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RESEARCH ARTICLE

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CEO hubris and corporate carbon footprint: The role of gender diversity

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Abstract

This paper investigates the effect of an overconfident CEO on firm greenhouse gas emissions. Using panel data of 160,115 firm-year observations from 41 countries for 2000–2021, we find a negative relationship between CEO overconfidence and greenhouse gas emissions. Additionally, drawing on the theories of gender socialisation and diversity, we find that great representation of females on the board further compels overconfident CEOs to reduce firm carbon emissions. Our findings are robust to varying estimation techniques and identification strategies. These findings offer important insights to green investors, corporate boards, managers and policymakers on the role of overconfident CEOs and female leadership in the carbon abatement efforts of public companies.

KEYWORDS

corporate carbon footprint, female directors, gender diversity, greenhouse gas emissions, overconfident CEOs

1 | INTRODUCTION

Growing concerns about greenhouse gas (GHG) emissions are dominating national and international conversations. The narrative manifests in firm corporate governance decisions, board composition and corporate strategies in general. Academics are beginning to place the spotlight on the leadership of firms to understand their role in corporate decarbonisation efforts and corporate greenness (Liu et al. 2018; Marchini et al., 2021). One strand of the literature that has sought to answer this question is the literature on CEO proclivity. Prior studies have identified factors such as CEO's risk aversion, CEO's experience, CEO's social network and CEO's political ideologies as essential considerations in corporate carbon reduction efforts (Alonso et al., 2023; Garel & Petit-Romec, 2022; Hossain et al., 2023; Li et al., 2023). Although conversations on the subject matter are nascent, the literature on the role of CEO overconfidence in the corporate green transition is mute.

Several studies provide direct evidence linking overconfident CEOs to firms' economic outcomes. For instance, Huang et al. (2015) show the connection between CEO overconfidence and corporate debt maturity. Furthermore, Kim et al. (2016) demonstrate that stock crash risk is associated with CEO overconfidence. Broad studies on executive overconfidence mainly focus on the perspective of behavioural finance and the rationality of CEOs. Accordingly, our study embraces the concept of CEO overconfidence as it relates to environmental performance. Notably, we evince its effect on GHG emissions.

In this study, we investigate whether CEO overconfidence has varying effects on corporate carbon footprint. Furthermore, we examine to what extent the relationship between CEO overconfidence and GHG emissions can be explained by board gender diversity. Our motivation is derived from the gender socialisation and diversity theories that posit that women due to their upbringing are community-minded and care for others (Eagly & Crowley, 1986), and have greater concerns for the environment (2011). Following a recent study by

Huang et al. (2015), our concept of overconfidence is primarily derived from the notion of better-than-average. Thus, CEOs self-assess their traits and skills and overestimate their skills and abilities (Alicke, 1985; Svenson, 1981). An earlier study by Weinstein (1980) argues that this 'better-than-average' belief is also linked to unrealistic optimism about future events, which people express.

The question that naturally arises in the green finance literature when CEOs have this 'better-than-average' notion is: will they engage in environmentally enhancing activities? This is currently missing from the existing studies. Further, no empirical evidence documents how female board directors affect the dynamics of the relationship between CEO confidence level and GHG emissions. Existing studies have mainly examined the adverse effects of greenhouse carbon emissions. However, an overconfident CEO could potentially engage in greater greenhouse carbon emissions. Therefore, investigating factors that could influence an overconfident CEO to reduce emissions is not only timely but also important for policymakers.

Using a sample of 13,753 firms from 41 countries, we find that overconfident CEOs engage in environmental activities that reduce GHG emissions. One plausible explanation of our finding is that overconfident CEOs are over-optimistic in their abilities and skills and will, therefore, commit resources to reduce greenhouse emissions where they think an average CEO will not dare (Malmendier & Tate, 2005). Albeit, one proponent of the literature posits that overconfident CEOs are mainly short-termists as they mainly focus on immediate goals and outcomes to keep their job. The findings indicate that female board directors influence overconfident CEOs to reduce GHG emissions. The result is in line with the view that females are more concerned with the welfare of stakeholders and will induce overconfident CEOs to take actions to reduce environmental risk (Altunbas et al., 2022).

This study makes three significant contributions to the literature on corporate environmental risk and CEO optimism. First, the findings extend the conversation on CEO overconfidence; prior studies in this area have so far focussed on how overconfident CEOs can influence corporate economic outcomes, investor welfare and policies (Kim et al., 2015; Malmendier & Tate, 2008; Heaton, 2002). However, no existing studies have examined the environmental consequences of overconfident CEOs. We fill this gap in the literature and discuss how this feature may affect corporate environmental outcomes.

Second, our paper extends the literature on factors influencing greenhouse carbon emissions. Our study is different from existing studies that have investigated the economic outcomes of carbon emissions risk (Adamolekun et al., 2022; Base et al., 2021; Nguyen and Phan (2020); Ramelli et al., 2021; Huang et al., 2021). Previous studies have investigated whether carbon risk matters for domestic and international acquisitions (Base et al., 2021). Given the substantial loss of shareholders' wealth because of environmental litigation risk and suits (Karpoff et al., 2005; Bhagat et al., 1998) and investor rewards for environmental responsibility (Garel & Petit-Romec, 2021). What contributes to firms' ability to reduce GHG emissions remains an important empirical question that needs to be answered.

Third, this study provides additional insights into the burgeoning literature on the role of gender diversity in the race to net zero. In particular, we focus on the interplay between overconfident CEOs, board gender diversity and corporate environmental policies. We are motivated to pursue this line of enquiry because it is evident that individual decision-making is significantly influenced by gender (Ryan, 2017). Furthermore, female board representation and CEO gender are well documented to influence firm policies (Levi et al., 2014; Huang & Kisgen, 2013; Adams & Ferreira, 2009). A plethora of studies have examined how board gender diversity affects corporate decisions (see, for instance, Altunbas et al., 2022; Atiff et al., 2020; Joecks et al., 2013; Adams & Ferreira, 2009; Erhardt et al., 2003). How board gender diversity can influence overconfident CEOs to reduce GHG emissions remains an important question but is yet to be investigated. The findings from this study provide significant implications for corporate boards of directors, investors and policymakers. The presence of female board members in firms with overconfident CEOs could offer a positive signal to environmental activist investors. The results add to the growing global demand for more female representation on the corporate board, including mandatory gender quotas.

The rest of the paper is organised as follows: Section 2 provides the literature review and hypotheses development. Section 3 offers data and variable descriptions. Section 4 presents the empirical results and analysis, and Section 5 concludes the paper.

2 | LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

We use behavioural and organisational theories analyse the relationship between GHG emissions, overconfident CEOs and gender diversity. We posit that an overconfident CEO will potentially engage in riskier projects and may ignore the long-term environmental implications of their decisions which potentially could lead to higher GHG emissions. Malmendier and Tate (2005) document that, overconfident CEOs are likely to overestimate their ability to generate returns from investments, which can include neglecting sustainable practices for immediate financial gain. However, gender diversity in leadership can mitigate such CEO's overconfidence and foster more environmentally conscious decision-making. The existing literature argues that diversity brings a wider range of perspectives and risk assessments, potentially leading to more balanced and sustainable business strategies. For instance, Adams and Funk (2012) show that female directors often prioritise ethical standards and social responsibility, which include environmental considerations.

Prior theoretical argument, for instance, Kanter's (1977) tokenism theory highlights that gender-diverse boards may challenge the homogeneity and groupthink that characterise male-dominated executive teams, promoting innovative approaches to environmental sustainability. Therefore, increasing gender diversity in corporate leadership can serve as a counterbalance to overconfident CEOs, encouraging more prudent and eco-friendly business practices and reducing GHG emissions.

2.1 | CEO overconfidence and greenhouse gas emissions

The risk of climate change has attracted global attention in the past decades. Evidence suggests that the association between global climate change and GHG emissions plays a crucial role in inducing the redistribution of valuation from companies that cannot successfully control GHG emissions to companies that effectively manage and distribute resources (Adamolekun et al., 2022; Bolton & Kacperczyk, 2023). With most firms incentivising CEOs by linking their compensation to firm value (Kumar & Sivaramakrishnan, 2008), corporate executives would prioritise decarbonisation. Accordingly, some CEO attributes may offer significant advantages in corporate carbon reduction efforts.

For instance, corporate executives exposed to climate change in the form of hot temperatures are more likely to pursue aggressive corporate decarbonisation (Garel & Petit-Romec, 2022). Furthermore, risk-averse managers may be more reluctant to transition to greener production processes (Hossain et al., 2022). The social network of a CEO could also prove valuable in firm carbon reduction efforts (Li et al., 2023). Correspondingly, Alonso et al. (2023) demonstrate that CEOs' political ideologies are essential when examining corporate GHG emissions. Despite the burgeoning discussion on CEO attributes and corporate decarbonisation efforts, the literature on the role of CEO overconfidence is mute.

Notably, several factors influence managerial behaviour (Healy & Palepu, 2001). Prior studies show that overconfident CEOs engage in unethical activities and fraud (Blair et al., 2008; Chatterjee et al., 2013). In addition, CEO overconfidence is valuable in understanding corporate innovation. To this end, Galasso and Simcoe (2011) demonstrate that overconfident CEOs pursue aggressive corporate innovation policies. The choice of innovation, however, is motivated by overconfident CEOs' ability to be stakeholders. Similarly, the confidence level of a CEO has vast, broad implications for corporate investment. Overconfident CEOs may overinvest because of miscalculations in estimating their return on investment and cost of capital (Malmendier & Tate, 2005). The effects of CEO overconfidence have also been documented in the merger and acquisition literature. Accordingly, firms with overconfident CEOs tend to overpay for targets (Malmendier & Tate, 2008). A CEO's confidence level also has profound implications for firm decisions. For example, overconfident CEOs favour lower dividend payments and high cash holdings (Deshmukh et al., 2013). Regarding firm financing behaviour, overconfident CEOs prioritise debts with short-term maturity (Huang et al., 2016).

There are also theoretical paradigms that can help understand overconfident CEOs' priority concerning corporate environmental practice. To this end, extrapolating Jensen and Meckling's agency theory, an overconfident CEO wants to maximise their private benefits through environmental activities and disclosure of GHG emissions. Therefore, overconfident CEOs' behaviour may align with sustainable practices and be more committed to environmental responsibility. This is because they believe they can navigate any challenges or consequences. Their confidence may lead them to downplay the potential adverse effects of their company's carbon emissions or to prioritise short-term profits over long-term environmental concerns. Due to their overconfidence, they may be less receptive to advice or criticism from others, potentially hindering efforts to adopt more sustainable practices. Accordingly, Jensen and Meckling (1976) argue that overconfident CEOs over-commit resources and disclose environmental issues to improve their reputational capital as ecological citizen champions.

Put together, overconfident CEOs are associated with a higher desire to enhance their positive self-image and attention while demanding praise. This will motivate the overconfident CEO to reduce GHG emissions. Overconfident CEOs excessively trust their abilities, which may lead to errors and prejudices in decision-making. With prior literature identifying the inclination of overconfident CEOs to pursue aggressive corporate innovation and overinvestment, drawing on the above, we hypothesise that:

> **H1.** : CEOs with significant overconfidence reduce corporate greenhouse gas emissions.

2.2 | Moderating role of gender diversity

In the last decades, a significant proportion of females have been serving as board directors in US firms (Catalyst, 2016). An earlier study by Adams and Funk (2012) advocated more female representation on corporate boards. This is consistent with the view that there is a business case for gender diversity on the board (Adams & Funk, 2012; Adams & Ferreira, 2009; Rose, 2007). Other studies provide direct evidence of female directors' contribution to firms' performance (Liu et al., 2014; Adams & Ferreira, 2009; Campbell & Minguez-Vera, 2008).

We explore the relationship between powerful CEOs and gender diversity as a mechanism to explain the reduction in GHG emissions. Environmental issues are greatly influenced by gender. This is driven by the gender socialisation theory, which postulates that women, due to their upbringing, care for others and are community-minded (Eagly & Crowley, 1986; Gilligan, 1977; Carlson, 1972). A body of academic research relates corporate board gender diversity to a force for good corporate decisions, including reduced empire-building (Chen et al., 2016a; Levi et al., 2014), accounting misreporting (Garcia Lara et al., 2017; Cumming et al., 2015) and tax avoidance (Richardson et al., 2016; Lanis et al., 2015).

Females have more significant environmental concerns and actively work to address climate change and reduce carbon emissions. Prior studies document that women have more concerns for the stakeholders and will thus pre-empt environmental risks that can adversely affect communities (Adams et al., 2011; Carlson, 1972). Evidence shows that a diverse board, including female directors, can bring different perspectives and expertise to the table, potentially influencing decision-making at the executive level. Diversity theory argues that female directors improve environmental issues by offering a broad range of environmentally friendly solutions (Estelyi & Nisar, 2016; Cumming et al., 2015; Westphal & Bednar, 2005; Erhardt et al., 2003). Similarly, Chen et al. (2019) demonstrate that female board representation lessens CEO overconfidence and improves corporate outlook. As most female directors have higher qualifications, experience and assertiveness, they can influence the decision-making process on environmental issues. Drawing on gender socialisation and diversity theories, we argue that female directors have more environmental awareness and will influence overconfident CEOs to reduce GHG emissions. We therefore theorise that:

> **H2.** : Female board members will induce overconfident CEOs to reduce corporate greenhouse gas emissions.

3 | DATA AND VARIABLE DESCRIPTIONS

3.1 | Data sources and sampling

To test our conjecture, we collect firm-level data available from 41 countries worldwide from 2000 to 2021. We were constrained to this period and the number of countries because of data availability. We rely on three databases for our firm-level data. For firm-level carbon emissions, we turn to Rifintiv Eikon. We rely on data from Boardex on corporate executives and other board features. For other firm-level characteristics, we collect data from Worldscope. Across the three databases, we match firms based on their unique ISIN code. The initial result of our matching across databases was 211,824 firm-year observations. Upon considering the availability of all variables, we had 160,115 firm-year observations in our final sample.

3.2 | Variable descriptions and measurements

3.2.1 | Dependent variable

Our dependent variable in this study is firm GHG emissions level. To measure firm GHG emissions, we follow prior studies in the corporate environmental practice literature and normalise the reported value of firm carbon emissions by transforming the value to its natural log (see, for instance, Altunbas et al., 2022; Adamolekun et al., 2022; Bolton & Kacperczyk, 2021). To ensure the results of our analyses are rigorous, we also standardise firm carbon emissions by deflating the reported value by firm total assets. Our study's carbon emissions value accounts for Scope 1 (direct) and Scope 2 (indirect) emissions.

3.2.2 | Explanatory and moderating variables

Our key dependent variable is CEO overconfidence. The existing literature, such as Larwood and Whittaker (1977), Kahneman (2011) and Hill et al. (2014), define overconfidence as the tendency of individuals to overstate their acumen relative to the average when evaluating their relative skills. This literature used the exercising of the stock options or CEO option holding as a measure of CEO overconfidence; however, we argue that this proxy may not necessarily measure overconfidence as exercising stock options may depend on other factors such as power, fund availability and firms' strategy plan. For instance, Hwang et al. (2020) find that the CEO power increases the probability of a CEO being overconfident. Therefore, we follow the existing studies such as Han et al. (2016) and Hwang et al. (2020) to comprehensively capture CEO overconfidence by constructing an index that comprises five power-led overconfidence items: CEO pay slice, CEO tenure, CEO share ownership, CEO duality and CEO directorship. Bebchuk et al. (2011) define CEO slice as the ratio of the CEO's total compensation to the total compensation of the top five executives. We then followed Han et al. (2016) to construct the CEO slice variable as an indicator variable that takes a value of one if the CEO slice is above the sector median for each year and zero otherwise. Hwang et al. (2020) argue that CEO power-led overconfidence increases as they spend time in the company. Therefore, we construct the CEO tenure variable as an indicator variable, which equals one if the CEO tenure is above the sector median CEOs' tenures for each year. Also, Tang et al. (2011) hold that CEOs are more confident if they hold a significant portion of the equity share within the organisation. Therefore, we construct a CEO ownership variable that equals one if the CEO ownership is above the sector median and otherwise zero. The existing CEO-Chair duality suggests that the CEO holds power in the firm and is more overconfident. Therefore, in line with Hwang et al. (2020), we construct the CEO duality variable as an indicator variable, which takes a value of one if the CEO also sits on the board as a chair and zero otherwise. Morse et al. (2011) and Hwang et al. (2020) document that the CEO's power-led confidence to influence the board increases with the number of directorships in other companies and the proportion of insider directors in the boardroom. Thus, we follow Morse et al. (2011) and Hwang et al. (2020) to construct the CEO directorship variable as an indicative variable, which equals one if the CEO is a director in more than two other companies and the proportion of insider directors in their firms' boardroom is above the sector median and otherwise zero. This approach is motivated by studies in the literature that have sought to develop encompassing proxies for various phenomena in finance. Thus, our selected items as a measure of power-led CEO overconfidence align with studies in this area of the literature (Bebchuk et al., 2009; Gompers et al., 2003; Han et al., 2016; Hwang et al., 2020; Malmendier & Tate, 2005; Tang et al., 2011). Finally, we summed all five items to obtain a CEO overconfidence (CEOVC) variable and deflated the actual score with the total expected score (5).

We also consider the role of gender diversity in the carbon ambitions of overconfident CEOs. Chen et al. (2019) argue that female representation in the boardroom plays a significant role in regulating male overconfidence in the boardroom. In this context, we included gender diversity to investigate how the effect of CEO overconfidence on greenhouse carbon emissions is moderated by the presence of female directors in the boardroom. To measure gender diversity, we identify the number of female board members on a corporate board divided by the total board size. This approach aligns with prior studies in the literature (see, for example, Chen et al., 2019; Altunbas et al., 2022; Konadu et al., 2022).

3.2.3 | Control variables

To ensure our estimations are robust, we follow prior studies that have attempted to model firm greenhouse emissions and include factors that have been documented to be valuable (see, for instance, Azar et al., 2021; Konadu et al., 2022; Garel & Petit-Romec, 2022; Altunbas et al., 2023). Accordingly, the regression model accounts for factors such as leverage, cash, firm size (FSZ), slack (SLK), return on assets (ROA), market-to-book ratio (MTB), capital expenditure (CAPEX), board independence (BIN), board size (BSZ), co-opt board (COPT) and GDP growth rate (GDPG).

3.3 | Model specifications

In line with Fulgence, et al. (2023), we employed ordinary least squares (OLS) to examine the relationship between CEO overconfidence and GHG emissions. We used the following specifications to test our hypotheses.

$$\mathrm{GHG}_{i,t} = a_i + \gamma_1 M^1_{i,t} + \gamma_2 C^2_{i,t} + \delta\gamma_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{i,t}, \tag{1}$$

$$\mathrm{GHG}_{i,t} = a_i + \gamma_1 M^1_{i,t} + \gamma_1 MB^1_{i,t} + \gamma_1 B^1_{i,t} + \gamma_2 C^2_{i,t} + \delta\gamma_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{i,t}, \tag{2}$$

where M^1 represents the independent variables, MB^1 represents the interaction variable between CEO overconfidence and gender diversity, B^1 represents the gender diversity variable, and C^2 is a set of control variables and λ_t is the time dummies vector, $\delta\gamma_{i,t-1}$ is the fixed effects of a vector of the mean differences of all time-variant variables, μ_i is the sector's and countries' effect,[1] and $\varepsilon_{i,t}$ is the cluster-robust standard error[2] it was adopted across all estimations.

We used fixed effects estimation (FE) for the robust analysis and all sensitivity tests. In addition, we have conducted a battery of additional analyses using the alternative proxies of CEO overconfidence. For sensitivity analysis, endogeneity and validation of the main findings, we have also used the step-by-step sampling approach, lag effect, higher-dimensional fixed effect and two-stage least squares (2SLS).

[1] We create a sector identification variable (SecID) and include the SecID variable in all our regression to control for the effect of sector characteristics in our results. We do the same for countries.

[2] We follow existing studies such as Petersen (2009), Thompson (2011), Gyapong et al. (2016) and Fulgence et al. (2023) to reduce heteroscedasticity.

4 | EMPIRICAL ANALYSIS

4.1 | Descriptive and correlations analysis

Tables 1a and 2 present the descriptive statistics and correlation matrix for the entire sample. Table 1b shows that the overall CEO overconfidence ranges between 0.000 and 0.997 with an average of 0.499, while gender diversity ranges between 0% and 50% with an average of 12.20%. A country analysis in Table 1b shows that Brazil and Indonesia have highly overconfident CEOs with a record of 0.99. In contrast, the United States is reported to have fewer overconfident CEOs, scoring only 0.3. Regarding gender diversity, Norway reports the highest number of female-diverse boards, averaging 31.6%, while countries like the United Arab Emirates and South Korea only report 3.4% of females in the boardroom. Sectorial analysis shows that overconfident CEOs manage diversified industries and the electricity sector. In contrast, sectors like household products, food and drug retailers, and clothing and personal products boardrooms demonstrated a higher female diversity of about 17% across all sectors. Our sample distribution country-wise shows that the United Kingdom and the United States comprise more than 50% of our sample. In contrast, sectorial sample distribution shows that (i) banks, (ii) real estate, (iii) software and computer services and (iv) pharmaceutical and biotechnology each comprise more than 6%, making a total of 25% for these four sectors. The rest of the sectors contribute less than 6% in our sample.

Table 2 presents the correlation analysis for this study's independent and control variables, demonstrating the rigorous methodology used. We observe that the correlation coefficient among the

TABLE 1a Descriptive statistics.

Variable	N	Mean	Std. dev.	Min	Max
CLog	175,956	2.354	0.583	0.411	3.019
CLev	160,878	0.255	0.847	0.000	6.448
CEOVC	211,387	0.499	0.301	0.000	0.997
GEN	211,748	0.122	0.129	0.000	0.500
BSZ	211,824	9.221	4.733	3.000	30.000
BIN	211,824	0.720	0.171	0.250	0.960
COPT	211,813	0.503	0.323	0.000	1.000
MTB	211,808	2.607	5.175	−11.850	35.130
FSZ	211,824	20.823	3.014	14.287	29.677
CAPEX	211,816	0.043	0.061	0.000	0.365
RD	211,813	0.105	0.204	0.000	0.764
CASH	211,795	0.193	0.231	0.000	0.979
LEV	211,824	0.221	0.208	0.000	0.818
ROA	193,410	0.007	0.147	−0.430	0.203
SLK	211,803	0.477	0.261	0.024	0.997
GDPG	211,824	1.313	2.899	−8.598	8.013

Note: This represents the descriptive statistics. All variables are detailed in Appendix A.

TABLE 1b Data distribution—country breakdown.

Country		Freq.	Percent	Mean distribution for dependent and independent variables			
				CO2 log	CO2 level	CEO overconfidence	Female
1	Australia	9003	4.25	2.7687	0.5972	0.7822	0.1236
2	Austria	734	0.35	2.0412	0.0257	0.3615	0.1187
3	Belgium	1743	0.82	2.2062	0.0815	0.9163	0.1671
4	Brazil	1633	0.77	0.7882	0.0011	0.9945	0.0817
5	Canada	12,266	5.79	2.7576	0.5850	0.3875	0.1085
6	Chile	419	0.20	1.5364	0.0038	0.9492	0.0796
7	China	7552	3.57	1.9905	0.0379	0.7568	0.1129
8	Cyprus	268	0.13	1.8551	0.2228	0.6382	0.1315
9	Denmark	980	0.46	1.8975	0.0232	0.4652	0.1687
10	Finland	1262	0.60	2.1634	0.0606	0.4859	0.2540
11	France	7192	3.40	1.6155	0.0670	0.6757	0.2297
12	Germany	6003	2.83	2.1930	0.0834	0.3796	0.1140
13	Greece	761	0.36	1.9729	0.0154	0.7689	0.0778
14	Hong Kong	5558	2.62	2.0685		0.6973	0.1204
15	India	6008	2.84	0.5326	0.0002	0.5996	0.1305
16	Indonesia	815	0.38	0.7454	0.0002	0.9962	0.1124
17	Ireland	1687	0.80	2.1781	0.2903	0.4622	0.1024
18	Israel	1329	0.63	2.0502	0.0965	0.7231	0.1851
19	Italy	2521	1.19	1.8278	0.0151	0.6239	0.1925
20	Japan	4284	2.02	2.1948	0.0022	0.9632	0.0496
21	Korea (South)	687	0.32	2.4788	0.0018	0.9486	0.0335
22	Luxembourg	653	0.31	2.8486	0.0819	0.5025	0.0889
23	Malaysia	2072	0.98	2.0470	0.1061	0.9633	0.1548
24	Mexico	891	0.42	1.3220	0.0003	0.4084	0.0648
25	Netherlands	2063	0.97	2.2537	0.0563	0.5065	0.1113
26	New Zealand	680	0.32	1.9268	0.0767	0.5800	0.2187
27	Norway	2054	0.97	2.0123	0.0177	0.5525	0.3164
28	Philippines	601	0.28	0.4111	0.0001	0.7061	0.1309
29	Poland	489	0.23	2.0683	0.0033	0.7039	0.1308
30	Portugal	554	0.26	1.5961	0.0349	0.7023	0.1110
31	Russian Federation	776	0.37	2.4325	0.0156	0.6918	0.0723
32	Singapore	3594	1.70	2.1192	0.1192	0.8695	0.1011
33	South Africa	2316	1.09	2.0504	0.0126	0.4046	0.2028
34	Spain	1989	0.94	1.7762	0.0116	0.3683	0.1385
35	Sweden	4080	1.93	1.4674	0.0113	0.9361	0.2468
36	Switzerland	2986	1.41	1.6125	0.0237	0.7138	0.1140
37	Thailand	1110	0.52	1.3310	0.0425	0.3682	0.1594
38	Turkey	494	0.23	1.5334	0.0005	0.3659	0.1343
39	United Arab Emirates	467	0.22	2.9719	0.0292	0.7410	0.0340
40	United Kingdom	30,854	14.57	1.9658	0.5937	0.4988	0.0930
41	United States	80,396	37.95	2.8266	0.1638	0.3115	0.1135
Total		211,824	100.00				

Note: This table reports the country-level distribution of the data in our sample with the mean distribution of our main dependent and independent variables.

TABLE 1c Data distribution—sector breakdown.

Sector		Freq.	Percent	Mean distribution for dependent and independent variables			
				CO2 log	CO2 level	CEO overconfidence	Female
1	Aerospace and defence	1336	0.63	2.3991	0.1275	0.4527	0.1129
2	Automobiles and parts	3250	1.53	2.1738	0.0723	0.5409	0.1225
3	Banks	13,720	6.48	2.4469	0.0116	0.4400	0.1331
4	Beverages	1824	0.86	2.0758	0.1088	0.5291	0.1497
5	Business services	8054	3.80	2.3464	0.2772	0.4774	0.1232
6	Chemicals	4654	2.20	2.2351	0.1523	0.5381	0.1243
7	Clothing and personal products	3566	1.68	2.1339	0.0945	0.5465	0.1727
8	Construction and building materials	7295	3.44	2.1264	0.0660	0.5494	0.1148
9	Consumer services	821	0.39	2.5559	0.1374	0.4243	0.1538
10	Containers and packaging	1119	0.53	2.3463	0.0991	0.4952	0.1232
11	Diversified industrials	3424	1.62	1.8950	0.0252	0.6778	0.1361
12	Electricity	2268	1.07	1.9270	0.0296	0.6300	0.1317
13	Electronic and electrical equipment	9782	4.62	2.5106	0.2706	0.4350	0.0936
14	Engineering and machinery	8441	3.99	2.2643	0.1379	0.5277	0.1029
15	Food and drug retailers	1473	0.70	2.2328	0.0804	0.4910	0.1677
16	Food producers and processors	5500	2.60	2.1929	0.1455	0.5323	0.1448
17	Forestry and paper	1481	0.70	2.2723	0.0397	0.4919	0.1312
18	General retailers	6028	2.85	2.3652	0.1088	0.4550	0.1606
19	Health	8111	3.83	2.4526	0.4009	0.4643	0.1306
20	Household products	2380	1.12	2.2548	0.1430	0.5190	0.1705
21	Information technology hardware	4620	2.18	2.4222	0.2553	0.4868	0.0950
22	Insurance	3829	1.81	2.5152	0.0484	0.3916	0.1375
23	Investment companies	4607	2.17	2.0737	0.2598	0.5212	0.1596
24	Leisure and hotels	6458	3.05	2.2815	0.1674	0.4985	0.1260
25	Leisure goods	1009	0.48	2.3262	0.2864	0.4866	0.1251
26	Media and entertainment	6290	2.97	2.1885	0.3687	0.4848	0.1401
27	Mining	10,280	4.85	2.4798	0.8271	0.5465	0.0677
28	Oil and gas	10,701	5.05	2.4006	0.2872	0.4940	0.0879
29	Pharmaceuticals and biotechnology	12,847	6.07	2.4091	0.4534	0.4566	0.1316
30	Real estate	13,477	6.36	2.2769	0.0906	0.5239	0.1320
31	Renewable energy	2498	1.18	2.1450	0.3988	0.5191	0.1057
32	Software and computer services	12,929	6.10	2.3008	0.4172	0.4739	0.1141
33	Speciality and other finance	11,188	5.28	2.2203	0.3417	0.5239	0.1248
34	Steel and other metals	2881	1.36	2.1757	0.1702	0.5852	0.1033
35	Telecommunication services	4698	2.22	2.2723	0.1826	0.4982	0.1155
36	Transport	6167	2.91	2.2479	0.0657	0.5337	0.1084
37	Utilities—other	2812	1.33	2.5359	0.0347	0.4241	0.1612
Total		211,818	100.00				

Note: This table reports the sector-level distribution of the data in our sample with the mean distribution of our main dependent and independent variables.

independent variables is significantly low. A further check using the variance inflation factors (VIFs) procedure confirms that the average VIF for each variable is 2.23, which is far less than the threshold of 10, suggesting that multicollinearity is not a concern in this study (Hair et al., 1995). This robust methodology ensures the reliability and validity of our findings, enhancing confidence in the results.

TABLE 2 Correlation matrix.

Variables	1	2	5	6	7	8	9	10	11	12	13	14	15	16	17	18	VIF
(1) CLog	1.000																
(2) CLev	**−0.033**	1.000															1.57
(5) CEOVC	**−0.395**	**−0.059**	1.000														1.31
(6) GEN	**−0.128**	**0.127**	**0.038**	1.000													1.20
(7) BSZ	**0.096**	**0.238**	**−0.191**	**0.159**	1.000												3.23
(8) BIN	**0.087**	**0.247**	**−0.178**	**0.230**	**0.896**	1.000											2.62
(9) COPT	**−0.036**	**−0.010**	**0.029**	−0.003	**−0.042**	**−0.059**	1.000										1.01
(10) MTB	**0.086**	**−0.115**	**−0.086**	**−0.012**	0.003	**−0.016**	**0.013**	1.000									1.08
(11) FSZ	**−0.228**	**0.475**	**0.141**	**0.202**	**0.520**	**0.483**	**−0.024**	**−0.177**	1.000								2.53
(12) CAPEX	**0.043**	**−0.031**	−0.001	**−0.057**	**−0.036**	**−0.048**	−0.001	**0.014**	**−0.024**	1.000							1.10
(13) RD	0.006	**−0.365**	−0.002	**−0.080**	**−0.222**	**−0.218**	**0.007**	**0.091**	**−0.419**	**−0.014**	1.000						1.33
(14) CASH	**0.100**	**−0.236**	**−0.025**	**−0.085**	**−0.165**	**−0.160**	**0.014**	**0.167**	**−0.337**	**−0.111**	**0.272**	1.000					1.77
(15) Lev	**−0.042**	**0.069**	−0.001	**0.049**	**0.105**	**0.115**	**−0.011**	**−0.074**	**0.243**	**0.115**	**−0.107**	**−0.325**	1.000				1.22
(16) ROA	**−0.069**	**0.454**	0.002	**0.114**	**0.224**	**0.187**	0.004	**−0.049**	**0.403**	**0.043**	**−0.359**	**−0.390**	**0.050**	1.000			1.55
(17) SLK	−0.002	**−0.161**	**−0.007**	**−0.047**	**−0.123**	**−0.137**	**0.014**	**0.111**	**−0.243**	**−0.214**	**0.187**	**0.535**	**−0.276**	**−0.195**	1.000		1.53
(18) GDPG	**−0.223**	**0.051**	**0.088**	**0.011**	−0.003	**−0.013**	0.000	**−0.020**	**0.164**	**0.021**	**−0.031**	**0.015**	0.006	**0.054**	**0.038**	1.000	2.01

Note: All values significant at ≤1% are reported in bold for brevity and space. All variables are detailed in Appendix A.
Abbreviation: VIF, variance inflation factor.

TABLE 3 The moderating effect of female director.

Variables	Pooled OLS regression		Fixed effect regression	
	Model (1) CO2_Log	Model (2) CO2_Level	Model (3) CO2_Log	Model (4) CO2_Level
CEOVC	−0.4254***	−0.2948***	−0.0553***	0.0179
	(−26.69)	(−11.90)	(−11.42)	(0.41)
GEN	0.1061**	0.3034***	0.0071	0.3041***
	(2.42)	(5.48)	(0.95)	(6.82)
CEOVC × GEN	−0.6321***	−0.8405***	−0.0468***	−0.2230***
	(−8.82)	(−8.77)	(−3.76)	(−3.18)
BSZ	0.0053***	0.0351***	−0.0017***	−0.0024
	(3.27)	(22.35)	(−6.81)	(−1.49)
BIN	0.0122***	−0.0365***	0.0004	0.0149***
	(5.86)	(−18.98)	(1.25)	(7.23)
COPT	−0.0414***	−0.0101	−0.0017*	0.0056
	(−5.36)	(−1.03)	(−1.96)	(0.83)
MTB	0.0009**	0.0071***	0.0003***	0.0043***
	(2.40)	(6.25)	(6.38)	(5.97)
FSZ	−0.0396***	−0.1059***	0.0022***	−0.3801***
	(−20.30)	(−41.07)	(3.13)	(−34.20)
CAPEX	0.3468***	0.3809***	−0.0451***	0.1005
	(8.13)	(5.08)	(−8.95)	(1.58)
RD	−0.2336***	0.5424***	0.0046***	0.1846***
	(−23.64)	(19.06)	(4.83)	(12.94)
CASH	0.2862***	−0.0871***	−0.0088***	−0.0301
	(18.22)	(−3.50)	(−3.09)	(−0.73)
Lev	0.0109	0.1787***	0.0019	0.3043***
	(0.66)	(6.91)	(0.85)	(9.75)
ROA	−0.1396***	−1.6650***	−0.0196***	−0.7849***
	(−6.38)	(−33.54)	(−6.26)	(−18.15)
SLK	−0.2011***	0.0940***	0.0033	0.3070***
	(−12.70)	(4.90)	(0.99)	(6.77)
GDPG	−0.0478***	0.0058***	−0.0046***	−0.0019
	(−26.53)	(3.48)	(−34.03)	(−1.57)
Year effect	*Yes*	*Yes*	*Yes*	*Yes*
Sector effect	*Yes*	*Yes*	*Yes*	*Yes*
Country effect	*Yes*	*Yes*	*Yes*	*Yes*
Constant	3.6054***	2.0655***	2.4485***	7.5719***
	(86.14)	(38.44)	(60.84)	(21.45)
Adjusted R^2	0.2899	0.3594	0.7650	0.2748
Observation	192,947	160,115	192,947	160,115

Note: The table reports the pooled OLS (Models 1–2) and fixed effect (Models 3–4) results, which examine the moderating role of female directors on the effect of CEO overconfidence on greenhouse carbon emissions. All variables are defined in Appendix A. All models are executed using the standard error robustness. The *t*-statistics are shown in parentheses.

Abbreviation: OLS, ordinary least squares.

*Statistically significant at 10% level.

**Statistically significant at 5% level.

***Statistically significant at 1% level.

TABLE 4 Endogeneity—Lag 1 and 2 of CEO overconfidence and moderating effect of female director.

	Direct models				Moderating effect models			
Variables	Model (1) CO2_Log	Model (2) CO2_Level	Model (3) CO2_Log	Model (4) CO2_Level	Model (5) CO2_Log	Model (6) CO2_Level	Model (7) CO2_Log	Model (8) CO2_Level
CEOVC$_{(t-1)}$	−0.0583***		−0.1408***		−0.0528***		−0.0181***	
	(−12.21)		(−3.01)		(−10.63)		(−4.44)	
CEOVC$_{(t-2)}$		−0.0552***		−0.0895**		−0.0502***		−0.0789***
		(−11.24)		(−2.27)		(−9.82)		(−3.91)
GEN$_{(t-1)}$					0.0120		0.2259***	
					(1.50)		(5.15)	
GEN$_{(t-2)}$						0.0114		0.2034***
						(1.35)		(4.46)
[CEOVC × GEN]$_{(t-1)}$					−0.0572***		−0.1758**	
					(−4.36)		(−2.33)	
[CEOVC × GEN]$_{(t-2)}$						−0.0535***		−0.1363***
						(−3.90)		(−4.71)
BSZ	−0.0013***	−0.0013***	0.0026*	−0.0009	−0.0013***	−0.0013***	−0.0019	−0.0008
	(−4.79)	(−4.32)	(1.73)	(−0.58)	(−4.77)	(−4.31)	(−1.25)	(−0.51)
BIN	0.0001	0.0000	−0.0154***	0.0133***	0.0001	0.0001	0.0143***	0.0131***
	(0.26)	(0.13)	(−7.54)	(6.62)	(0.29)	(0.15)	(7.15)	(6.54)
COPT	−0.0024**	−0.0033***	−0.0071	0.0013	−0.0023**	−0.0032***	0.0059	0.0012
	(−2.46)	(−3.13)	(−0.96)	(0.16)	(−2.42)	(−3.09)	(0.80)	(0.14)
MTB	0.0003***	0.0003***	−0.0032***	0.0029***	0.0003***	0.0003***	0.0034***	0.0029***
	(6.22)	(6.70)	(−4.08)	(3.48)	(6.18)	(6.67)	(4.38)	(3.47)
FSZ	0.0012	0.0005	0.3500***	−0.3557***	0.0012	0.0005	−0.3627***	−0.3561***
	(1.56)	(0.66)	(28.32)	(−26.96)	(1.59)	(0.66)	(−29.89)	(−26.98)
CAPEX	−0.0393***	−0.0335***	−0.0641	0.0709	−0.0394***	−0.0337***	0.0522	0.0704
	(−7.06)	(−5.59)	(−0.86)	(0.92)	(−7.05)	(−5.61)	(0.75)	(0.91)
RD	0.0044***	0.0047***	−0.1679***	0.1639***	0.0044***	0.0047***	0.1675***	0.1639***
	(4.41)	(4.39)	(−11.17)	(10.59)	(4.36)	(4.32)	(11.39)	(10.59)
CASH	−0.0099***	−0.0109***	0.0218	−0.0661	−0.0097***	−0.0107***	−0.0459	−0.0667
	(−3.20)	(−3.32)	(0.48)	(−1.34)	(−3.14)	(−3.24)	(−1.01)	(−1.36)
Lev	0.0011	0.0012	−0.2967***	0.2788***	0.0009	0.0011	0.2875***	0.2796***
	(0.45)	(0.47)	(−8.93)	(7.62)	(0.38)	(0.43)	(8.54)	(7.64)
ROA	−0.0154***	−0.0126***	0.7519***	−0.7260***	−0.0154***	−0.0126***	−0.7519***	−0.7260***
	(−4.60)	(−3.53)	(15.28)	(−14.56)	(−4.59)	(−3.53)	(−16.19)	(−14.57)
SLK	0.0018	0.0015	−0.2974***	0.3291***	0.0016	0.0013	0.3133***	0.3304***
	(0.51)	(0.39)	(−6.15)	(6.26)	(0.46)	(0.33)	(6.43)	(6.28)
GDPG	−0.0032***	−0.0023***	0.0010	−0.0014	−0.0032***	−0.0024***	−0.0010	−0.0013
	(−23.22)	(−15.71)	(0.80)	(−1.11)	(−23.46)	(−16.00)	(−0.85)	(−1.09)
Year Effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Sector effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Country effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	2.4854***	2.5035***	−6.9728***	7.2692***	2.4825***	2.5016***	7.3356***	7.2632***
	(61.04)	(50.25)	(−17.45)	(15.83)	(60.71)	(50.05)	(19.20)	(15.94)
Adjusted R^2	0.7787	0.7826	0.2442	0.2519	0.7790	0.7829	0.2615	0.2524
Observation	168,355	146,796	139,384	121,006	168,340	146,784	139,374	121,002

Note: The table reports the fixed effect results examining the effect of CEO overconfidence on greenhouse carbon emission (Models 1–4) and moderating effect (Models 4–8) using the first and second lag of independent/moderating variables. All variables are defined in Appendix A. All models are executed using the standard error robustness. The *t*-statistics are shown in parentheses.
*Statistically significant at 10% level.
**Statistically significant at 5% level.
***Statistically significant at 1% level.

TABLE 5 Endogeneity check using higher-dimensional fixed effect.

Variables	Direct models				Moderating effect models			
	Model (1) CO2_Log	Model (2) CO2_Log	Model (3) CO2_Level	Model (4) CO2_Level	Model (5) CO2_Log	Model (6) CO2_Log	Model (7) CO2_Level	Model (8) CO2_Level
CEOVC	−0.0609***		−0.3671***		−0.0554***		−0.0216	
	(−21.09)		(−27.06)		(−32.40)		(−1.55)	
$CEOVC_{(t-1)}$		−0.0872***		−0.1555***		−0.0529***		−0.0029
		(−29.05)		(−11.49)		(−30.34)		(−0.21)
GEN					0.0071**		0.5758***	
					(2.26)		(22.07)	
$GEN_{(t-1)}$						0.0119***		0.4777***
						(3.61)		(17.50)
CEOVC × GEN					−0.0468***		−0.2999***	
					(−9.40)		(−6.93)	
$[CEOVC \times GEN]_{(t-1)}$						−0.0571***		−0.2399***
						(−10.90)		(−5.28)
BSZ	0.0219***	0.0233***	0.0133***	0.0171***	−0.0017***	−0.0013***	−0.0132***	−0.0135***
	(107.18)	(108.80)	(13.58)	(17.62)	(−13.96)	(−10.12)	(−13.60)	(−14.13)
BIN	−0.0242***	−0.0252***	−0.0281***	−0.0309***	0.0004***	0.0001	0.0262***	0.0266***
	(−93.74)	(−91.85)	(−22.49)	(−24.44)	(2.62)	(0.62)	(21.11)	(21.36)
COPT	−0.0000	−0.0025***	−0.0057	−0.0093**	−0.0017***	−0.0024***	0.0043	0.0073*
	(−0.02)	(−2.61)	(−1.34)	(−2.07)	(−3.49)	(−4.40)	(1.03)	(1.66)
MTB	0.0004***	0.0003***	−0.0041***	−0.0033***	0.0003***	0.0003***	0.0042***	0.0035***
	(8.74)	(5.51)	(−16.37)	(−12.34)	(8.82)	(8.96)	(17.18)	(13.44)
FSZ	−0.0589***	−0.0609***	0.3173***	0.3060***	0.0022***	0.0012***	−0.3459***	−0.3284***
	(−144.60)	(−133.60)	(153.20)	(137.92)	(8.43)	(4.20)	(−165.54)	(−148.50)
CAPEX	0.1125***	0.1270***	−0.0086	0.0371	−0.0449***	−0.0392***	0.0166	−0.0253
	(21.46)	(21.40)	(−0.34)	(1.34)	(−14.93)	(−11.79)	(0.66)	(−0.94)
RD	−0.0225***	−0.0225***	−0.2031***	−0.1856***	0.0045***	0.0043***	0.2000***	0.1814***
	(−16.75)	(−15.36)	(−30.80)	(−27.24)	(5.93)	(5.32)	(30.72)	(27.20)
CASH	−0.0131***	−0.0201***	0.0076	0.0245*	−0.0088***	−0.0097***	−0.0337***	−0.0488***
	(−5.21)	(−7.15)	(0.60)	(1.81)	(−6.13)	(−6.19)	(−2.69)	(−3.70)
Lev	−0.0082***	−0.0116***	−0.3205***	−0.3068***	0.0019*	0.0009	0.3118***	0.2963***
	(−4.33)	(−5.68)	(−33.95)	(−31.43)	(1.76)	(0.79)	(33.47)	(31.01)
ROA	0.0834***	0.0843***	0.8447***	0.8023***	−0.0195***	−0.0153***	−0.8284***	−0.7877***
	(29.55)	(27.40)	(60.34)	(55.16)	(−12.06)	(−8.91)	(−59.92)	(−55.31)
SLK	0.0052**	0.0070**	−0.3006***	−0.3069***	0.0032**	0.0016	0.3181***	0.3239***
	(2.05)	(2.50)	(−23.54)	(−22.84)	(2.24)	(1.00)	(25.23)	(24.64)
GDPG	0.0018***	0.0014***	0.0002	−0.0013**	−0.0046***	−0.0032***	−0.0008	0.0005
	(22.95)	(17.31)	(0.26)	(−2.08)	(−48.35)	(−31.59)	(−1.21)	(0.83)
Sector × Year	−0.0001***	−0.0001***	−0.0000***	−0.0000***	0.0001***	0.0001***	0.0000***	0.0000***
	(−93.79)	(−92.76)	(−11.68)	(−10.46)	(9.64)	(8.63)	(8.01)	(7.68)
Constant	6.8556***	7.3543***	−4.3443***	−4.2957***	2.3309***	2.3471***	5.6956***	5.3280***
	(194.21)	(182.25)	(−26.01)	(−23.68)	(422.83)	(391.77)	(34.17)	(29.71)
Adjusted R^2	0.9792	0.9792	0.7886	0.7974	0.9933	0.9936	0.8003	0.8097
Observations	190,427	165,657	158,126	137,213	190,396	165,640	158,099	137,207

Note: The table reports higher-dimensional fixed effect (HDFE) results for the endogeneity check run with the first lag. Models 1–4 report the direct effects results, whereas Models 5–8 report the moderating effect results. All variables are defined in Appendix A. All models are executed by absorbing two HDFE groups—the country effect and the firm-specific effect. The *t*-statistics are shown in parentheses.

*Statistically significant at 10% level.

**Statistically significant at 5% level.

***Statistically significant at 1% level.

TABLE 6 Endogeneity check using 2SLS.

Variables	Direct models Model (1) CO2_Log	Model (2) CO2_Log	Model (3) CO2_Level	Model (4) CO2_Level	Moderating effect models Model (5) CO2_Log	Model (6) CO2_Log	Model (7) CO2_Level	Model (8) CO2_Level
CEOVC	−0.4784***		−0.1427***		−0.1726***		−0.3566**	
	(−11.51)		(−4.99)		(−4.83)		(−2.21)	
$CEOVC_{(t-1)}$		−0.4837***		−0.1441***		−0.1945***		−0.2061
		(−11.08)		(−4.86)		(−4.79)		(−1.47)
GEN					2.3517***		6.1427***	
					(10.02)		(3.59)	
$GEN_{(t-1)}$						2.7022***		4.9400***
						(9.36)		(3.11)
CEOVC × GEN					−2.4901***		−5.9969***	
					(−9.99)		(−3.52)	
$[CEOVC \times GEN]_{(t-1)}$						−2.8800***		−4.7892***
						(−9.33)		(−3.02)
BSZ	−0.0307***	−0.0380***	0.0153***	0.0131***	−0.0762***	−0.0813***	−0.0514***	−0.0469***
	(−6.18)	(−6.59)	(4.48)	(3.35)	(−15.77)	(−15.43)	(−8.57)	(−8.90)
BIN	−0.0399***	−0.0320***	−0.0516***	−0.0492***	0.0561***	0.0604***	0.0436***	0.0403***
	(−9.05)	(−8.11)	(−16.97)	(−18.33)	(10.26)	(10.84)	(9.67)	(10.06)
COPT	−0.0210	0.0166	0.0031	0.0143	−0.0665**	−0.0759***	0.0195*	0.0205**
	(−1.37)	(0.96)	(0.30)	(1.22)	(−2.50)	(−2.58)	(1.92)	(2.16)
MTB	−0.0021	−0.0026*	0.0108***	0.0107***	−0.0108***	−0.0084***	−0.0125***	−0.0115***
	(−1.42)	(−1.71)	(10.68)	(10.51)	(−4.22)	(−3.10)	(−9.82)	(−10.58)
FSZ	0.0762***	0.0798***	−0.0279***	−0.0269***	−0.0526***	−0.0593***	0.0697***	0.0712***
	(6.08)	(5.99)	(−3.23)	(−2.97)	(−5.80)	(−5.55)	(21.47)	(22.28)
CAPEX	−0.1844	−0.1120	−0.1390*	−0.1169	0.3553***	0.3169**	−0.3218***	−0.3163***
	(−1.59)	(−0.98)	(−1.74)	(−1.50)	(2.66)	(2.18)	(−5.77)	(−6.10)
RD	0.1333	0.1778	1.8236***	1.8363***	−0.8519***	−0.9659***	−1.4179***	−1.4188***
	(1.17)	(1.47)	(23.21)	(22.31)	(−6.55)	(−6.56)	(−29.09)	(−30.16)
CASH	0.2228***	0.2335***	−0.3394***	−0.3361***	0.2801***	0.3095***	0.2480***	0.2547***
	(8.03)	(8.39)	(−17.77)	(−17.78)	(6.63)	(6.78)	(14.45)	(16.19)
Lev	−0.1904***	−0.1892***	0.0790***	0.0795***	0.1227***	0.1740***	−0.1403***	−0.1405***
	(−6.56)	(−6.36)	(3.96)	(3.93)	(2.90)	(3.58)	(−8.91)	(−9.24)
ROA	−0.3171***	−0.2528***	−1.7133***	−1.6941***	0.2457***	0.2404***	1.7323***	1.6960***
	(−8.11)	(−6.45)	(−63.70)	(−63.63)	(2.85)	(2.72)	(42.94)	(50.98)
SLK	−0.1127***	−0.1065***	0.0461***	0.0479***	0.0660*	0.0871**	0.0441**	0.0277
	(−6.80)	(−6.29)	(4.04)	(4.17)	(1.94)	(2.35)	(2.02)	(1.45)
GDPG	−0.0974***	−0.0947***	−0.0036	−0.0028	−0.1018***	−0.0972***	−0.0004	0.0004
	(−28.14)	(−27.40)	(−1.51)	(−1.18)	(−14.87)	(−14.13)	(−0.17)	(0.16)
Year effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Sector effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Country effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	4.5384***	4.4757***	1.9491***	1.9299***	2.4008***	2.3344***	−1.7680***	−1.6678***
	(44.70)	(44.79)	(27.89)	(28.42)	(12.42)	(11.41)	(−16.42)	(−18.85)
Adjusted R^2	0.3130	0.3248	0.4135	0.3886	0.8974	0.9583	0.7225	0.7389
Observations	134,698	134,697	134,698	134,697	134,697	105,392	134,697	105,392

Note: The table reports two-stage least square regression (2SLS) results for the endogeneity check run with the first lag. Models 1–4 report the direct effects results, whereas Models 5–8 report the moderating effect results. All variables are defined in Appendix A. The *t*-statistics are shown in parentheses.
*Statistically significant at 10% level.
**Statistically significant at 5% level.
***Statistically significant at 1% level.

TABLE 7 The effect of performance-led and option-led CEO overconfidence on carbon footprint.

	Performance-led overconfident CEOs				Net_Buyer-led overconfident CEOs			
	Direct models		Moderating role models		Direct models		Moderating role models	
Variables	1	2	3	4	5	6	7	8
PL_CEOVC	−0.0066***	−0.1822***	−0.0026***	−0.2151***				
	(−10.76)	(−26.69)	(−3.33)	(−24.98)				
GEN			−0.0055	−0.2550***			−0.0225***	−0.1730***
			(−1.23)	(−8.48)			(−4.75)	(−5.90)
PL_CEOVC × GEN			−0.0348***	−0.3147***				
			(−7.49)	(−9.37)				
NB_CEOVC					0.0006**	0.0208***	−0.0006	0.0143***
					(2.02)	(8.09)	(−1.53)	(3.65)
NB_CEOVC × GEN							−0.0104***	−0.0609***
							(−4.08)	(−2.92)
BSZ	−0.0008***	0.0058***	−0.0008***	0.0057***	−0.0008***	0.0043***	−0.0008***	0.0043***
	(−2.98)	(3.86)	(−3.03)	(3.78)	(−3.17)	(2.81)	(−3.25)	(2.78)
BIN	−0.0005	−0.0188***	−0.0005	−0.0185***	−0.0005	−0.0176***	−0.0004	−0.0171***
	(−1.62)	(−9.25)	(−1.41)	(−9.17)	(−1.50)	(−8.52)	(−1.30)	(−8.35)
COPT	−0.0025***	−0.0105	−0.0023***	−0.0099	−0.0025***	−0.0102	−0.0023***	−0.0091
	(−2.87)	(−1.56)	(−2.69)	(−1.48)	(−2.84)	(−1.49)	(−2.67)	(−1.34)
MTB	0.0003***	−0.0034***	0.0003***	−0.0034***	0.0003***	−0.0040***	0.0003***	−0.0040***
	(7.28)	(−4.81)	(7.38)	(−4.82)	(6.73)	(−5.55)	(6.82)	(−5.53)
FSZ	0.0016**	0.3428***	0.0019***	0.3420***	0.0024***	0.3651***	0.0025***	0.3657***
	(2.28)	(32.06)	(2.62)	(32.03)	(3.36)	(32.49)	(3.48)	(32.50)
CAPEX	−0.0438***	−0.0665	−0.0439***	−0.0651	−0.0458***	−0.1214*	−0.0457***	−0.1197*
	(−8.67)	(−1.00)	(−8.68)	(−0.98)	(−9.03)	(−1.79)	(−9.01)	(−1.77)
RD	0.0050***	−0.1702***	0.0050***	−0.1708***	0.0046***	−0.1826***	0.0046***	−0.1833***
	(5.26)	(−12.07)	(5.24)	(−12.14)	(4.81)	(−12.65)	(4.80)	(−12.72)
CASH	−0.0090***	0.0009	−0.0086***	−0.0006	−0.0088***	0.0046	−0.0087***	0.0068
	(−3.14)	(0.02)	(−3.00)	(−0.02)	(−3.07)	(0.11)	(−3.01)	(0.17)
LEV	0.0017	−0.3188***	0.0015	−0.3207***	0.0019	−0.3125***	0.0017	−0.3153***
	(0.76)	(−10.36)	(0.66)	(−10.43)	(0.85)	(−10.01)	(0.76)	(−10.10)
ROA	−0.0083**	1.1072***	−0.0087**	1.1122***	−0.0193***	0.8110***	−0.0195***	0.8094***
	(−2.45)	(21.36)	(−2.57)	(21.49)	(−6.02)	(17.43)	(−6.07)	(17.41)
SLK	0.0045	−0.2605***	0.0040	−0.2590***	0.0034	−0.2901***	0.0031	−0.2916***
	(1.35)	(−5.93)	(1.20)	(−5.90)	(1.00)	(−6.50)	(0.93)	(−6.53)
GDPG	−0.0045***	0.0027**	−0.0045***	0.0030**	−0.0045***	0.0018	−0.0045***	0.0020*
	(−33.27)	(2.34)	(−33.14)	(2.54)	(−33.35)	(1.54)	(−33.24)	(1.70)
Year effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.4392***	−6.6578***	2.4323***	−6.6233***	2.4196***	−7.2344***	2.4184***	−7.2418***
	(62.68)	(−18.93)	(62.29)	(−19.17)	(63.48)	(−19.29)	(62.72)	(−19.39)
Adjusted R^2	0.7628	0.2749	0.7633	0.2765	0.7623	0.2574	0.7626	0.2579
Observation	193,364	160,435	193,330	160,408	193,364	160,435	193,330	160,408

Note: The table reports the fixed effect results examining the effect of performance-led CEO overconfidence on greenhouse carbon emission. Models 1–4 report the results for overconfident CEOs, while Models 5–8 reports those for non-overconfident CEOs. All models include year, sector and country dummies. The PL_CEOVC is performance-led CEO overconfidence, NB_CEOVC is option-led CEO overconfidence and PL_CEOVC × GEN and NB_CEOVC × GEN are moderating variables. The rest of the variables are defined in Appendix A. All models are executed using the standard error robustness. The *t*-statistics are shown in parentheses.
*Statistically significant at 10% level.
**Statistically significant at 5% level.
***Statistically significant at 1% level.

TABLE 8 Sensitivity analysis: alternative measures for CEO overconfidence.

Panel a: direct models										
	CEO pay slice		CEO tenure		CEO share ownership		CEO duality		CEO directorship	
Variables	Model (1) CO2_Log	Model (2) CO2_Level	Model (3) CO2_Log	Model (4) CO2_Level	Model (5) CO2_Log	Model (6) CO2_Level	Model (7) CO2_Log	Model (8) CO2_Level	Model (9) CO2_Log	Model (10) CO2_Level
CEOPS	−0.0575***	−0.3586***								
	(−12.58)	(−7.14)								
CEOT			−0.0548***	−0.2966***						
			(−5.16)	(−4.18)						
CEOS					−0.0152***	−0.1020***				
					(−2.79)	(−3.26)				
CEOD							−0.0045***	−0.0148***		
							(−6.58)	(−2.66)		
CEODP									−0.0529***	−0.1016**
									(−7.02)	(−2.12)
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Sector effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Country effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	2.4508***	−7.0359***	2.4183***	−7.2418***	2.4185***	−7.2380***	2.4190***	−7.2405***	2.4557***	−6.2369***
	(61.16)	(−18.58)	(63.91)	(−19.42)	(63.34)	(−19.44)	(63.38)	(−19.43)	(47.05)	(−14.72)
Adjusted R^2	0.7647	0.2610	0.7625	0.2573	0.7629	0.2571	0.7625	0.2571	0.7855	0.2353
Observation	193,950	160,118	193,364	160,435	192,947	160,115	193,364	160,435	152,778	128,862

Panel b: moderating effect models										
	CEO pay slice		CEO tenure		CEO share ownership		CEO duality		CEO directorship	
Variables	Model (1) CO2_Log	Model (2) CO2_Level	Model (3) CO2_Log	Model (4) CO2_Level	Model (5) CO2_Log	Model (6) CO2_Level	Model (7) CO2_Log	Model (8) CO2_Level	Model (9) CO2_Log	Model (10) CO2_Level
CEOPS	−0.0529***	−0.3968***								
	(−11.17)	(−7.55)								
GEN	0.0079	−0.3719	−0.0166***	−0.1093***	−0.0195*	−0.1424***	−0.0358*	−0.1247***	−0.0168***	−0.0981***
	(1.06)	(−1.41)	(−3.16)	(−3.13)	(−1.71)	(−4.69)	(−1.86)	(−3.95)	(−3.07)	(−2.94)
CEOPS × GEN	−0.0477***	−0.4264***								
	(−3.92)	(−5.62)								
CEOT			−0.0517***	−0.2022**						
			(−4.01)	(−2.29)						

(Continues)

TABLE 8 (Continued)

Panel b: moderating effect models										
	CEO pay slice		CEO tenure		CEO share ownership		CEO duality		CEO directorship	
Variables	Model (1) CO2_Log	Model (2) CO2_Level	Model (3) CO2_Log	Model (4) CO2_Level	Model (5) CO2_Log	Model (6) CO2_Level	Model (7) CO2_Log	Model (8) CO2_Level	Model (9) CO2_Log	Model (10) CO2_Level
CEOT × GEN			−0.0411*	−0.9979***						
			(−1.83)	(−3.00)						
CEOS					−0.0301***	−0.0543				
					(−4.53)	(−1.31)				
CEOS × GEN					−0.0993***	−0.3591*				
					(−3.41)	(−1.94)				
CEOD							−0.0115***	−0.0060		
							(−12.13)	(−0.79)		
CEOD × GEN							−0.0658***	−0.0920***		
							(−12.27)	(−2.59)		
CEODP									−0.0705***	−0.0101
									(−7.18)	(−0.16)
CEODP × GEN									−0.1433***	−0.8250***
									(−3.38)	(−3.64)
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Sector effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Country effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	2.4481***	−7.0373***	2.4162***	−7.2590***	2.4174***	−7.2495***	2.4194***	−7.2528***	2.4554***	−6.2444***
	(60.83)	(−18.68)	(63.32)	(−19.51)	(62.74)	(−19.53)	(62.54)	(−19.50)	(47.02)	(−14.86)
Adjusted R^2	0.7650	0.2620	0.7628	0.2579	0.7631	0.2576	0.7635	0.2576	0.7856	0.2358
Observation	192,950	160,115	193,364	160,435	192,947	160,115	193,364	160,435	152,778	128,682

Note: Panel a reports the fixed effect results sensitivity analysis, for alternative measures for CEO overconfidence. We use each item included in our CEO overconfidence index as a separate measure of CEO overconfidence. The CEOPS represent CEO pay slice, CEOT represents CEO tenure, CEOS represents CEO share ownership which is the percentage of equity shares owned CEO, CEOD represents CEO duality where the CEO also chairs the board, and CEODP represents CEO directorship in other companies. The rest of the variables are defined in Appendix A. All models are executed using the standard error robustness. The *t*-statistics are shown in parentheses. Panel b reports the fixed effect results sensitivity analysis, for moderating effect on the alternative measures for CEO overconfidence. We use each item included in our CEO overconfidence index as a separate measure of CEO overconfidence. The CEOPS represent CEO pay slice, CEOT represents CEO tenure, CEOS represents CEO share ownership which is the percentage of equity shares owned CEO, CEOD represents CEO duality where the CEO also chairs the board, and CEODP represents CEO directorship in other companies. The rest of the variables are defined in Appendix A. All models are executed using the standard error robustness. The *t*-statistics are shown in parentheses.

*Statistically significant at 10% level.

**Statistically significant at 5% level.

***Statistically significant at 1% level.

TABLE 9 Greenhouse carbon and CEO overconfidence.

	Pooled OLS regression		Fixed effect regression	
Variables	Model (1) CO2_Log	Model (2) CO2_Level	Model (3) CO2_Log	Model (4) CO2_Level
CEOVC	−0.5048***	−0.3263***	−0.0598***	−0.3697***
	(−37.42)	(−15.05)	(−12.81)	(−7.21)
BSZ	0.0073***	−0.0359***	−0.0017***	−0.0014
	(4.54)	(−24.01)	(−6.76)	(−0.89)
BIN	0.0083***	0.0353***	0.0004	−0.0120***
	(4.01)	(20.74)	(1.11)	(−5.87)
COPT	−0.0418***	0.0099	−0.0018**	−0.0058
	(−5.38)	(1.03)	(−2.11)	(−0.85)
MTB	0.0008**	−0.0065***	0.0003***	−0.0041***
	(2.07)	(−5.92)	(6.37)	(−5.74)
FSZ	−0.0391***	0.1045***	0.0022***	0.3643***
	(−19.97)	(39.72)	(3.06)	(32.46)
CAPEX	0.3649***	−0.4371***	−0.0450***	−0.1191*
	(8.52)	(−5.45)	(−8.95)	(−1.76)
RD	−0.2318***	−0.5195***	0.0046***	−0.1829***
	(−23.30)	(−18.95)	(4.89)	(−12.71)
CASH	0.2901***	0.0718***	−0.0090***	0.0036
	(18.41)	(2.94)	(−3.14)	(0.09)
Lev	0.0077	−0.1776***	0.0021	−0.3118***
	(0.47)	(−7.00)	(0.95)	(−10.03)
ROA	−0.1610***	1.6071***	−0.0197***	0.7818***
	(−7.33)	(33.62)	(−6.30)	(17.32)
SLK	−0.2063***	−0.0706***	0.0034	−0.2896***
	(−13.01)	(−3.74)	(1.03)	(−6.50)
GDPG	−0.0470***	−0.0047***	−0.0046***	0.0017
	(−26.01)	(−2.78)	(−33.81)	(1.41)
Year effect	*Yes*	*Yes*	*Yes*	*Yes*
Sector effect	*Yes*	*Yes*	*Yes*	*Yes*
Country effect	*Yes*	*Yes*	*Yes*	*Yes*
Constant	3.6266***	−1.9949***	2.4513***	−7.0358***
	(86.12)	(−38.36)	(61.17)	(−18.58)
Adjusted R^2	0.2866	0.3470	0.7647	0.2610
Observation	192,947	160,115	192,947	160,115

Note: The table reports the pooled OLS (Models 1–2) and fixed effect (Models 3–4) results to examine the effect of CEO overconfidence on greenhouse carbon emission. All variables are defined in Appendix A. All models are executed using the standard error robustness. The *t*-statistics are shown in parentheses.

Abbreviation: OLS, ordinary least squares.

*Statistically significant at 10% level.

**Statistically significant at 5% level.

***Statistically significant at 1% level.

4.2 | Baseline multivariate analysis

4.2.1 | CEO overconfidence and greenhouse gas emissions

The study examines the effect of CEO overconfidence on greenhouse emissions. We test our first hypothesis, which states that 'CEOs with significant overconfidence reduce corporate greenhouse gas emissions' (H1) using Equation (1), and Table 3 reports the results. Our OLS results in Models 1 and 2 indicate that the coefficients for CEO overconfidence are negative and statistically significant at the 1% level. In Models 3 and 4, the coefficients of CEO overconfidence [CEOVC] remain statistically significant when estimated using fixed effect (FE) regressions. Economically, the finding suggests that a one standard deviation change (increase) in CEO overconfidence leads to a decrease of about 14.1% and 9.4% [100 (exp(−0.5048*0.301)−1)] and [100(exp(−0.3263*0.301)−1)] reduction in GHG emissions and GHG emissions level. Thus, the results support our first hypothesis.

Theoretically, the results align with agency theory, which posits that an overconfident CEO has a strong desire through environmental activities and disclosure of GHG emissions to maximise their private benefits and gain legitimisation. This may, however, be motivated by the overconfident CEOs' proclivity to gain popularity for their outperformance (Galasso & Simcoe, 2011). Therefore, overconfident CEOs' self-inclination behaviour may align with sustainable practices and be more committed to environmental responsibility. Empirically, our findings complement the view that firms with overconfident CEOs may pursue aggressive innovations to demonstrate the superiority of the CEO (Galasso & Simcoe, 2011). Therefore, the emergence of new production technologies with less reliance on hydrocarbons may be well received by firms with overconfident CEOs.

On an empirical level, our findings align with the existing literature, which suggests that individuals with narcissistic traits have a strong need for responsiveness and admiration (Lee, 2021). Similarly, Lee's (2021) research indicates that overconfident CEOs in South Korea are likelier to voluntarily disclose more GHG emissions. Our findings, therefore, echo the conclusions of Petrenko et al. (2016), who identified three reasons why overconfident CEOs may aggressively work to reduce their carbon footprint. These empirical implications further strengthen the case for the role of CEO overconfidence in shaping environmental sustainability practices.

4.2.2 | Moderating role of gender diversity

In this section, we examine whether the female diversity in the boardroom moderates the associations between CEO overconfidence and GHG emissions. The evidence shows that female directors are likely to be greener. Thus, there is an expectation that the combined effort of female directors and CEO overconfidence may reduce GHG emissions (Konadu et al., 2022). Thus, we examine our second hypothesis, which states that "female board members will induce overconfident CEOs to reduce corporate greenhouse gas emissions H2" overconfidence by adding an interactive variable [CEOVC × -GEN] in Equation (2). Table 3 reports the results. The individual coefficients of CEO overconfidence and gender diversity now represent conditional rather than additive effects. Hence, their respective coefficient diverges from those in the previous models (see Chizema et al., 2015; Friedrich, 1982). The OLS results in Models 1 and 2 support the conditional impact of CEO overconfidence on GHG emissions. In the absence of a female director (i.e., when the gender diversity is equal to zero), the effect of CEO overconfidence on greenhouse carbon emissions is negative. It has a significant coefficient *[β - 0.4254 in Model 1 and β - 0.2948 in Model 2]*. However, in the aftermath of introducing gender diversity, the negative effect of CEO overconfidence on greenhouse carbon emission is further strengthened, as shown by a negative and significant coefficient *[$\beta = -0.6321$ in Model 1 and $\beta = -0.8405$ in Model 2]*. This suggests that when the proportion of board gender diversity increases by one standard deviation (0.129), the net impact of the CEO overconfidence on GHG emissions is *[−0.4254-(−0.6321*0.129 = −0.3439, $p < .001$, and −0.2948-(−0.8405*0.129 = −0.1864, $p < .001$]*. Economically, these findings suggest that when the proportion of gender diversity changes (increase by one standard deviation) in the boardroom, the GHG emissions and greenhouse carbon emission level decrease by about 29.1% *[100(exp(−0.3439)−1)]* and 17% *[100(exp(−0.1864)−1)]*, respectively. This is twice the reduction evidenced in Section 4.2.1 without including the moderating role of female directors. Based on these results, our second hypothesis (H2) is supported.

The findings support the notion that females have greater environmental concerns and actively work friendly in enhancing sustainability to address climate change and reduce carbon emissions (Adams et al., 2011; Estelyi & Nisar, 2016). Empirically, our findings are consistent with Konadu et al. (2022) and Altunbas et al. (2022), who examine the impact of female representation on firm carbon emissions. Our study complements the existing body of research that shows that female board representation mitigates the adverse effect of CEO overconfidence and improves corporate outlook (Chen et al., 2019). Also, our findings agree with the existing studies, such as Lee (2021), which document that the influence of CEO overconfidence on voluntary GHG emissions is more pronounced for firms with more female representation on boards. This implies that women directors effectively monitor overconfident CEOs.

4.2.3 | Endogeneity tests

A potential issue with our research design is that overconfident CEOs may prefer to work in greener companies. Therefore, rather than the former influencing the reduction of carbon emissions, the company's efforts improve the carbon perception of the overconfident CEO. To address this, we adopted three methods. First, in line with Zhu et al. (2022) and Fulgence, Kwabi, et al. (2023), we

TABLE 10 Step-by-step sensitivity tests—exclusion of sectors and countries with higher frequency.

Variables	Banks, real estate, pharmaceutical, and software and computer services sectors excluded from the sample				The United Kingdom and the United States excluded from the sample			
	Model (1) CO2_Log	Model (2) CO2_Level	Model (3) CO2_Log	Model (4) CO2_Level	Model (5) CO2_Log	Model (6) CO2_Level	Model (7) CO2_Log	Model (8) CO2_Level
CEOVC	−0.0640***	−0.3918***	−0.0590***	−0.0324	−0.0315***	−0.2300***	−0.0176**	0.1094**
	(−12.25)	(−6.91)	(−10.89)	(−0.67)	(−4.49)	(−3.85)	(−2.46)	(2.16)
GEN			0.0087	0.2889***			0.0241*	0.0999
			(0.96)	(5.67)			(1.86)	(1.41)
CEOVC × GEN			−0.0508***	−0.1980**			−0.1064***	−0.1392***
			(−3.54)	(−2.51)			(−5.97)	(−3.69)
BSZ	−0.0020***	−0.0025	−0.0020***	−0.0014	−0.0001	−0.0090***	−0.0002	0.0085***
	(−6.58)	(−1.38)	(−6.62)	(−0.76)	(−0.19)	(−4.63)	(−0.39)	(4.46)
BIN	0.0006*	−0.0134***	0.0007*	0.0161***	−0.0020***	−0.0040	−0.0017***	0.0033
	(1.70)	(−5.56)	(1.81)	(6.68)	(−3.53)	(−1.50)	(−3.14)	(1.31)
COPT	−0.0028***	−0.0025	−0.0026**	0.0008	−0.0006	−0.0207*	−0.0003	0.0187*
	(−2.64)	(−0.31)	(−2.51)	(0.10)	(−0.41)	(−1.95)	(−0.17)	(1.82)
MTB	0.0003***	−0.0048***	0.0003***	0.0050***	−0.0000	−0.0033**	−0.0000	0.0025*
	(6.38)	(−5.78)	(6.39)	(6.14)	(−0.20)	(−1.96)	(−0.14)	(1.67)
FSZ	0.0015*	0.3691***	0.0015**	−0.3814***	0.0077***	0.3634***	0.0080***	−0.3530***
	(1.89)	(27.96)	(1.97)	(−29.36)	(6.85)	(17.84)	(7.09)	(−18.73)
CAPEX	−0.0572***	−0.1300	−0.0571***	0.0952	−0.0502***	−0.2094*	−0.0489***	0.2175**
	(−9.67)	(−1.63)	(−9.65)	(1.30)	(−7.58)	(−1.91)	(−7.37)	(2.17)
RD	0.0049***	−0.1981***	0.0049***	0.1990***	0.0055***	−0.1522***	0.0054***	0.1448***
	(4.51)	(−11.68)	(4.46)	(11.83)	(4.07)	(−6.84)	(4.03)	(6.91)
CASH	−0.0066**	−0.1390***	−0.0065**	0.1190**	−0.0160***	−0.1368**	−0.0157***	0.1249**
	(−2.01)	(−2.95)	(−1.98)	(2.57)	(−3.70)	(−2.08)	(−3.62)	(1.97)
Lev	0.0025	−0.3263***	0.0022	0.3172***	−0.0007	−0.4012***	−0.0014	0.4069***
	(0.94)	(−8.95)	(0.83)	(8.81)	(−0.18)	(−8.21)	(−0.39)	(8.62)
ROA	−0.0218***	0.9106***	−0.0217***	−0.9075***	−0.0276***	0.7334***	−0.0271***	−0.6914***
	(−6.07)	(16.40)	(−6.03)	(−17.51)	(−5.20)	(10.85)	(−5.11)	(−11.07)
SLK	−0.0020	−0.2523***	−0.0020	0.2644***	0.0103**	−0.3275***	0.0101**	0.3190***
	(−0.54)	(−4.87)	(−0.55)	(5.07)	(2.28)	(−5.20)	(2.26)	(5.25)
GDPG	−0.0047***	0.0031**	−0.0047***	−0.0031**	−0.0046***	0.0040***	−0.0045***	−0.0030**
	(−30.19)	(2.28)	(−30.31)	(−2.29)	(−34.53)	(2.93)	(−33.59)	(−2.36)
Year effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Sector effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Country effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	2.4588***	−7.2192***	2.4559***	7.6948***	1.4265***	−2.6689***	1.9087***	3.0805***
	(56.83)	(−17.98)	(56.66)	(20.37)	(19.12)	(−3.78)	(21.61)	(4.39)
Adjusted R^2	0.7627	0.2737	0.7631	0.2880	0.5162	0.2845	0.5194	0.2904
Observation	143,633	119,503	143,602	119,479	88,080	65,618	88,054	65,598

Note: The table reports the fixed effect results examining the effect of CEO overconfidence on greenhouse carbon emission (Models 1–2 and 5–6) and the moderating role of female directors on the effect of CEO overconfidence on greenhouse carbon emission (Models 3–4 and 7–8). Models 1–4 report the results where banks, real estate, pharmaceutical, and software and computer services sectors are excluded, while Models 5–8 report the results where the United Kingdom and the United States are excluded from the sample. All variables are defined in Appendix A. All models are executed using the standard error robustness. The *t*-statistics are shown in parentheses.

*Statistically significant at 10% level.

**Statistically significant at 5% level.

***Statistically significant at 1% level.

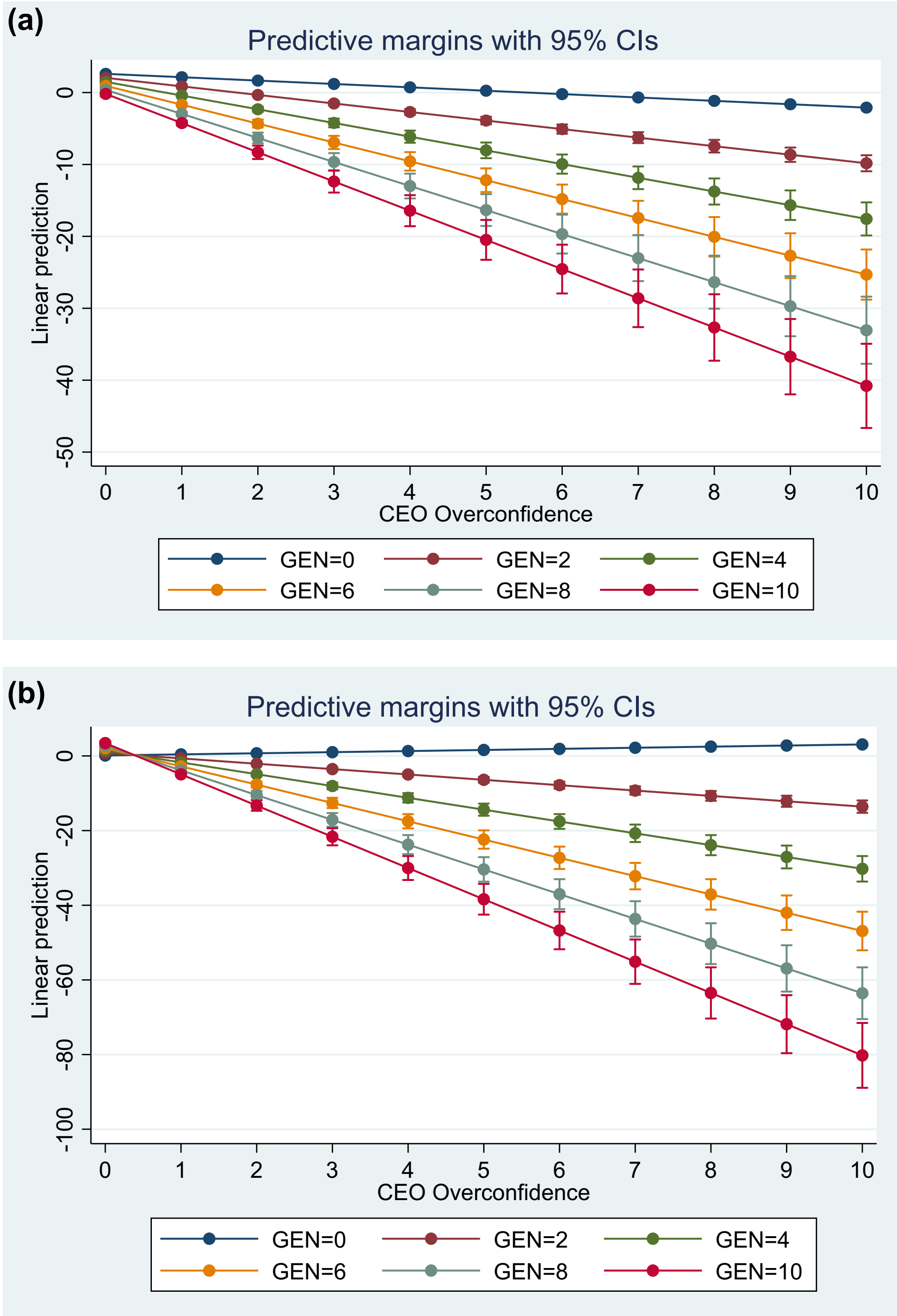

FIGURE 1 The moderating role of females on the association between CEO overconfidence and greenhouse carbon emission. (a) Moderating role of female on the association between CEO overconfidence and carbon emission (CO2_Log). (b) The moderating role of females on the association between CEO overconfidence and level of carbon emission (CO2_Lev).

estimated a conversational Mincerian equation with two-dimensional fixed effect to run high-dimensional fixed effect models to address unobservable heterogeneity across the firms as well as time-invariant heterogeneity, and our results are quantitatively similar. We also use lag effect and 2SLS models to address this potential endogeneity concern and report the results in Tables 4–6, which support our baseline results.

4.3 | Sensitivity analysis

4.3.1 | Alternative measures for CEO overconfidence

We conduct several sensitivity analyses to test the robustness of our baseline results. First, informed by behaviour finance literature, managerial hubris is related to the 'better-than-average' effect, which suggests that individuals with overconfidence overstate their abilities relative to others and are thus proud when they perform better than others (Hwang et al., 2020; Larwood & Whittaker, 1977; Moore & Healy, 2008). Informed by these studies, we constructed performance-based CEO overconfidence. We did this by first estimating the change in ROA. We construct an indicative variable, performance-based CEO overconfidence (PL_CEOVC), which equals one if the change in ROA is positive and above the sector median for three consecutive years and zero otherwise. We re-run the primary regression by replacing the CEO Overconfidence variable with the PL_CEOVC variable and report the results in Models 1–4 in Table 7. The results show that a performance-based, overconfident CEO reduces carbon emissions. Also, the negative effect of CEO overconfidence is more pronounced in the presence of female directors. These results imply that female directors play a significant role in enhancing an overall greener environment.

Second, we follow Malmendier and Tate (2005) to construct the third measure of CEO overconfidence—Net Buyer. In line with Malmendier and Tate (2005), we exploit the tendency of some of the CEOs to purchase additional company stock despite already having a high exposure to company risk. The existing literature (Ahmed & Duellman, 2013; Campbell et al., 2011; Li et al., 2018; Malmendier & Tate, 2005, 2008) argue that CEOs are overconfident if they were net buyers of company equity during their first 5 years. That is if they bought stock on the net in more years than they sold out on the net during their first 5 years. Thus, we use a disjoint subsample of CEO years to establish Net Buyer CEO overconfidence (NB_CEOVC) as an indicative variable equal to one if the CEO bought stock on the net in more years than they sold and zero otherwise. We re-run the regression and report the results in Models 5–8 in Table 7. The results show that Net Buyer-Led CEO overconfidence is associated with a high carbon footprint (Models 5 and 6); however, when introducing a female director in the boardroom, the coefficient of NB_CEOVC $\times$ GEN in Models 7 and 8 becomes negative and significant, indicating that female directors can are good at monitoring overconfident CEOs in reduction of carbon footprint.

Third, since our CEO overconfidence measure consists of five items, we examine each item separately to establish how much each power-led overconfidence item influences carbon emission. The results in Table 8 are quantitively similar to those in Tables 9 and 3, thus continuing to support our results.

Thus, we can conclude that power-led and performance-led overconfidence reduce carbon emissions; however, Net Buyer-led CEO overconfidence increases the carbon footprint. Female directors in the boardroom manage this characteristic, as they can effectively monitor the CEO's hubris by reducing the carbon footprint.

4.3.2 | Sectorial and country analysis

The sample distribution results in Table 1b show that the United Kingdom and the United States are significant countries in our sample, representing 14.57% and 37.95%, respectively. To find out whether our findings are driven by firms from the United Kingdom or the United States, we replicate our main tests by excluding United Kingdom and United States firms one at a time,[3] and further excluding both the United Kingdom and the United States. Despite this additional restriction, we find robust results in Models 5–8 of Table 8. Also, the sample distribution in Table 1c shows that (i) banks, (ii) pharmaceutical and biotechnology, (iii) real estate and (iv) software and computer services are major sectors in our sample, with each representing more than 6% (in total 25%). To find out whether these sectors drive our findings, we replicate our main tests by excluding each sector firm one at a time[4] and further exclude both the United Kingdom and the United States and find robust results in Models 1–4 of Table 10.

4.3.3 | Marginal effects plots for moderation role

To determine the level of gender diversity at which CEO overconfidence is significantly affected, we examine the marginal effect of interactive variables of gender diversity and the impact of CEO overconfidence on GHG emissions. The graphs in Figure 1a,b show a negative marginal effect of interactive variables of gender diversity. These results are supported by our main results in Tables 9 and 3, which show that the negative impact of CEO overconfidence on GHG emissions is strengthened as the number of female directors increases in the boardroom. This suggests that female directors should complement CEO overconfidence in the boardroom.

5 | CONCLUSION

Considering global attention to carbon reduction efforts, we examine if the behavioural attributes of executives can be leveraged for decarbonisation. Specifically, we proxy CEO overconfidence in three forms: power-led CEO, performance-led CEO and Net-Buyer-led CEO overconfidence, to investigate the role of CEO overconfidence in a firm's carbon footprint. We also examine how female representation on corporate boards affects the carbon priorities of overconfident CEOs. The results of our analysis indicate that firms with power-led and performance-led overconfident CEOs emit less GHG; however, firms with Net-Buyer-led overconfident CEOs emit a higher carbon footprint. In examining the role of female boards, we demonstrate that having more female representation on boards could induce overconfident CEOs to take stringent decarbonisation action. Our results are robust to alternative econometric specifications and a battery of tests. Our study recommends the consideration of executive behavioural

[3]We find robust results; however, for brevity and space management, we did not report a step-by-step exclusion; rather, we have reported the results for the exclusion of both the United Kingdom and the United States.

[4]We find robust results; however, for brevity and space management, we did not report a step-by-step exclusion; rather, we have reported the results for exclusion in all four sectors.

traits and gender representation when developing corporate carbon reduction strategies.

The study has potential implications for practitioners, policymakers and regulatory authorities. First, for corporate stakeholders, when designing decarbonisation strategies, it is important to consider how the CEO's perception of his/her abilities could affect the potential deliverables from the strategy. As we demonstrate, depending on the form of managerial overconfidence, the leverageable benefit could be positive or adverse. For managers at the helm of a low-carbon transition policy, conviction and charisma are valuable tools that can enhance the effectiveness and efficiency of the transition. For regulators, it is important to consider the role of corporate governance at large when designing corporate environmental regulatory policies. For investors seeking talents for the green transition, the degree of confidence the potential CEO exudes and female representation on boards could provide added advantages.

Future studies could examine how the degree of CEO overconfidence level affects corporate outcomes of other forms of climate risk. Furthermore, researchers can explore market reaction to the exit of overconfident CEOs who belonged to firms with high climate risk. Other CEO features like marital status, childhood upbringing, religious values and other lived experiences could affect firm green outcomes.

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APPENDIX A: MEASUREMENT VARIABLES AND DEFINITION.

Variable	Name	Measurement
CEOVC	CEO overconfidence	This is measured by the index which is the total sum of the CEO pay slice, CEO tenure, CEO share ownership, CEO duality and CEO directorship.
GEN	Gender	This is measured as the percentage of female directors in the boardroom obtained by dividing the number of females in the boardroom by the total number of board members (board size) multiplied by 100.
BSZ	Board size	This is measured as the total number of board members in the boardroom.
BIN	Board independence	This is measured as the total number of independent non-executive directors deflated by board size.
COPT	Co-opt board	This is measured as the number of co-opted directors deflated by board size.
MTB	Market-to-book ratio	This is measured as the market value of equity divided by the firm's book value of equity.
FSZ	Firm size	This is measured as the natural logarithm of a firm's total assets.
CAPEX	Capital expenditure	This is measured as a firm's total capital expenditures deflated by a firm's total assets.
RD	Research and development	This is measured as a firm's total research and development expenditures deflated by a firm's total assets.
CASH	Cash	This is measured as the firm's net cash and cash equivalent deflated by a firm's total assets.
LEV	Leverage	This is measured as the total value of debts deflated by the total value of assets.
ROA	Return on assets	This is measured as earnings before interest, taxes, depreciation and amortisation (EBITDA) deflated by total assets.
SLK	Slack	This is the total value of current assets deflated by the total value of assets.
GDPG	GDP growth rate	This is the gross domestic product growth rate.