lucas-Pérez, Minguez-Vera, & Yagüe, 2017). The results using 2SLS regressions and SGMM, testing for Hypothesis 1, show negative and significant coefficients for the linear models but no significant coefficients for the quadratic models. For CP, we additionally use direct Scope 1 GHG emission intensity. Scope 1 emissions are included as a separate indicator of CP because a company's board may have more influence on direct emissions than indirect emissions and only Scope 1 is regulated under the ETS (Qian & Schaltegger, 2017). For Hypothesis 1, the 2SLS and the SGMM models provide similar results compared with total GHG emissions intensity. Furthermore, models testing critical mass (Hypothesis 2) confirm our results of a critical mass of at least two women directors also for Scope 1 intensity. Third, as previously discussed, the use of a two-step SGMM is superior to other GMM methods. However, some researchers have recognized that the two-step procedure, which is required to obtain efficiency, may give rise to bias in the point estimate and standard error. Therefore, Windmeijer (2005) proposed a corrected standard error estimation to account for the added variability in the two-step procedure, which is also known as Windmeijer corrections. Therefore, we employ Windmeijer corrections to gain robust standard errors. Due to the correction, the significance of most of the control variables decrease. However, for models investigating the linear relationship, the coefficients remain negative and significant for the Blau index ($p < 0.1$) and become slightly insignificant for *B.Female* ($p = 0.12$). Results stay similar for the squared models (Hypothesis 1). For models analyzing the existence of a critical mass in the relationship (Hypothesis 2), the coefficient for at least one woman director is insignificant whereas coefficients of at least, two, three, or four female directors remain negative and significant at the 5% level. This provides robustness to our findings, indicating that a critical mass of at least two women directors negatively impacts total GHG emission intensity. Moreover, the Sargan and AR2 tests are both insignificant for all models using Windmeijer corrections. Finally, following the recommendation of Larcker and Rusticus (2010), Petersen (2009), and Gow, Ormazabal, and Taylor (2010), we additionally employ classical OLS regressions, panel regressions with RE, and models with year- and firm-clustered standard errors. For a better comparison, we run the regressions using the exact same sample as in our main SGMM models. Results of OLS and RE models with year- and firm-clustered standard errors similarly indicate a linear relationship and critical mass. For brevity, these robustness tests are not tabulated but may be provided upon request.

5 | DISCUSSION

As presented in the previous section, this study empirically shows a positive linear relationship between BGD and CP. This indicates that BGD enhances climate mitigation strategies, that is, reduces total GHG emissions intensity. These results, based on SGMM and 2SLS with IV approaches, are robust to endogeneity issues, alternative regression methods (OLS and panel regressions with RE, year- and firm-clustered standard errors, or GMM Windmeijer corrections), and the use of alternative proxies of BGD and CP. Thus, organizations may increase board effectiveness by increasing BGD to gain legitimacy and ultimately respond to societal expectations about reducing GHG emissions. Our findings support previous research on the positive relationship of BGD and environmental performance (e.g., Burkhardt et al., 2020; Cordeiro et al., 2020; Galia et al., 2015; Kassinis et al., 2016; Li et al., 2017; Lu & Herremans, 2019) and add to the limited amount of literature with CP (García Martín & Herrero, 2020; Haque, 2017). We further provide some indication of a curvilinear, U-shaped relationship in line with the empirical results of Birindelli et al. (2019) and the TLGT effect (Barnett & Salomon, 2012; Haans et al., 2016). The inconclusive results regarding a nonlinear relationship may be based on the highly skewed boards of this sample. In the case that a TLGT effect exists, few (or no) data points are available for boards with gender parity and higher numbers of women on the board (i.e., the right side of the possible U-shaped link between female directors on the board and CP).

We also find robust empirical results, showing that female directors need to reach a critical mass of at least two women on the board of directors in order to have a significant positive impact on CP (i.e., reduced GHG intensity). The critical mass of two women directors is in line with our theoretical framework and prior literature, which argues that there is a threshold for the number of female directors needed to influence environmental outputs (Birindelli et al., 2019; Burkhardt et al., 2020; Cordeiro et al., 2020; He & Jiang, 2019; Post et al., 2011) and especially carbon-related issues (Ben-Amar et al., 2017; Hollindale et al., 2019). This result suggests that companies should aim for higher numbers and at least two women directors to improve their CP.

The results provide implications for businesses, investors, researchers, and regulators. For researchers, the results highlight the need for cross-country samples but also the need for better statistical methods with regard to endogeneity concerns and the standardization of variables. Our literature review indicates that a great variety of environmental and carbon outputs have been used in prior research. Although actual carbon emissions have not been included in much of the previous research, carbon-related proxies are often used as a simple dummy variable (e.g., participation in the CDP). Though easy to measure, this leads to a limited validity of studies and interpretability regarding actual carbon emissions. Moreover, future researchers should clearly differentiate between proactive versus reactive carbon strategies, past versus future-oriented measures, and mandatory versus voluntary carbon emission regimes. As CP proxies are heterogeneous, variations in CP proxies as robustness checks should be included in order to strengthen the comparability of CP studies. As CP and disclosure represent interdependent proxies, additional moderators and mediator analysis regarding that link would be rather useful (Velte et al., 2020). The recognition of moderators and the need for mediator analysis are very low in empirical carbon research to date. We also note that both BGD and CP strategies can be related to greenwashing behavior and information overload. These challenges should be included in future research designs.

For businesses, this study shows that managers should aim for highly gender diverse boards and at least two women directors to increase CP. Regulators may consider setting quotas or providing incentives for higher BGD to decrease carbon emissions. Especially, the EC may take action with a new EU directive laying down rules on board composition because existing measures to promote BGD in many EU Member States are fragmented and slow (EY, 2020). Finally, for (sustainable) investors, the results suggest that a holistic analysis of CG can help when allocating capital or investing into low carbon portfolios.

6 | CONCLUSIONS AND LIMITATIONS

This paper empirically investigated the impact of BGD as a major proxy of board effectiveness on CP for European non-financial firms listed in the STOXX600 index, over the 2009–2018 period. The study makes a threefold contribution to prior studies from a European perspective on the impact of female directors on environmental outputs (Baalouch et al., 2019; Burkhardt et al., 2020; Galia et al., 2015; Haque & Jones, 2020) and carbon-related issues (García Martín & Herrero, 2020; Haque, 2017; Liao et al., 2015; Tingbani et al., 2020): first, we use a "theory mix" in order to analyze the linear and curvilinear relationship as well as the existence of a critical mass of female directors for BGD and CP. Second, we do not only rely on a disclosure measure or one unscaled measure of CP but include actual total GHG emission intensity and Scope 1 intensity in our research design. Finally, the study makes use of advanced econometric methods including 2SLS with an IV approach and two-step SGMM to address endogeneity concerns. Our study provides clear indications for a linear positive link between BGD with CP and a threshold of at least two female directors.

In this context, we mention the *limitations* of our study. First, the generalizability of the study is limited due to its focus on a European sample. Further research could include non-European regimes and compare these with the European setting. Furthermore, the use of quantitative databanks does not allow for a qualitative analysis of companies' environmental management systems and reporting. Thus, further research could analyze how environmental management systems mediate the relationship between board characteristics and CP. Due to the focus on large corporations, it remains unclear if the observed relationship also holds true for small- and medium-sized enterprises (SMEs). Regulators have debated a future extension of sustainability reporting, and further research could deal with SMEs, considering their combined importance in sustainable development (Johnson, 2015).

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APPENDIX 1: VARIANCE INFLATION FACTORS (VIFs)

	GVIF	Df	GVIF^(1/(2*Df))
B.Female	1.143225	1	1.069217
B.Affiliations	1.142413	1	1.068837
B.Independence	1.301067	1	1.140643
D_CSRCommittee	1.126694	1	1.061459
B.Size	1.597009	1	1.263728
B.Meetings	1.121477	1	1.058998
D_Duality	1.199960	1	1.095427
D_ESG.Comp	1.148296	1	1.071586
Exec.Comp	1.124996	1	1.060658
D_Emission.Trading	1.182081	1	1.087235
ROA	5.140579	1	2.267285
CF_sales_ratio	1.341798	1	1.158360
Cap.In	1.123675	1	1.060036
Debt	1.178279	1	1.085486
Tobin's Q	4.983942	1	2.232474
Env.Enforce	1.244973	1	1.115783
Civil.Law	1.395297	1	1.181227
Factor (*IND*)	1.430103	2	1.093558

APPENDIX 2: 2SLS REGRESSION RESULTS FOR TESTING HYPOTHESIS 1 USING THE BLAU INDEX AS AN ALTERNATIVE PROXY FOR BGD

	2SLS		
	First stage	Second stage	
	BGD (*B.Blau.Gender*)	CP (*total GHG intensity*)	
B.Blau.Gender		−1.637*	2.49
B.Blau.Gender^2			−5.364
Control variables			
B.Affiliations	0.015***	−0.050*	−0.067***
B.Independence	0.001***	0.003***	0.002**
Sust.Com	0.008	0.075	0.049
B.Meetings	0.002***	−0.010*	−0.010*
Duality	0.006	−0.061	−0.047
ESG.Comp	0.013***	0.038	0.012
Exec.Comp	0.002	0.004	−0.002
ETS	−0.026***	0.244***	0.256***
ROA	0.001***	−0.002	−0.003
CF	0.0001	0.004**	0.004**
Cap.In	0.012	3.107***	3.222***
Debt	0.022	−0.086	−0.166
Tobin's Q	0.002	−0.088***	−0.081***
Env.Enforce	0.004	0.025	0.014
Civil.Law	0.027***	−0.048	−0.058
IND (2)	0.009	0.327***	0.311***
IND (3)	−0.043***	0.008	0.094
Instruments			
B.Size	0.004***		
Retirement	0.0001***		
Constant	0.046	0.309	0.159
Year	Y	Y	Y
Observations	2727	2727	2727
Adj. R^2	0.338		
Partial R^2	0.0222		
Weak instruments test		31.604 ($p < 0.01$)	31.112 ($p < 0.01$)
Wu–Hausman test		1.31 ($p = 0.2524$)	0.987 ($p = 0.3205$)
Overidentifying restrictions test		5.106 ($p = 0.0238$)	5.259 ($p = 0.0218$)
Wald test		10.36 ($p < 0.01$)	10.54 ($p < 0.01$)

Note. The table presents results of two-stage least squares (2SLS) with instrumental variable (IV) regressions for the independent board gender diversity (BGD) variable *B.Blau.Gender* and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, country-related governance, industry, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports adj. R^2 to describe the explanatory power of the first stage regressions and the values for the specification tests: the test for weak instruments, test of overidentifying restrictions, and the Hausman test. Finally, Wald statistic for the robust test on the 2SLS coefficient on CP is presented.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

APPENDIX 3: GMM REGRESSION RESULTS FOR TESTING HYPOTHESIS 1 USING THE BLAU INDEX AS AN ALTERNATIVE PROXY FOR BGD

	System GMM	
	Model 1	**Model 2**
	CP (*total GHG intensity*)	
B.Blau.Gender	−0.036**	−0.025
B.Blau.Gender^2		−0.021
B.Affiliations	−0.001	−0.0005
B.Independence	−0.00001	−0.00003
Sust.Com	−0.007	−0.006
B.Size	0.002**	0.001**
B.Meetings	0.001	0.001
Duality	−0.006*	−0.006
ESG.Comp	0.001	0.001
Exec.Comp	−0.001	−0.001
ETS	0.014***	0.013***
ROA	−0.001**	−0.001**
CF	0.0003*	0.0003*
Cap.In	0.213**	0.209***
Debt	0	−0.004
Tobin's Q	0.001	0.001
Lag I total GHG intensity	0.727***	0.731***
Lag II total GHG intensity	0.16***	0.158***
Year	Y	Y
Firm	Y	Y
Observations	3123	3123
Number of instruments	35	36
Sargan test statistic	46.92 (p = 0.0858)	48.21 (p = 0.08387)
AR2	−0.8496 (p = 0.3956)	−0.8342411 (p = 0.40415)
Wald test for coefficients	120,832.4 (p < 0.01)	116,625.6 (p < 0.01)
Wald test for time dummies	29.044 (p < 0.01)	29.0003 (p < 0.01)

Note. The table presents results of two-step system generalized method of moments (GMM) regressions for the independent board gender diversity (BGD) variable *B.Blau.Gender* and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of instruments, Sargan test of overidentification, and Arellano–Bond test for second-order autocorrelation (AR2). Finally, Wald statistics for the coefficients of variables on CP and year dummies are presented.

*p < 0.1.

**p < 0.05.

***p < 0.01.

APPENDIX 4: 2SLS REGRESSION RESULTS FOR TESTING HYPOTHESIS 1 USING SCOPE 1 INTENSITY AS AN ALTERNATIVE PROXY FOR CP

	2SLS		
	First stage	Second stage	
	BGD (*B.Female*)	CP (*Scope 1 intensity*)	
B.Female		−0.038***	−0.039
B.Female²			0.001
Control variables			
B.Affiliations	1.289***	−0.009	−0.046
B.Independence	0.065***	0.003***	0.002**
Sust.Com	1.039	0.016	−0.004
B.Meetings	0.203***	−0.006	−0.012**
Duality	0.040	−0.099**	−0.102**
ESG.Comp	1.221***	0.078*	0.039
Exec.Comp	0.165	0.008	0.004
ETS	−2.618***	0.161***	0.232***
ROA	0.113***	0.002	−0.001
CF	0.019	0.001	0.002
Cap.In	8.857	3.497***	2.718***
Debt	1.354	−0.204*	−0.185*
Tobin's Q	0.301	−0.087***	−0.094***
Env.Enforce	−1.250***	−0.009	0.044
Civil.Law	3.988***	0.143*	−0.033
IND (2)	0.628	0.373***	0.352***
IND (3)	−3.823***	−0.058	0.041
Instruments			
B.Size	5.082		
Retirement	0.014***		
Constant	0.461	0.363	0.387
Year	Y	Y	Y
Observations	2727	2474	2474
Adj. R^2	0.334		
Partial R^2	0.0179		
Weak instruments test		19.764 ($p < 0.01$)	28.883 ($p < 0.01$)
Wu–Hausman test		6.649 ($p = 0.00998$)	0.895 ($p = 0.3441$)
Overidentifying restrictions test		0.28 ($p = 0.59639$)	5.928 ($p = 0.0149$)
Wald test		7.658 ($p < 0.01$)	8.571 ($p < 0.01$)

Note. The table presents results of two-stage least squares (2SLS) with instrumental variable (IV) regressions for the independent board gender diversity (BGD) variable *B.Female* and dependent carbon performance (CP) variable *direct Scope 1 intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, country-related governance, industry, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports adj. R^2 to describe the explanatory power of the first stage regressions and the values for the specification tests: the test for weak instruments, test of overidentifying restrictions, and the Hausman test. Finally, Wald statistic for the robust test on the 2SLS coefficient on CP is presented.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

APPENDIX 5: GMM REGRESSION RESULTS FOR TESTING HYPOTHESIS 1 USING SCOPE 1 INTENSITY AS AN ALTERNATIVE PROXY FOR CP

	System GMM	
	Model 1	Model 2
	CP (*direct Scope 1 intensity*)	
B.Female	−0.0002**	−0.001**
B.Female^2		0.00001*
B.Affiliations	−0.001	−0.001
B.Independence	0.00001	0.00001
Sust.Com	−0.004	−0.004
B.Size	0.001***	0.001***
B.Meetings	0.0004	0.0004
Duality	−0.0003	−0.001
ESG.Comp	−0.001	−0.001
Exec.Comp	−0.002**	−0.002**
ETS	0.007**	0.006**
ROA	−0.0005**	−0.0004**
CF	0.0001	0.0001
Cap.In	0.045	0.046
Debt	−0.003	−0.004
Tobin's Q	0.002**	0.001*
Lag I total GHG intensity	0.981***	0.983***
Lag II total GHG intensity	−0.036***	−0.038***
Year	Y	Y
Firm	Y	Y
Observations	3711	3711
Number of instruments	35	36
Sargan test statistic	58.13 (p = 0.0083)	58.92 (p = 0.0093)
AR2	−0.5609 (p = 0.575)	−0.5318 (p = 0.5949)
Wald test for coefficients	660,969.2 (p < 0.01)	686,640.0 (p < 0.01)
Wald test for time dummies	35.80 (p < 0.01)	37.25 (p < 0.01)

Note. The table presents results of two-step system generalized method of moments (GMM) regressions for the independent board gender diversity (BGD) variable *B.Female* and dependent carbon performance (CP) variable *direct Scope 1 intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of instruments, Sargan test of overidentification, and Arellano–Bond test for second-order autocorrelation (AR2). Finally, Wald statistics for the coefficients of variables on CP and year dummies are presented.

*p < 0.1.

**p < 0.05.

***p < 0.01.

APPENDIX 6: GMM REGRESSION RESULTS FOR TESTING HYPOTHESIS 2 USING SCOPE 1 INTENSITY AS AN ALTERNATIVE PROXY FOR CP

	System GMM			
	Model 1	Model 2	Model 3	Model 4
	CP (*Scope 1 intensity*)			
One woman	−0.006			
Two women		−0.005*		
Three women			−0.008***	
Four women				−0.007***
B.Affiliations	−0.001	−0.001	−0.001	−0.001
B.Independence	0.00002	0.00004	0.00002	−0.00002
Sust.Com	−0.005	−0.005*	−0.005	−0.004
B.Size	0.001***	0.001***	0.002***	0.002***
B.Meetings	0.0003	0.0003	0.0003	0.0005
Duality	−0.002	−0.002	−0.001	−0.0004
ESG.Comp	−0.002	−0.001	−0.001	−0.001
Exec.Comp	−0.002**	−0.002**	−0.002**	−0.002**
ETS	0.007***	0.007***	0.007**	0.007**
ROA	−0.001***	−0.001***	−0.001**	−0.001**
CF	0.0001	0.0001	0.0001	0.0001
Cap.In	0.039	0.037	0.058*	0.044
Debt	−0.003	−0.001	−0.002	−0.004
Tobin's Q	0.002**	0.002**	0.002**	0.002**
Lag I Scope 1 intensity	0.980***	0.977***	0.980***	0.983***
Lag II Scope 1 intensity	−0.036***	−0.032***	−0.035***	−0.038***
Year	Y	Y	Y	Y
Firm	Y	Y	Y	Y
Observations	3711	3711	3711	3711
Number of instruments	35	35	35	35
Sargan test statistic	55.74 ($p = 0.0143$)	58.82 ($p = 0.0071$)	57.35 ($p = 0.0099$)	56.8 ($p = 0.0113$)
AR2	−0.5598 ($p = 0.5756$)	−0.81209 ($p = 0.5707$)	−0.5719 ($p = 0.5673$)	−0.5348 ($p = 0.5928$)
Wald test for coefficients	628,398.6 ($p < 0.01$)	648,256.2 ($p < 0.01$)	671,209.9 ($p < 0.01$)	788,687.9 ($p < 0.01$)
Wald test for time dummies	35.33 ($p < 0.01$)	37.36 ($p < 0.01$)	35.99 ($p < 0.01$)	36.23 ($p < 0.01$)

Note. The table presents results of two-step system generalized method of moments (GMM) regressions for the independent variables at least one, two, three, and four women on the board and dependent carbon performance (CP) variable *Scope 1 intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of instruments, Sargan test of overidentification, and Arellano–Bond test for second-order autocorrelation (AR2). Finally, Wald statistics for the coefficients of variables on CP and year dummies are presented.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

APPENDIX 7: GMM REGRESSION RESULTS WITH WINDMEIJER CORRECTIONS FOR TESTING HYPOTHESIS 1

	System GMM Windmeijer corrections	
	Model 1	**Model 2**
	CP (*total GHG intensity*)	
B.Female	−0.0003	−0.001
B.Female^2		0.00001
B.Affiliations	−0.0004	−0.0003
B.Independence	−0.00003	−0.00002
Sust.Com	−0.006	−0.006
B.Size	0.001	0.001
B.Meetings	0.001	0.001
Duality	−0.006	−0.006
ESG.Comp	0.001	0.001
Exec.Comp	−0.001	−0.001
ETS	0.013	0.013
ROA	−0.001	−0.001
CF	0.0003	0.0003
Cap.In	0.213*	0.202*
Debt	−0.004	−0.005
Tobin's Q	0.001	0.001
Lag I total GHG intensity	0.728***	0.730***
Lag II total GHG intensity	0.160	0.159
Year	Y	Y
Firm	Y	Y
Observations	3123	3123
Number of instruments	35	36
Sargan test statistic	49.62 (p = 0.0518)	50.14 (p = 0.0589)
AR2	−0.6973 (p = 0.4856)	−0.696 (p = 0.4864)
Wald test for coefficients	4595.085 (p < 0.01)	4862.49 (p < 0.01)
Wald test for time dummies	15.24 (p = 0.033)	15.31 (p = 0.0322)

Note. The table presents results of two-step system generalized method of moments (GMM) regressions with Windmeijer corrections for the independent board gender diversity (BGD) variable *B.Female* and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of instruments, Sargan test of overidentification, and Arellano–Bond test for second-order autocorrelation (AR2). Finally, Wald statistics for the coefficients of variables on CP and year dummies are presented.

*p < 0.1.

**p < 0.05.

***p < 0.01.

APPENDIX 8: GMM REGRESSION RESULTS WITH WINDMEIJER CORRECTIONS FOR TESTING HYPOTHESIS 1 USING THE BLAU INDEX AS AN ALTERNATIVE PROXY FOR BGD

	System GMM Windmeijer corrections	
	Model 1	Model 2
	CP (*total GHG intensity*)	
B.Blau.Gender	−0.036*	−0.025
B.Blau.Gender^2		−0.021
B.Affiliations	−0.001	−0.0005
B.Independence	−0.00001	−0.00003
Sust.Com	−0.007	−0.006
B.Size	0.002*	0.001
B.Meetings	0.001	0.001
Duality	−0.006	−0.006
ESG.Comp	0.001	0.001
Exec.Comp	−0.001	−0.001
ETS	0.014	0.013
ROA	−0.001	−0.001
CF	0.0003	0.0003
Cap.In	0.213*	0.209*
Debt	−0.003	−0.004
Tobin's Q	0.001	0.001
Lag I total GHG intensity	0.727***	0.731***
Lag II total GHG intensity	0.16	0.158
Year	Y	Y
Firm	Y	Y
Observations	3123	3123
Number of instruments	35	36
Sargan test statistic	46.92 (p = 0.0858)	48.21 (p = 0.0838)
AR2	−0.6959 (p = 0.4864)	−0.6848 (p = 0.4935)
Wald test for coefficients	4637.7 (p < 0.01)	4947.5 (p < 0.01)
Wald test for time dummies	16.20 (p = 0.0233)	15.69 (p = 0.0281)

Note. The table presents results of two-step system generalized method of moments (GMM) regressions with Windmeijer corrections for the independent board gender diversity (BGD) variable *B.Blau.Gender* and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of instruments, Sargan test of overidentification, and Arellano–Bond test for second-order autocorrelation (AR2). Finally, Wald statistics for the coefficients of variables on CP and year dummies are presented.

*p < 0.1.

**p < 0.05.

***p < 0.01.

APPENDIX 9: GMM REGRESSION RESULTS WITH WINDMEIJER CORRECTIONS FOR TESTING HYPOTHESIS 2

	System GMM Windmeijer corrections			
	Model 1	Model 2	Model 3	Model 4
	CP (*total GHG intensity*)			
One woman	0.001			
Two women		−0.013**		
Three women			−0.011**	
Four women				−0.012**
B.Affiliations	−0.002	−0.002	−0.001	−0.002
B.Independence	0.00003	0.00000	0.00002	−0.00001
Sust.Com	−0.008	−0.008	−0.007	−0.007
B.Size	0.002	0.002*	0.002*	0.002*
B.Meetings	0.001	0.001	0.0005	0.001
Duality	−0.007	−0.007	−0.005	−0.005
ESG.Comp	0.0003	0.002	0.0001	0.002
Exec.Comp	−0.001	−0.001	−0.001	−0.001
ETS	0.016*	0.014	0.016*	0.014
ROA	−0.001	−0.001	−0.001	−0.001
CF	0.0004	0.0004	0.0003	0.0004
Cap.In	0.214*	0.219*	0.236**	0.206**
Debt	−0.003	−0.001	−0.002	−0.004
Tobin's Q	0.002	0.001	0.001	0.001
Lag I total GHG intensity	0.731***	0.735***	0.723***	0.733***
Lag II total GHG intensity	0.155	0.151	0.162	0.154
Year	Y	Y	Y	Y
Firm	Y	Y	Y	Y
Observations	3123	3123	3123	3123
Number of instruments	35	35	35	35
Sargan test statistic	43.94 (p = 0.1428)	44.12 (p = 0.1388)	43.73 (p = 0.1478)	42.97 (p = 0.1667)
AR2	−0.671 (p = 0.5017)	−0.675 (p = 0.4994)	−0.7019 (p = 0.4827)	−0.6631 (p = 0.5072)
Wald test for coefficients	4346.4 (p < 0.01)	4310.4 (p < 0.01)	4643.3 (p < 0.01)	4535.2 (p < 0.01)
Wald test for time dummies	15.82 (p = 0.0268)	17.04 (p = 0.0171)	16.56 (p = 0.0204)	18.66 (p = 0.0093)

Note. The table presents results of two-step system generalized method of moments (GMM) regressions with Windmeijer corrections for the independent variables at least one, two, three, and four women on the board and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of instruments, Sargan test of overidentification, and Arellano–Bond test for second-order autocorrelation (AR2). Finally, Wald statistics for the coefficients of variables on CP and year dummies are presented.

*p < 0.1.

**p < 0.05.

***p < 0.01.

APPENDIX 10: OLS REGRESSION RESULTS WITHOUT AND WITH YEAR-CLUSTERED AND FIRM-CLUSTERED STANDARD ERRORS FOR TESTING HYPOTHESIS 1

	OLS	OLS (clustered SEs)		
	Model 1	Model 2	Model 3	Model 4
	CP (*total GHG intensity*)			
B.Female	−0.005***	−0.010**	−0.005**	−0.010*
B.Female^2		0.0001		0.0001
B.Affiliations	−0.051**	−0.051**	−0.051	−0.051
B.Independence	0.003***	0.003***	0.003**	0.003**
Sust.Com	0.019	0.018	0.019	0.018
B.Size	0.009*	0.010**	0.009	0.01
B.Meetings	−0.009*	−0.009*	−0.009	−0.009
Duality	−0.036	−0.038	−0.036	−0.038
ESG.Comp	0.039	0.04	0.039	0.04
Exec.Comp	−0.011	−0.011	−0.011	−0.011
ETS	0.286***	0.286***	0.286***	0.286***
ROA	−0.004	−0.004	−0.004*	−0.004*
CF	0.002	0.002	0.002	0.002
Cap.In	2.610***	2.579***	2.61	2.579
Debt	−0.063	−0.06	−0.063	−0.06
Tobin's Q	0.003	0.003	0.003	0.003
Env.Enforce	0.024	0.029	0.024	0.029
Civil.Law	−0.098***	−0.105***	−0.098	−0.105
IND (2)	0.285***	0.287***	0.285	0.287*
IND (3)	0.227***	0.227***	0.227*	0.227*
Constant	0.094	0.096	0.094	0.096
Year-clustered SE			Y	Y
Firm-clustered SE			Y	Y
Observations	3123	3123	3123	3123
R^2	0.091	0.092		
Adj. R^2	0.086	0.086		
F statistic	16.431*** (df = 19; 3103)	15.709*** (df = 20; 3102)		

Note. The table presents results of ordinary least squares (OLS) regressions without (Models 1 and 2) and with clustered standard errors (SEs) (Models 3 and 4) for the independent board gender diversity (BGD) variable *B.Female* and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of observations, R^2, and adj. R^2. Finally, *F* statistics are presented.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

APPENDIX 11: RANDOM EFFECTS (RE) REGRESSION RESULTS WITHOUT AND WITH YEAR-CLUSTERED AND FIRM-CLUSTERED STANDARD ERRORS FOR TESTING HYPOTHESIS 1

	Random effects (RE)		RE (clustered SEs)	
	Model 1	Model 2	Model 3	Model 4
	CP (*total GHG intensity*)			
B.Female	−0.002***	−0.003	−0.002***	−0.003*
B.Female^2		0		0
B.Affiliations	−0.019	−0.019	−0.019	−0.019
B.Independence	0.0005	0.0005	0.0005	0.0005
Sust.Com	0.014	0.014	0.014	0.014
B.Size	0.003	0.003	0.003	0.003
B.Meetings	0.004	0.004	0.004***	0.004***
Duality	0.024	0.024	0.024	0.024
ESG.Comp	0.001	0.001	0.001	0.001
Exec.Comp	−0.011*	−0.011*	−0.011*	−0.011*
ETS	0.013	0.013	0.013	0.013
ROA	−0.004***	−0.004***	−0.004***	−0.004***
CF	0.006***	0.006***	0.006**	0.006**
Cap.In	−0.026	−0.027	−0.026	−0.027
Debt	−0.154*	−0.154*	−0.154	−0.154
Tobin's Q	−0.007	−0.007	−0.007	−0.007
Env.Enforce	0.016	0.016	0.016	0.016
Civil.Law	−0.133	−0.134	−0.133	−0.134
IND (2)	0.353***	0.353***	0.353***	0.353***
IND (3)	0.341	0.341	0.341***	0.341***
Constant	0.408	0.408	0.408	0.408
Year-clustered SE			Y	Y
Firm-clustered SE			Y	Y
Observations	3123	3123	3123	3123
R^2	0.019	0.019		
$R^2_{adj.}$	0.013	0.013		
F statistic	3.223*** (df = 19; 3103)	3.061*** (df = 20; 3102)		

Note. The table presents results of random effects (RE) regressions without (Models 1 and 2) and with clustered standard errors (SEs) (Models 3 and 4) for the independent board gender diversity (BGD) variable *B.Female* and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of observations, R^2, and adj. R^2. Finally, F statistics are presented.

*p < 0.1.

**p < 0.05.

***p < 0.01.

APPENDIX 12: OLS REGRESSION RESULTS WITHOUT AND WITH YEAR-CLUSTERED AND FIRM-CLUSTERED STANDARD ERRORS FOR TESTING HYPOTHESIS 2

	OLS				OLS (clustered SEs)			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
	CP (*total GHG intensity*)							
One woman	−0.099*				−0.099*			
Two women		−0.105***				−0.105		
Three women			−0.109***				−0.109*	
Four women				−0.171***				−0.171***
B.Affiliations	−0.056**	−0.052**	−0.052**	−0.055**	−0.056	−0.052	−0.052	−0.055
B.Independence	0.003***	0.003***	0.003***	0.003***	0.003**	0.003**	0.003**	0.003**
Sust.Com	0.021	0.02	0.018	0.017	0.021	0.02	0.018	0.017
B.Size	0.009*	0.012**	0.013***	0.016***	0.009	0.012	0.013	0.016**
B.Meetings	−0.010**	−0.009**	−0.009**	−0.009*	−0.01	−0.009	−0.009	−0.009
Duality	−0.042	−0.039	−0.039	−0.031	−0.042	−0.039	−0.039	−0.031
ESG.Comp	0.027	0.032	0.034	0.039	0.027	0.032	0.034	0.039
Exec.Comp	−0.01	−0.009	−0.01	−0.011	−0.01	−0.009	−0.01	−0.011
ETS	0.301***	0.296***	0.293***	0.285***	0.301***	0.296***	0.293***	0.285***
ROA	−0.004	−0.004	−0.004	−0.004	−0.004*	−0.004*	−0.004*	−0.004*
CF	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cap.In	2.572***	2.607***	2.620***	2.544***	2.572	2.607	2.62	2.544
Debt	−0.061	−0.067	−0.063	−0.064	−0.061	−0.067	−0.063	−0.064
Tobin's Q	0.002	0.003	0.003	0.002	0.002	0.003	0.003	0.002
Env.Enforce	0.027	0.029	0.023	0.02	0.027	0.029	0.023	0.02
Civil.Law	−0.121***	−0.116***	−0.103***	−0.093**	−0.121	−0.116	−0.103	−0.093
IND (2)	0.284***	0.287***	0.283***	0.279***	0.284	0.287*	0.283	0.279
IND (3)	0.235***	0.234***	0.234***	0.232***	0.235*	0.234*	0.234*	0.232*
Constant	0.09	−0.005	−0.001	−0.004	0.09	−0.005	−0.001	−0.004
Year-clustered SE					Y	Y	Y	Y
Firm-clustered SE					Y	Y	Y	Y
Observations	3123	3123	3123	3123				
R^2	0.088	0.09	0.091	0.093				
Adj. R^2	0.083	0.084	0.085	0.088				
F statistic (df = 19; 3103)	15.794***	16.112***	16.276***	16.835***				

Note. The table presents results of ordinary least squares (OLS) regressions without (Models 1–4) and with clustered standard errors (SEs) (Models 5–8) for the independent variables at least one, two, three, and four women on the board and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of observations, R^2, and adj. R^2. Finally, *F* statistics are presented.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

APPENDIX 13: RE REGRESSION RESULTS WITHOUT AND WITH YEAR-CLUSTERED AND FIRM-CLUSTERED STANDARD ERRORS FOR TESTING HYPOTHESIS 2

	Random effects (RE)				RE (clustered SEs)			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
	CP (*total GHG intensity*)							
One woman	−0.026				−0.026			
Two women		−0.035**				−0.035*		
Three women			−0.066***				−0.066**	
Four women				−0.062***				−0.062**
B.Affiliations	−0.019	−0.02	−0.019	−0.021	−0.019	−0.02	−0.019	−0.021
B.Independence	0.0001	0.0002	0.0004	0.0003	0.0001	0.0002	0.0004	0.0003
Sust.Com	0.013	0.013	0.012	0.011	0.013	0.013	0.012	0.011
B.Size	0.003	0.004	0.005	0.005	0.003	0.004	0.005*	0.005**
B.Meetings	0.003	0.004	0.004	0.004	0.003**	0.004**	0.004**	0.004***
Duality	0.015	0.016	0.02	0.025	0.015	0.016	0.02	0.025
ESG.Comp	−0.009	−0.006	−0.002	−0.003	−0.009	−0.006	−0.002	−0.003
Exec.Comp	−0.01	−0.01	−0.011*	−0.011*	−0.01	−0.01	−0.011*	−0.011*
ETS	0.022	0.019	0.013	0.019	0.022	0.019	0.013	0.019
ROA	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***
CF	0.006***	0.006***	0.006***	0.006***	0.006**	0.006**	0.006**	0.006**
Cap.In	0.035	0.028	−0.042	0.003	0.035	0.028	−0.042	0.003
Debt	−0.148	−0.149*	−0.153*	−0.147	−0.148	−0.149	−0.153	−0.147
Tobin's Q	−0.008	−0.008	−0.008	−0.009	−0.008	−0.008	−0.008	−0.009
Env.Enforce	0.017	0.018	0.015	0.014	0.017	0.018	0.015	0.014
Civil.Law	−0.150*	−0.147*	−0.136	−0.138	−0.15	−0.147	−0.136	−0.138
IND (2)	0.353***	0.354***	0.354***	0.353***	0.353***	0.354***	0.354***	0.353***
IND (3)	0.344*	0.346*	0.344*	0.338	0.344***	0.346***	0.344***	0.338***
Constant	0.387	0.361	0.369	0.361	0.387	0.361	0.369	0.361
Year-clustered SE					Y	Y	Y	Y
Firm-clustered SE					Y	Y	Y	Y
Observations	3123	3123	3123	3123				
R^2	0.016	0.017	0.021	0.019				
Adj. R^2	0.01	0.011	0.015	0.013				
F statistic (df = 19; 3103)	2.606***	2.771***	3.420***	3.125***				

Note. The table presents results of random effects (RE) regressions without (Models 1–4) and with clustered standard errors (SEs) (Models 5–8) for the independent variables at least one, two, three, and four women on the board and dependent carbon performance (CP) variable *total GHG intensity* over a period from 2009 to 2018. The regression includes corporate governance controls, firm characteristics, and year controls. Table 3 summarizes all variables used in the analysis. The lower part of the table reports number of observations, R^2, and adj. R^2. Finally, *F* statistics are presented.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.