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Board Directorships and Carbon Emissions: Curvilinear Relationships and Moderating Roles of Other Board Characteristics

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Abstract: Our research investigates the moderating roles of various board characteristics (independence, gender diversity, tenure, duality, and size) on the curvilinear relationship between board directorships and carbon emissions using a two-step generalized method of moments (GMM) system approach. We use a total of 1582 observations from 391 firms listed in the US Standard and Poor 500 (S&P 500) index collected from 2015 to 2021. Our findings provide empirical evidence in four aspects: (1) there is a U-shaped curvilinear relationship between board directorships and carbon emissions; (2) board directors should not go over two directorships because carbon emissions are likely to increase; (3) board independence, duality, and size positively moderate curvilinear relationships between board directorships and carbon emissions; and (4) board tenure and gender diversity negatively moderate curvilinear relationships. Our study contributes to expanding the existing literature related to sustainable corporate governance in the US market, and also has implications for regulatory issues, business practice, and further research.

Keywords: carbon emissions; board characteristics; corporate governance

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1. Introduction

Carbon emissions are one of the main reasons for climate change, which leads to various natural disasters (Tanthanongsakkun et al. 2022), and environmental sustainability is becoming a major strategy for firms to increase their competitive advantages (Ammer et al. 2020). Recent research findings suggest that firms display their environmental endeavors to internal and external stakeholders to increase their competitive advantages by improving their reputation, reducing business risks, and ultimately increasing their financial performance (Kalyar et al. 2020).

Board directors have the power to control firms' industrial processes and environmental practices, which have impacts on carbon emissions; therefore, researchers and business practitioners strive to identify appropriate corporate governance mechanisms to improve carbon performance. Legitimacy theory (Dowling and Pfeffer 1975) utilizes several board characteristics to investigate the relationships between board oversight quality and carbon performance, providing theoretical support for the relationship between board characteristics and carbon performance. Moreover, whereas some researchers found insignificant or negative results (Krishnamurti and Velayutham 2018; Li et al. 2018), most found that boards with desirable characteristics improve carbon performance (García Martín and Herrero 2020; Haque 2017; Liao et al. 2015; Tingbani et al. 2020).

Researchers have analyzed the positive and linear effects of different board characteristics on environmental performance or carbon disclosure. However, based on different frameworks such as the legitimacy, agency, stewardship, attention/busyness, and resource dependence theories, as well as the management friendliness (or entrenchment) and expertise hypotheses, we postulate that these effects might not necessarily be positive and proportional. Therefore, our study investigates the curvilinear relationships between multiple board directorships and carbon outputs, as well as the moderating roles of other board characteristics, such as gender diversity, and board independence, tenure, duality, and size. Our research fills gaps in the literature and provides empirical evidence on the interplay between board characteristics and carbon emissions. We address the following research questions:

RQ1: Is there a curvilinear (U-shaped) relationship between board directorships and carbon performance for listed US firms?

RQ2: Do other board characteristics moderate the curvilinear relationship between board directorships and carbon performance?

In addressing this research question, we make five contributions. First, this is the first study that examines the curvilinear relationship between board directorships and actual carbon emissions. Our unique findings in this study will enable policymakers to mandate the maximum number of board directorships. Second, because recent research only focuses on general environmental indicators, such as carbon disclosure, we consider actual carbon emissions as the key indicators of carbon performance. In contrast to carbon disclosure, carbon emissions are good indicators of human, financial, and technological resources, which better reflect firms' continuous environmental commitments (Luo et al. 2012). Third, this is the first study that investigates the moderating roles of various board characteristics. Our unique findings provide inspiration to policymakers for possible regulations on board structure to strengthen the benefits of the knowledge and experience obtained from other board directorships while weakening the adverse effects of busyness due to multiple directorships. Fourth, our results provide inspiration to practitioners to compose their boards while considering the effects of various board characteristics on the curvilinear relationships between board directorships and carbon emissions. Finally, our research provides insights for other researchers studying the relationships between board directorships and carbon emissions, namely that they should take into account curvilinear, rather than linear, relationships between board directorships and carbon emissions.

Our paper is structured as follows: Section 2 provides a theoretical background on, and a literature review of, the link between board characteristics and carbon emissions. Then, based on legitimacy theory and the literature, we develop our six main hypotheses. Section 3 provides a description of the data, variables, and the econometric model. Thereafter, we present our results (Section 4), which is followed by a discussion of our findings (Section 5). Finally, we conclude the paper in Section 6.

2. Theoretical Background, Literature Review, and Hypothesis Development

2.1. Theoretical Background

Although scholars have used various theories to explain the relationship between board characteristics and carbon performance (e.g., principal agent, stakeholder, and resource dependence theories), the most widely used is legitimacy theory (Kılıç and Kuzey 2019), which is based on a "social contract" formed between organizations and society—organizations should behave properly and desirably within the norms, values, and beliefs of society (Suchman 1995). If organizations' behaviors considerably deviate from the norms of society, they are seriously sanctioned. Consequently, organizations must recruit board members with appropriate characteristics to improve carbon performance to meet societal expectations. Thereby, organizations that enhance board effectiveness in improving carbon emissions meet societal expectations, which ultimately enhances their legitimacy (Suchman 1995). As organizations are currently under tremendous pressure to be responsive to climate changes, they must strive to improve board characteristics to reduce carbon emissions and enhance their legitimacy. However, organizations often engage in impression management—organizations with poorer environmental performance often disclose more information concerning environmental protections (Cho et al. 2012). Thus, there are concerns regarding whether boards with effective characteristics only engage in impression management to secure legitimacy rather than a genuine desire to oversee their organizations' carbon performances (de Villiers and Staden 2011; Post et al. 2011).

2.2. Hypotheses Development

2.2.1. Effects of Board Directorships on Carbon Emissions

Currently, contrastive empirical findings provide support to two competing views, namely resource dependence theory and the attention/busyness hypothesis (Hundal 2017; Lu and Herremans 2019). The resource dependence theory suggests that directors with multiple directorships are more experienced in dealing with environmental issues, which may contribute to their firms' better carbon performances. The attention/busyness theory hypothesizes that busy board members holding multiple directorships may diversify their attention and commitment between different firms (Ahn et al. 2010). Consequently, serving on too many boards may negatively affect firms' carbon emission performance. In the US, there is no set limit on the number of outside boards on which directors can serve. Nevertheless, the Principles of Corporate Governance indicate that multi-directorship may negatively affect board members' capabilities to discharge their responsibilities (Business Roundtable 2016). Though increasing the number of directorships may guarantee more resources for firms to reduce carbon emissions, after a certain level, board members may become too busy to carry out their duties toward monitoring the environmental issues. Considering these contradictory theoretical arguments, we postulate that board directorships may have a curvilinear relationship with carbon emissions. Based on the discussion above, we develop the following hypothesis:

H1. *There is a U-shaped relationship between board directorships and carbon performance.*

2.2.2. The Moderating Role of Board Gender Diversity

Agency theory posits that gender-diversified boards mitigate the agency problems arising from the separation of ownership and control (Arvanitis et al. 2022). The presence of women on a board encourages participative management styles and open communication in dealing with environment-related issues, promoting different perspectives about environmental performance (Lu and Herremans 2019) and contributing to increased effectiveness in monitoring carbon performance. In addition, women tend to have higher levels of empathy and dedication to the environment, which have a positive association with environmental behaviors (Al-Najjar and Salama 2022). Recent studies showed that diversified boards with women directors have positive impacts on carbon emissions (Al-Najjar and Salama 2022; Ben-Amar et al. 2017). Nevertheless, social identity theory suggests a different view—board diversity may be harmful to a firm's operation and performance. Gender-diverse boards may promote poor cohesion and misunderstanding between different gender groups, hindering the boards from solving problems and making decisions (Arvanitis et al. 2022). Therefore, we postulate the following hypothesis:

H2. *The presence of women on the board moderates the U-shaped relationship between board directorships and carbon performance.*

2.2.3. The Moderating Role of Board Independence

Agency theory promotes that independent boards monitor managers' opportunistic behaviors to improve firm performance and lower agency costs (de Villiers and Staden 2011). As independent directors are not involved in day-to-day firm operations, boards with a large proportion of independent directors are inclined to increase information transparency levels and facilitate considerable corporate governance compared with a board dominated by insiders (Armstrong et al. 2014). Independent directors with different expertise and backgrounds can help to achieve a balance between environmental and financial accountability (Khan et al. 2021), resulting in improvements in environmental performance (Alipour et al. 2019). However, Walls et al. (2012) argues that board independence could have negative impacts on environmental performance because the presence of independent directors might result in the neglect of executive directors' knowledge and experience (Dalton et al. 2007). Based on the discussion above, we develop the following hypothesis:

H3. *The presence of independent directors on the board moderates the U-shaped relationship between board directorships and carbon performance.*

2.2.4. The Moderating Role of Board Tenure

Board tenure can be defined as the average number of years the firm's directors have served on the board (Hambrick and D'Aveni 1992). Results from empirical studies provide conflicting conclusions about the effect of board tenure on firm environmental performance (Wertheim et al. 2016). Such polarized conclusions can be explained by two competing hypotheses, namely the management friendliness (or entrenchment hypothesis) and expertise hypotheses (Vafeas 2003; Wertheim et al. 2016). The former suggests that the presence of long-tenured directors is detrimental to firm environmental performance. The increased director tenure may result in close relationships between management and the directors, resulting in a lack of board objectivity and independence, which leads to an over-reliance on management's assertions, which is called management-friendly bias (Patro et al. 2018). The negative impacts induced by bias results in ignorance toward shareholder concerns and substandard environmental performance (Schnake et al. 2006). Alternatively, the expertise hypothesis presumes that longer board tenure will enhance firm environmental performance as directors accumulate experience, knowledge, and competence over time (Liang and Wang 2021), and that their accumulated expertise and understanding regarding firm-related matters will make them capable advisors for monitoring management (Brickley and Zimmerman 2010). In addition, directors of longer board tenure are believed to have higher reputational concerns, more professional commitment, and a better understanding of environmental changes (Hussain et al. 2018). The impact of director tenure on environmental performance can be considered a compromise between a loss of independence and expertise accumulation (Patro et al. 2018); therefore, we postulate the following hypothesis:

H4. *Board tenure moderates the U-shaped relationship between board directorships and carbon performance.*

2.2.5. The Moderating Role of Duality

CEO duality refers to the practice of an individual simultaneously serving as both the CEO and board chair in an organization (Krause et al. 2014). The impact of CEO duality on firm performance has been an inconclusive topic of corporate governance in academic and practical fields (Carty and Weiss 2012). From one perspective, CEO duality is unfavorable for firm performance because it considerably empowers the CEO/board chair, exposing minority shareholders' interest at risk (Haniffa and Cooke 2002). As a result, firms may have less involvement in managing environmental issues, such as carbon emissions (Muttakin and Subramaniam 2015). However, from the perspective of stewardship theory, CEO duality has a positive association with firm performance. Combining the two managerial positions of CEO and board chair into a single role helps to establish unified commands for facilitating firm decision making (Pham and Pham 2020).

Some scholars regard CEO duality as a potential moderating factor instead of an antecedent. For instance, Velte (2019) finds that under the presence of powerful CEOs, the positive correlation between environmental and financial performance becomes more considerable, which aligns with the research conducted by Walls and Berrone (2017)—they argue that CEO duality moderates the positive relationship between shareholder activism and sustainability performance. However, while empirical findings reveal that CEO duality is associated with a low tendency to voluntarily disclose limited environmental measures (Gul and Leung 2004), extant study results suggest that a board directorship has a positive relationship with environmental performance. Therefore, we postulate that CEO duality intensifies the effects of director busyness and weakens the effects of expertise obtained from other directorships on carbon performance. Accordingly, we develop the following hypothesis:

H5. *CEO duality moderates the U-shaped relationship between board directorships and carbon performance.*

2.2.6. The Moderating Role of Board Size

Devising appropriate sustainable business strategies and monitoring and disclosing material environmental risks are the main responsibilities of boards (Ben-Amar et al. 2017). There are diverse opinions regarding board size on environmental performance (Palaniappan 2017). Some scholars suggest that larger boards strengthen their monitoring functions and capacities, which are positively associated with carbon emission disclosure (Farag and Mallin 2017; García Martín and Herrero 2020 and environmental performance (de Villiers and Staden 2011). Other study results affirm that larger boards underperform compared with smaller boards, which allow for faster decision making and better management and monitoring functions (Goud 2022; Jizi et al. 2014; Orozco et al. 2018). However, among those studies, few researchers investigated the relationship between board size and actual carbon emissions. Therefore, we develop the following hypothesis:

H6. *The number of members on the board moderates the U-shaped relationship between board directorships and carbon performance.*

3. Research Design

We built the following econometric models to test H1–H6:

To test H1:

$$\begin{aligned}\mathrm{LNTCAR}_{it} = {} & \beta_0 + \beta_1\mathrm{BDIRECT}_{it} + \beta_2\,\mathrm{BDIRECT2}_{it} + \beta_3\,\mathrm{LNBREN}_{it} + \beta_4\mathrm{CAPEXP}_{it} + \beta_5\mathrm{LEV}_{it} \\ & + \beta_6\mathrm{MVBV}_{i,t} + \beta_7\mathrm{ROA}_{it} + \beta_8\mathrm{LNTA}_{it} + \beta_9\mathrm{IND}_{it} + e_{it}\end{aligned}$$

To test H2:

$$\begin{aligned}\mathrm{LNTCAR}_{it} = {} & \beta_0 + \beta_1\mathrm{BDIRECT}_{it} + \beta_2\,\mathrm{BDIRECT2}_{it} + \beta_3\,\mathrm{BDIRECT2}_{it} \times \mathrm{BGEN}_{it} + \beta_4\,\mathrm{BDIRET}_{it} \times \mathrm{BGEN} \\ & + \beta_5\,\mathrm{BGEN}_{it} + \beta_6\,\mathrm{LNBREN}_{it} + \beta_7\mathrm{CAPEXP}_{it} + \beta_8\mathrm{LEV}_{it} + \beta_9\mathrm{MVBV}_{i,t} + \beta_{10}\mathrm{ROA}_{it} \\ & + \beta_{11}\mathrm{LNTA}_{it} + \beta_{12}\mathrm{IND}_{it} + e_{it}\end{aligned}$$

To test H3:

$$\begin{aligned}\mathrm{LNTCAR}_{it} = {} & \beta_0 + \beta_1\mathrm{BDIRECT}_{it} + \beta_2\,\mathrm{BDIRECT2}_{it} + \beta_3\,\mathrm{BDIRECT2}_{it} \times \mathrm{BIND}_{it} \\ & + \beta_4\,\mathrm{BDIRECT}_{it} \times \mathrm{BIND} + \beta_5\,\mathrm{BIND}_{it} + \beta_6\,\mathrm{LNBREN}_{it} + \beta_7\mathrm{CAPEXP}_{it} + \beta_8\mathrm{LEV}_{it} \\ & + \beta_9\mathrm{MVBV}_{i,t} + \beta_{10}\mathrm{ROA}_{it} + \beta_{11}\mathrm{LNTA}_{it} + \beta_{12}\mathrm{IND}_{it} + e_{it}\end{aligned}$$

To test H4:

$$\begin{aligned}\mathrm{LNTCAR}_{it} = {} & \beta_0 + \beta_1\mathrm{BDIRECT}_{it} + \beta_2\,\mathrm{BDIRECT2}_{it} + \beta_3\,\mathrm{BDIRECT2}_{it} \times \mathrm{BTEN}_{it} \\ & + \beta_4\,\mathrm{BDIRECT}_{it} \times \mathrm{BTEN} + \beta_5\,\mathrm{BTEN}_{it} + \beta_6\,\mathrm{LNBREN}_{it} + \beta_7\mathrm{CAPEXP}_{it} + \beta_8\mathrm{LEV}_{it} \\ & + \beta_9\mathrm{MVBV}_{i,t} + \beta_{10}\mathrm{ROA}_{it} + \beta_{11}\mathrm{LNTA}_{it} + \beta_{12}\mathrm{IND}_{it} + e_{it}\end{aligned}$$

To test H5:

$$\begin{aligned}\mathrm{LNTCAR}_{it} = {} & \beta_0 + \beta_1\mathrm{BDIRECT}_{it} + \beta_2\,\mathrm{BDIRECT2}_{it} + \beta_3\,\mathrm{BDIRECT2}_{it} \times \mathrm{DUALITY}_{it} \\ & + \beta_4\,\mathrm{BDIRECT}_{it} \times \mathrm{DUALITY} + \beta_5\,\mathrm{DUALITY}_{it} + \beta_6\,\mathrm{LNBREN}_{it} + \beta_7\mathrm{CAPEXP}_{it} + \beta_8\mathrm{LEV}_{it} \\ & + \beta_9\mathrm{MVBV}_{i,t} + \beta_{10}\mathrm{ROA}_{\ it} + \beta_{11}\mathrm{LNTA}_{it} + \beta_{12}\mathrm{IND}_{it} + e_{it}\end{aligned}$$

Finally, to test H6:

$$\begin{aligned}\mathrm{LNTCAR}_{it} = {} & \beta_0 + \beta_1\mathrm{BDIRECT}_{it} + \beta_2\,\mathrm{BDIRECT2}_{it} + \beta_3\,\mathrm{BDIRECT2}_{it} \times \mathrm{LNBSIZE}_{it} \\ & + \beta_4\,\mathrm{BDIRECT} \times \mathrm{LNBSIZE}_{it} + \beta_5\,\mathrm{LNBSIZE}_{it} + \beta_6\,\mathrm{LNBREN}_{it} + \beta_7\mathrm{CAPEXP}_{it} + \beta_8\mathrm{LEV}_{it} \\ & + \beta_9\mathrm{MVBV}_{i,t} + \beta_{10}\mathrm{ROA}_{it} + \beta_{11}\mathrm{LNTA}_{it} + \beta_{12}\mathrm{IND}_{it} + e_{it}\end{aligned}$$

The definitions of variables are found in Table 1.

Table 1. Descriptive statistics.

Variable	Description	Mean	STD	Min	Max
LNTCAR	Natural log value of total carbon emissions.	13.15	2.35	−1.24	18.64
BDIRECT	Average of board members' directorships.	1.04	0.55	0	6.91
BGEN	Proportion of female directors on the board	23.9	9.61	0	66.67
BIND	Proportion of independent directors on the board.	84.99	9.11	37.5	100
LNBSIZE	Natural log value of number of board members.	2.37	0.21	0	3.33
DUALITY	1 if CEO and chairperson are the same person, 0 otherwise.	0.33	0.47	0	1
BTEN	Average of board members' tenure.	9.10	3.54	0	29.44
LNBREN	Natural log value of total board remuneration.	14.84	0.52	10.51	18.76
MVBV	Market-to-book value ratio.	2.24	77.14	−2218.63	1331.24
LEV	Total assets divided by total liabilities.	1.92	4.19	−108.17	183.11
CAPEXP	Addition of capital expenditure.	0.036	0.04	0	0.42
ROA	Net income divided by total assets.	0.07	0.08	−1.22	1.21
IND	If a firms operates in a carbon-intensive industry: industrials; materials; energy; utilities; or transportation, the dummy variable takes a value of 1, otherwise 0.	0.266	0.44	0	1
LNTA	Natural log value of total assets.	16.86	1.43	12.01	22.04

3.1. Sampling and Data Collection

We collected the data from all firms listed on the Standard and Poor 500 (S&P 500) from 2015 to 2021, which are extracted from Thomson Reuters Datastream and companies' annual reports. We selected the samples from the United States, a country facing serious warming-climate threats, because it ranked second among the largest emitter countries in the world (BP 2018). We chose the periods from 2015 to 2021 because the United States joined the Paris agreement in 2015 but then withdrew in 2017—we wanted to observe how board characteristics contributed to carbon management in this period of time. After dropping firms with unavailable financial, board, and carbon emission data, our final sample covered 391 firms for a total of 1582 observations.

3.2. Variables

Our research uses the natural log value of total carbon emissions (LNTCAR) (Moussa et al. 2020) as a dependent variable. We measured the key variable, board directorships (BDIRECT), as the average of board members' directorships. Previous research showed that board memberships enables directors to gain additional knowledge and expertise from other directorships for performing their monitoring roles; however, the results of other studies showed that board members with 'over-directorships' are exhausted when performing their responsibilities. Thus, we postulated that the relationship between carbon emissions and board directorships is curvilinear.

We measured board gender diversity (BGEN) as the ratio of women on the board (García Martín and Herrero 2020). Women board members may be more risk-averse and ethical; therefore, they may perform their oversight roles more effectively. We expected board gender diversity to considerably moderate the relationship between board directorship and carbon emissions. Board independence (BIND) is reflected by the proportion of independent directors on the board. They are members who can resist influence from managers. We argued that board independence considerably moderates the relationships between board directorships and carbon emissions. Board tenure (BTEN) reflects the average number of years that directors have served on the board. Long-tenured boards may have more specific knowledge, which results in more effective firm monitoring. However, if board members have a close relationship with managers, the board's oversight ability may be reduced. We argued that board tenure considerably moderates the relationship between board directorships and carbon emissions. We measured board duality (DUALITY) through an indicator of 1 (if the chairperson and CEO are the same person) or 0. Board duality provides the board chairperson with stronger oversight powers; however, on the contrary, oversight quality is reduced because they may abuse their power to act for his or her benefit at the shareholders' cost. We argued that board duality considerably moderates the association between board directorships and carbon emissions. We measured board size (LNBSIZE) as the natural log value of the number of directors on a board. A larger board size ensures more human resources with which to perform its oversight role. We anticipated that board size would considerably moderate the relationship between board directorships and carbon emissions. Our study included a number of control variables, which recent research results found to affect carbon emission. For other board characteristics, we controlled for the impacts of board remuneration (LNBREN). For firm financial performance, we controlled for the influence of return on total assets (ROA) and market-to-book ratio (MVBV). We used leverage (LEV) to control for the effects of financial burden, and used natural log value of total assets (LNTA) to control for the effects of firm size. Lastly, we controlled for the effects of capital intensity using capital expenditure (CAPEXP). Following Konadu et al. (2022) and Nuber and Velte (2021), we controlled for the effects of the carbon emissions from firms operating in carbon-intensive industries by including a dummy variable (IND). If a firms operates in a carbon-intensive industry: industrials; materials; energy; utilities; or transportation, the dummy variable takes a value of 1, otherwise 0.

4. Results

4.1. Descriptive and Correlations

The descriptive statistics in Table 1 document that our sample's mean natural log value of total carbon emissions (LNTCAR) is 13.15, which is equivalent to 514,011 tons. The means of board members' directorships (BDIRECT), board gender diversity (BGEN), and board independence (BIND) are 1.04, 23.90%, and 84.99%, respectively. The mean of the natural log value of board size (LNBSIZE) is 2.37, which is equivalent to 10.70 members. Table 2 shows the Pearson correlations of the variables in our regression models and reflects the absence of the multicollinearity problem. Multicollinearity exists when a multiple linear regression analysis consists of variables that are significantly associated not only with the dependent variable but also to each other (Shrestha 2020), resulting in researchers being unable to discriminate between the individual effects of independent variables on dependent variables. As reflected in the correlation matrix, the coefficients for each explanatory variable in the regression models are between −0.198 and 0.587. Thus, these values are below the threshold, which suggests that there are no serious correlation problems among our regressors. Table 3 also shows the results of our variance inflation factor (VIF) tests for the models that we additionally ran to check for multicollinearity problems. The VIFs of our variables are lower than 2.00, suggesting a lack of multicollinearity (VIF > 10) (Mertens et al. 2017).

Table 2. Correlation matrix.

	LNTCAR	BDIRECT	BGEN	BIND	BTEN	LNBSIZE	DUALITY	LNBREN	CAPEXP	LEV	MVBV	ROA	LNTA	IND
LNTCAR	1													
BDIRECT	0.0851 ***	1												
BGEN	−0.0950 ***	0.127 ***	1											
BIND	0.121 ***	0.176 ***	0.119 ***	1										
BTEN	−0.118 ***	−0.151 ***	−0.0941 ***	−0.128 ***	1									
LNBSIZE	0.134 ***	0.0208	0.0298	0.0597 *	0.0211	1								
DUALITY	−0.0710 **	0.0169	−0.0176	0.0481 *	−0.198 ***	−0.105 ***	1							
LNBREN	0.0413	0.0485 *	0.0687 **	0.0483 *	−0.00132	0.483 ***	0.00329	1						
CAPEXP	0.452 ***	−0.0130	−0.106 ***	−0.0254	0.0310	−0.205 ***	0.0588 *	−0.116 ***	1					
LEV	−0.150 ***	−0.0458 *	−0.0485 *	−0.197 ***	0.0189	−0.163 ***	0.0920 ***	0.00605	0.0968 ***	1				
MVBV	−0.0265	−0.00196	−0.0244	−0.0105	−0.0203	0.00992	0.00249	0.00770	−0.0215	0.0148	1			
ROA	−0.184 ***	−0.0372	0.0280	−0.0277	0.0572 *	−0.0825 ***	−0.0131	0.0184	−0.0668 **	0.191 ***	0.00231	1		
LNTA	0.194 ***	0.158 ***	0.0857 ***	0.113 ***	−0.088 ***	0.424 ***	−0.105 ***	0.387 ***	−0.159 ***	−0.210 ***	−0.0080	−0.29 ***	1	
IND	0.587 ***	0.0596 *	−0.0378	0.127 ***	−0.0358	−0.0442	0.0104	−0.087 ***	0.375 ***	−0.0503 *	0.00876	−0.16 ***	−0.066 **	1

Note(s): *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. The definitions of variables are found in Table 1.

Table 3. Variance inflation factor.

Variable	VIF
LNTA	1.54
LNBIZE	1.50
LNBREN	1.44
CAPEXP	1.25
IND	1.23
ROA	1.18
LEV	1.14
BTEN	1.09
BDIRECT	1.08
BGEN	1.05
MVBV	1.00

The definitions of variables are found in Table 1.

4.2. Main Results

We used two-step GMM estimators (derived by Arellano and Bond 1991) and treated all explanatory variables as endogenous to avoid possible endogeneity problems and biases because of weak instruments. Tables 4 and 5 show our results.

Table 4. Main results: two-step GMM regression for Models 1, 2, and 3.

	Model 1	*p*-Value	Model 2	*p*-Value	Model 3	*p*-Value
L.LNTCAR	1.216 ***	0.000	0.538 ***	0.000	0.485 ***	0.000
BDIRECT	−0.280 ***	0.002	0.117	0.500	1.107	0.642
BDIRECT^2	0.0476 ***	0.003	0.0244	0.542	−1.028 *	0.069
BDIRECT^2 × BGEN			−0.002 *	0.050		
BDIRECT × BGEN			0.0005	0.923		
BGEN			−0.001	0.761		
BIDRECT^2 × BIND					0.0104 *	0.080
BDIECT × BIND					−0.009	0.745
BIND					0.013	0.608
CAPEXP	−0.5317 **	0.034	14.595 ***	0.000	15.446 ***	0.000
LEV	0.0591 ***	0.005	−0.087 ***	0.002	−0.0106 **	0.41
LNBREN	−0.0264	0.247	0.063	0.289	−0.092	0.303
MVBV	0.0002 **	0.005	−0.0004	0.141	−0.0002	0.601
ROA	0.303 *	0.07	−0.262	0.478	−0.210	0.737
LNTA	−0.1132 **	0.025	0.252 ***	0.000	0.296 ***	0.000
IND	−0.423 **	0.017	0.904 ***	0.000	1.135 ***	0.001
CON	−0.129	0.633	0.175	0.855	0.2976	0.901
N	1582		1582		1582	
AR(2) *p* value		0.505		0.901		0.724
SARGEN *p* value		0.000		0.000		0.000
HANSEN *p* value		0.103		0.000		0.058

Note(s): *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. The definitions of variables are found in Table 1.

Our analysis of Model (1) determined that board directorship (BDIRECT) and its squared term (DDIRECT^2) are both considerably related to total carbon emissions from a statistical standpoint. In detail, while the coefficient for BDIRECT is negative (β = −0.280, $p < 0.01$), the squared term presents a positive sign (β = 0.0476, $p < 0.01$). Our findings show a curvilinear relationship (U-shape) between board directorships and carbon emissions, providing support for H1. To further test the curvilinear relationship and identify the turning point of the curve where the negative relationship becomes positive, we performed u-test (Lind and Mehlum 2010). Table 6 showed that our results documented the existence of a U-shaped relationship and indicated that the turning point is equal to 2.45, suggesting that, on average, if board directorships go beyond 2.45, the negative effects become positive.

Table 5. Main results: two-step GMM regression for Models 4, 5, and 6.

	Model 4	*p*-Value	Model 5	*p*-Value	Model 6	*p*-Value
L.LNTCAR	0.550 ***	0.000	0.982 ***	0.000	0.982 ***	0.000
BDIRECT	−0.6046 *	0.073	0.009	0.879	17.833 ***	0.005
BDIRECT^2	0.310 **	0.012	−0.037	0.727	−2.95 ***	0.006
BDIRECT^2 × BTEN	−0.05 ***	0.005				
BDIRECT × BTEN	0.0094 **	0.027				
BTEN	−0.0342	0.244				
BDIRECT^2 × DUALITY			0.046 *	0.072		
BDIRECT × DUALITY			−0.36 ***	0.006		
DUALITY			0.322 ***	0.006		
BDIRECT^2 × LNBSIZE					1.21 ***	0.005
BDIRECT × LNBSIZE					−7.30 **	0.015
LNBSIZE					8.295 ***	0.002
CAPEXP	14.35 ***	0.000	1.30	0.235	2.92	0.199
LEV	−0.083 **	0.013	−0.012	0.265	0.058 *	0.078
LNBREN	0.054	0.500	0.010	0.616	−0.294 ***	0.004
MVBV	−0.0002	0.522	0.0001 **	0.044	0.0003 **	0.015
ROA	0.216	0.621	0.214 *	0.065	0.364	0.149
LNTA	0.263 ***	0.000	0.02	0.355	−0.051	0.304
IND	0.887 ***	0.000	0.014	0.863	−0.075	0.648
CON	0.164	0.894	−0.392	0.153	−14.94 ***	0.005
N	1582		1582		1582	
AR(2) *p* value		0.906		0.269		0.329
SARGEN *p* value		0.000		0.004		0.145
HANSEN *p* value		0.001		0.108		0.247

Note(s): *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. The definitions of variables are found in Table 1.

Table 6. Results of U-test.

Extreme Point	2.45	
	Lower bound	Upper bound
Interval	0	6.91
Slope	−0.547	0.999
t-value	−2.06	2.493
p-value	0.0201	0.0066
Overall test of presence of a U-shape H1: U shape H0: Monotone or inverse U-shape		
t-value	2.06	
p-value	0.0201 **	

Note(s): ** denote significance at the 5% level.

Next, we turn our attention to the moderating effects of other board characteristics on curvilinear relationships (H2–H6).

First, we empirically tested H2 by extending Model (1) to examine board gender diversity (BGEN) and the interactions between board gender diversity and board directorships (BDIRECT × BGEN) and the related squared term (BDIRECT^2 × BGEN). We observed that the coefficient of BGEN does not have significant associations with carbon emissions (β = −0.001, $p > 0.10$). When investigating the moderating effect, we observed that the coefficient of BDIRECT^2 × BGEN (β = −0.002, $p < 0.10$) is negative and significant. Moreover, the coefficient of BDIRECT × BGEN (β = 0.0005, $p > 0.10$) is statistically insignificant. Thus, our estimates marginally support the predicted moderating effects of board gender diversity on the curvilinear relationship.

To test H3–H6, we performed similar procedures by including the interaction term and the related squared term. When testing H3, our findings suggested that the coefficient of BIND is statistically insignificant (β = 0.013, $p > 0.10$). Moreover, the coefficient of BIRECT × BIND (β = −0.009, $p > 0.10$) is insignificant; however, BDIRECTˆ2 × BIND has a positive and significant coefficient (β = 0.0104, $p < 0.10$). Our findings marginally supported the board independence's moderating effect on the curvilinear relationship. When testing H4, our findings showed that the coefficient of BTEN is insignificant (β = −0.0342, $p > 0.10$); however, the coefficient of BDIRECT × BTEN is significant and positive (β = 0.0094, $p < 0.05$), while the coefficient of BDIRECTˆ2 × BTEN is significant and negative (β = −0.05, $p < 0.01$). Our results confirmed board tenure's moderating effect on the curvilinear relationship.

When testing H5, we found that the coefficient of DUALITY is significant and positive (β = 0.322, $p < 0.01$). Moreover, the coefficient of BDRECT × DUALITY (β = −0.36, $p < 0.01$) is negative and significant, while the coefficient of BDIRECTˆ2 × DUALITY is positive and significant (β = 0.046, $p < 0.10$). Our findings marginally supported the moderating effects of duality on the curvilinear relationship. When testing H6, we observed that the coefficient of LNBSIZE is positive and statistically significant (β = 8.295, $p < 0.01$). Moreover, the coefficient of BDIRECT × LNBSIZE is also negative and significant (β = −7.30, $p < 0.015$), whilst the coefficient of BDIRECTˆ2 × LNBSIZE is significant and positive (β = 1.21, $p < 0.01$), which supports H6. Thereby, it is evident that board size positively moderates the curvilinear relationship between board directorships and carbon emissions. Table 7 summarises the results of hypothesis testing.

Table 7. Results of hypothesis testing.

Hypotheses	Results
H1	Supported ($p < 0.01$)
H2	Marginally supported ($p < 0.10$)
H3	Marginally supported ($p < 0.10$)
H4	Supported ($p < 0.01$)
H5	Marginally supported ($p < 0.10$)
H6	Supported ($p < 0.01$)

4.3. Robustness Tests and Alternative Analyses

We conducted two diagnostic tests for each estimated GMM model. First, we carried out the Arellano–Bond test for second-order autocorrelation in the first difference errors (Arellano and Bond 1991; Sarto and Saggese 2022). Tables 4 and 5 show there is no significant evidence of serial correlation, with the AR (2) *p*-value between 0.269 and 0.906. Next, we ran the Sargan test to examine if the instrumental variables are not associated with the error term. We also concluded that the null hypothesis of zero correlation can be rejected (Roodman 2009; Sarto and Saggese 2022). We also performed a Hansen test to analyze the presence of over-identification problems. We found that our models are robust for over-identification problems because the null hypothesis of over-identification fails to be rejected at a significance level of 5%, except for Models 2 and 4.

To evaluate the reliability of our findings, we conducted further robustness analyses and re-ran Model (1) to (6) using an alternative measure of the dependent variables. We used the natural log value of direct carbon emission intensity as our alternative measure of carbon emissions. We used direct carbon emissions because boards have more control over direct carbon emissions (Nuber and Velte 2021). Tables 8 and 9 show that our results are similar to those in the main analysis except that the relationships between board independence and direct carbon emissions are negative and significant (β = −0.0191, $p < 0.10$).

Table 8. Robust test: Models 7, 8, and 9.

	Model 7	*p*-Value	Model 8	*p*-Value	Model 9	*p*-Value
L.LNDIRCAR	1.131 ***	0.000	0.983 ***	0.000	0.0783	0.395
BDIRECT	−0.259 **	0.025	0.842	0102	−8.1544 *	0.070
BDIRECT^2	0.075 ***	0.002	−0.246 *	0.054	−1.661 *	0.064
BDIRECT^2 × BGEN			0.009 **	0.019		
BDIRECT × BGEN			−0.0326 *	0.056		
BGEN			0.0175	0.230		
BIDRECT^2 × BIND					−0.0191 *	0.054
BDIECT × BIND					0.0953 *	0.062
BIND					−0.097 **	0.043
CAPEXP	−1.905	0.744	1.583	0.599	34.35 ***	0.000
LEV	0.067	0.330	0.0138	0.711	−0.385 ***	0.000
LNBREN	−0.065	0.366	−0.0105	0.814	0.183	0.344
MVBV	0.0003	0.223	0.0001	0.566	−0.001	0249
ROA	0.367	0.307	0.1136	0.626	−0.146	0.885
LNTA	−0.0515	0.586	0.0215	0.659	0.438 ***	0.000
IND	−0.4793	0.434	−0.009	0.978	2.85 ***	0.000
CON	0.508	0.513	−0.555	0.253	7.640	0.148
N	1582		1582		1582	
AR(2) *p* value		0.209		0.237		0.191
SARGEN *p* value		0.000		0.043		0.000
HANSEN *p* value		0.002		0.112		0.000

Note(s): *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. The definitions of variables are found in Table 1.

Table 9. Robust tests: Models 10, 11, and 12.

	Model 10	*p*-Value	Model 11	*p*-Value	Model 12	*p*-Value
L.LNDIRCAR	0.900 ***	0.000	0.812 ***	0.000	0.969 ***	0.000
BDIRECT	−0.683 **	0.025	0.426	0.306	12.084 **	0.030
BDIRECT^2	0.245 ***	0.002	−0.081	0.363	−2.04 **	0.027
BDIRECT^2 × BTEN	−0.025 **	0.011				
BDIRECT × BTEN	0.068 *	0.052				
BTEN	−0.0152	0.596				
BDIRECT^2 × DUALITY			0.141	0.126		
BDIRECT × DUALITY			−0.654	0.153		
DUALITY			0.282	0.453		
BDIRECT^2 × LNBSIZE					0.805 **	0.028
BDIRECT × LNBSIZE					−4.794 **	0.032
LNBSIZE					6.600 ***	0.005
CAPEXP	4.874	0.262	6.95 **	0.026	4.48	0.154
LEV	−0.0097	0.857	−0.035	0.336	0.070	0.152
LNBREN	−0.0103	0.890	0.061	0.293	−0.446 ***	0.002
MVBV	0.0001	0.594	−0.000	0.764	0.0001	0.265
ROA	0.0954	0.787	−0.251	0.432	0.1603	0.521
LNTA	0.0619	0.375	0.0715	0.157	−0.057	0.274
IND	0.2602	0.566	0.478	0.139	−0.0672	0.842
CON	0.2238	0.815	−0.509	0.506	−8.65	0.060
N	1582		1582		1582	
AR(2) *p* value		0.297		0.166		0.247
SARGEN *p* value		0.000		0.024		0.000
HANSEN *p* value		0.137		0.219		0.407

Note(s): *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. The definitions of variables are found in Table 1.

5. Discussion

Based on a sample of S&P 500-listed firms observed between 2015 and 2021, our study applies Arellano–Bond GMM estimators and investigates the relationships among carbon emissions and board directorships, gender diversity, tenure, independence, duality, and size.

Our findings confirmed the existence of a U-shaped relationship between board directorships and carbon emissions (H1). Specifically, as previous study results predicted, our results indicated that carbon emissions diminished in correlation to a particular level of board directorships, whilst after a certain threshold level, the higher the number of board directorships, the higher the levels of carbon emissions. Our exploratory study suggested that board directors generally become more knowledgeable from directorships in other firms, supporting the resource dependence theory that multiple directorships enable directors to accumulate valuable experiences from external sources regarding governance and environment issues that include (but are not limited to) green performance and management (de Villiers and Staden 2011). Oversight regarding environmental outcomes is complex; therefore, intensive knowledge is required (Ortiz-de-Mandojana Natalia et al. 2012; Hillman et al. 2000). Nevertheless, our results reflected that board effectiveness in monitoring carbon emissions diminishes as board directorships exceed a certain threshold. This supports the notion of busyness hypotheses, namely that multiple directorships result in limiting one's attention, time, and capacity to offer useful decision-making insights (Ahn et al. 2010; Jiraporn et al. 2009).

In our study, we also investigated H2–H6 to evaluate the moderating role of other board characteristics.

We found that the presence of women on the board improved environmental performance. We observed that board gender diversity negatively moderated the curvilinear relationships between board directorships and carbon emissions, which supports H2. Our findings are consistent with prior studies that found that gender-diversified boards mitigated agency problems arising from the separation of ownership and control (Arvanitis et al. 2022). The presence of women on the board encouraged participative management styles and open communication when dealing with environment-related issues (Lu and Herremans 2019). Furthermore, women on the board tended to have higher levels of empathy and dedication to the environment, which have positive associations with environmental behaviors (Al-Najjar and Salama 2022). Our findings are inconsistent with previous studies that suggested that according to social identity theory, board diversity may be harmful to a firm's operation and performance. Gender-diverse boards may promote poor cohesion and misunderstanding between different gender groups, hindering the boards from solving problems and making decisions (Arvanitis et al. 2022).

Regarding H3, our findings documented that the existence of independent directors on boards positively moderated the U-shaped relationship between board directorships and carbon emissions. Our findings are consistent with prior studies that opined that board independence could have negative impacts on environmental performance because the presence of independent directors might result in neglecting executive directors' knowledge and experience (Dalton et al. 2007). Nevertheless, our findings are inconsistent with previous studies that found that a large proportion of independent directors are inclined to increase information transparency and facilitate good corporate governance compared with boards dominated by insiders (Armstrong et al. 2014).

Our analyses support H4, namely, that a long board tenure moderates the curvilinear relationship between board directorships and carbon emissions. Our findings are consistent with prior studies that provided support for the expertise hypothesis, which presumes that a longer board tenure enables directors to accumulate experience, knowledge, and competence (Liang and Wang 2021), allowing them to monitor the industrial processes and environmental practices devised by management. Our findings are not consistent with prior studies that provided support for the management friendliness hypothesis, namely that increases in director tenure may result in close relationships between management and the directors, producing a lack of board objectivity and independence and leading to an over-reliance on management's assertions—management-friendly bias (Patro et al. 2018).

Our study also supports H5. As expected, board duality positively moderates the curvilinear relationships between carbon emissions and board directorships, supporting the argument that CEO duality is unfavorable for firm environmental performance because it empowers the CEO/board chair, exposing the minority shareholders' interests at risk (Haniffa and Cooke 2002; Muttakin and Subramaniam 2015). However, our findings do not support stewardship theory, namely, that CEO duality has a positive association with firm enviromental performance. Combining the two managerial positions of CEO and board chair into a single role helps to establish unified commands for facilitating the firm's decision making (Pham and Pham 2020).

Our findings also support H6 because we observed that board size considerably moderated the curvilinear relationship between board directorships and carbon emissions. Our findings are in line with prior studies that concluded that larger boards underperform compared with smaller ones because small boards allow faster decision making, in addition to better managing and monitoring functions (Goud 2022; Jizi et al. 2014; Orozco et al. 2018). However, our work was inconsistent with other studies that observed that larger boards strengthened their monitoring functions and capacities, resulting in improved carbon emission disclosures (Farag and Mallin 2017; García Martín and Herrero 2020) and environmental performance (de Villiers and Staden 2011).

6. Conclusions

Our empirical study offers a wide range of contributions to the literature; furthermore, our practice is based on a number of theoretical frameworks. Our research makes contributions regarding various theories related to the relationships between board directorships and carbon emissions.

First, we provided new insights into the literature regarding the governance antecedents of carbon emissions. Though prior studies showed that board composition has a positive association with carbon performance (Velte et al. 2020), far less is known about the impacts of various board characteristics on the curvilinear relationships between board directorships and carbon emissions. Our article fills the gaps in the literature and advances understanding on curvilinear relationships by analyzing U-shaped relationships. Recent studies have only tested the presence of a positive and linear effect; however, our research provides evidence that board directorships are beneficial regarding carbon emissions oversight; however, too high a number of directorships can limit this outcome. Furthermore, by offering insights into the moderating effects of board gender diversity, independence, tenure, duality, and size regarding the above-mentioned curvilinear relationship, our study fills gaps in the literature by integrating research on the interplay between board characteristics and carbon emissions.

Some managerial implications can be also inferred from our study. Our research highlights that long board tenure is a meaningful driver of board oversight effectiveness, while high levels of board independence, combining the role of CEO and board chairman, and a large board size, may be detrimental to the effectiveness of the board's oversight on carbon performance. Therefore, we believe that board nomination committees should take these elements into account when designing their firms' boards. In particular, our findings suggest that more women should be appointed to the board to improve the quality of oversight on carbon emissions. Our results advise against limiting board tenure because a long-tenured board strengthens the benefits of knowledge obtained from other directorships to monitor carbon emissions. Furthermore, boards should not appoint too many independent directors or have too large a board size. In addition, our results encourage separating the roles of CEO and chairperson because duality weakens the benefits of the knowledge obtained from other directorships in performing monitoring roles.

Lastly, our findings suggest that when board directorships go beyond two to three positions, negative effects will become positive. Our results are helpful for policymakers, who should mandate that boards be prohibited in having an average number of directorships greater than three and must refrain from combining the role of CEO and chairperson. Our findings do not promote regulation for the mandatory rotation of board members to reduce board tenure or for boards to consist of only independent directors. Our results support the implementation of regulation for limiting board sizes and separating the roles of CEO and chairperson. Future research may examine different types of directorships and their effects on carbon emissions. On the other hand, because our studies are conducted using samples from the US, our results may not be generalizable to Asian countries. Future research may study these relationships in Asian countries.

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