Received: 30 March 2022 | Revised: 30 July 2023 | Accepted: 12 August 2023
DOI: 10.1002/bse.3555

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

Impact of corporate governance diversity on carbon emission under environmental policy via the mandatory nonfinancial reporting regulation

Dewan Muktadir-Al-Mukit[1] | Firoz Haroon Bhaiyat[2]

[1]Department of Accounting & Finance, Management School, University of Liverpool, Liverpool, UK

[2]UA92 Business School, University Academy 92, Manchester, UK

Correspondence
Firoz Haroon Bhaiyat, UA92 Business School, University Academy 92, Brian Statham Way, Old Trafford, Manchester M16 0PU, UK.
Email: firoz.bhaiyat@ua92.ac.uk

Abstract

This study builds on the expanding literature on the interplay of corporate governance and corporate environment behaviour following the introduction of the carbon reporting directives of the UK Companies Act in 2013. We specifically focus on seeking clarity on the relationship between gender diversity, board independence, and board size with corporate environmental performance. The study examines these relationships under a mandatory nonfinancial reporting (NFR) requirement and tests the impact of regulatory shocks on board composition and channels affecting carbon emission. The findings confirm that board gender diversity and independence improve a firm's environmental performance. And while larger board sizes lead to larger environmental investments, the study finds that larger board sizes leads to poor environmental performance for the firm. The findings contribute to developments in countries, such as the United States, where there is an ongoing debate on the adoption of a mandatory NFR of carbon and the response of corporate boards.

KEYWORDS

board composition diversity, carbon regulation, corporate governance, emission performance, greenhouse gas, nonfinancial reporting

1 | INTRODUCTION

Corporations face increasing pressure to address societal concerns due to their responsibility and accountability to their stakeholders. Stakeholders, providers of social licences for operating in society, are taking a keen interest in the environmental impact of these firms (Bouten et al., 2011; Carroll, 2016). Shareholders are increasingly considering investing in socially responsible firms due to the material impact of sustainable business practices on their portfolio performance (Bolton & Kacperczyk, 2021; Consolandi et al., 2022; Krueger et al., 2020). Specifically, there is growing concern over climate risk (Chithambo et al., 2020), which threatens the survival of lives and livelihood and increases the risk of financial sustainability of the economy at large (Dafermos et al., 2018). Hence, given recent debates on environmental degradation, it is highly expected that being liable to its stakeholders and being in the ultimate position for leading

Abbreviations: CDP, Carbon Disclosure Project; CEO, Chief executive officer; CG, Corporate governance; CSR, Corporate social responsibility; DID, Difference in difference; EBIT, Earnings before interest and tax; ESG, Environment, social and governance; ETS, Emissions Trading Scheme; FE, Fixed effects; FTSE, Financial Times Stock Exchange; GHG, Greenhouse gas; GMM, Generalized method of moments; MNC, Multinational corporations; NFR, Nonfinancial reporting; PPE, Property, plant and equipment; PSM, Propensity score matching; RBV, Resource-based view; RDT, Resource dependence theory; RE, Random effect; RGGI, Regional Greenhouse Gas Initiative; ROA, Return on assets; TRBC, The Refinitiv Business Classification; VIF, Variance inflation factor.

and directing the firm, corporate boards have a crucial role in monitoring and guiding the carbon performance of their firms (Haque, 2017; Kassinis & Vafeas, 2006; McKendall et al., 1999; Moussa et al., 2020; Peters & Romi, 2014).

This paper argues that without satisfying social responsibility, directors may fail to achieve greater financial performance, as growing literature favours stakeholder theory. It emphasizes value creation by fulfilling the social responsibility of firms while balancing the interest of different stakeholder groups (Donaldson & Preston, 1995; Fernández-Guadaño & Sarria-Pedroza, 2018; Freeman, 1984; Freeman et al., 2010). The responsiveness of boards towards sustainable business practices arises due to social responsibility and wealth maximization of its shareholders, as studies show that carbon performance is significantly related to the value of the firm (Baboukardos, 2017; Chapple et al., 2013; Griffin et al., 2017; Krishnamurti & Velayutham, 2018; Krueger, 2015; Matsumura et al., 2014). In addition, equity market participants are now increasingly considering the materiality of climate risks for their portfolio and collectively getting involved in different environmental organizations or climate risk projects (Bolton & Kacperczyk, 2021; Busch, 2019; Busch et al., 2016; Cotter & Najah, 2012; Ivanova, 2017; Krueger et al., 2020).

However, researchers argue that the success of carbon reduction strategies relies on the effectiveness of boards, where board effectiveness largely depends on its characteristics and composition (Haque, 2017; John & Senbet, 1998; Naciti, 2019; Villiers et al., 2011). Therefore, this study aims to provide evidence about how the effect of carbon reporting regulation on greenhouse gas (GHG) performance is reinforced, by stronger corporate governance (CG) mechanisms, through board composition diversity.

This study incorporates firms listed on the FTSE All Share Index during 2013–2019. The index includes 382 unique firms, filtering missing data, resulting in 1951 firm-year observations. The results show that board gender diversity is negatively and board size is positively related to carbon performance (GHG emissions), where board independence shows a negative lag linear effect. In order to further our understanding of the impact of carbon reporting regulation, we performed a quasi-natural experiment. We extend our data back to the pre-regulatory period of 2009. Next, we include US firms listed on the S&P 500 index as a control group against UK firms. We find that after the regulatory shock in 2013, the carbon emission of UK firms shows a greater negative influence by board composition diversity.

This study provides significant contribution to the expanding literature on board effectiveness and carbon emission performance (Aggarwal & Dow, 2012; Bui et al., 2020; Haque, 2017; Haque & Ntim, 2020; Homroy & Slechten, 2019; Konadu, 2017; Lu & Herremans, 2019; Luo & Tang, 2021; Nuber & Velte, 2021; Prado-Lorenzo & Garcia-Sanchez, 2010; Shaukat et al., 2016). Where previous studies were conducted under a voluntary GHG reporting context or without segregating voluntary and mandatory reporting, this study avails the opportunity of using standardized GHG emissions data under the mandatory NFR framework.

In addition, this study provides significant empirical support to the theoretical justification of increased regulation designed to address environmental concern (Sullivan & Gouldson, 2012; Unerman & O'Dwyer, 2007). To the best of our knowledge, this study is the first to address the regulatory shock of mandatory carbon disclosure on board effectiveness for tackling carbon risk. Specifically, we examine whether regulatory shock reinforces the impact of board diversity on carbon emission performance. Our study suggests climate regulation better reflects the boards' commitment to addressing carbon risk.

Unlike prior studies, apart from the direct impact of board composition diversity, this study also explores the potential channels through which it can affect carbon performance under mandatory reporting regulation. We find that emission policy, environmental innovation, environmental impact management capacity, and environmental investment are four potential channels through which board composition diversity affects carbon performance, mostly in a post-regulatory period. Finally, a key contribution also lies in the proposed theoretical model, which supports the proposition of stakeholder and resource-based view (RBV) in the context of the nexus between CG and environmental performance.

2 | THEORY, LITERATURE REVIEW, AND HYPOTHESIS DEVELOPMENT

2.1 | Theoretical proposition

Our theoretical proposition is underpinned by stakeholder theory and resource-based view (RBV). Stakeholder theory justifies the response of corporate boards for pursuing firms towards environmentally sustainable business practices. On the other hand, RBV signifies how corporate boards can contribute to the best practice of such business concerns so that firms can gain a competitive advantage. The environmental accountability of firms has now become an important issue with increased societal expectations from different stakeholder groups (Kassinis & Vafeas, 2006; Yadav et al., 2017). The stakeholder theory provides a better realization of the importance of responding and balancing the interests of these parties while developing capabilities for sustainable business practices (Freeman et al., 2010; Sarkis et al., 2010). Moreover, CG guidelines also urge the board to fulfil the interest of different stakeholder groups who are now demanding greater societal responsibility from the business firms (Nielsen, 2012; Vilchez et al., 2017).

Firms must consider societal value as a part of a larger societal system because their survival is highly dependent on societal acceptance (Maso et al., 2018). Previous studies also show the value relevance of the environmental performance of the firm (Baboukardos, 2017; Chapple et al., 2013; Griffin et al., 2017; Matsumura et al., 2014). These empirical studies show that market investors negatively value the carbon emission performance of firms within their portfolios. Nondisclosing or high carbon-polluting firms may also face negative economic consequences due to increased costs of finance, customer boycott, poor credit rating, or staff turnover (Bonetti et al., 2015; Chabowski et al., 2019; Finster & Hernke, 2014; Nguyen & Phan, 2020; Nofsinger et al., 2019). Therefore, it is argued that boards should align corporate policy environmentally sustainable business practices to avoid any negative response to the firm, due to financial and nonfinancial implications of sustainable business practices (Kock et al., 2012; Mason & Simmons, 2014).

On the other hand, the RBV suggests how corporate boards can facilitate the acquisition of necessary resources and develop capabilities, which are crucial for achieving competitive advantage through sustainable business practices (Barney, 1996; Barney et al., 2001; Hart, 1995; Wernerfelt, 1984). Schnittfeld and Busch (2016) advance the theoretical understanding of factors facilitating and hindering sustainability management within supply chains through an underpinning of the resource dependence theory (RDT). They summarize Pfeffer and Salancik's (1978) argument on RDT into three basic concepts, that is, organizational effectiveness, interdependence, and external control. They argue that the RBV is a more successful lens than the agency theory when understanding corporate boards. Pfeffer and Salancik (1978, p. 1) state that "… to understand the behaviour of an organization you must understand the context of the behaviour—that is, the ecology of the organizations…." They argue that directors provide four specific benefits: advice and counsel, channels of information between the firm and environmental contingencies, preferential access to resources, and legitimacy. Thus, the top management, through their existing relationships within the external environment, provides access to necessary resources for their firm (Hillman et al., 2000), which enables them to pursue sustainable business practices. The RBV suggests that firms with higher management skills can implement a proactive social and environmental strategy, where superior social and environmental performance can lead to a long-run competitive advantage (Chung & Cho, 2018). Therefore, to achieve a sustainable competitive advantage, we expect that through better networking and utilization of resources, board composition diversity would result in a profound commitment to addressing carbon risk.

2.2 | Mandatory carbon reporting

Recent literature has explored the effectiveness of boards in addressing carbon performance under voluntary reporting (Velte et al., 2020). However, there is a lack of evidence assessing whether the effect of NFR regulation on carbon performance is reinforced by board diversity. Therefore, following the adoption of the mandatory carbon reporting regulation in 2013, this study shows the influence of board composition diversity on the carbon emission performance of UK-listed firms.

As a potential channel of demonstrating commitment and accountability to stakeholders, there is growing pressure on firms to report their carbon performance (Bui & de Villiers, 2017). However, researchers emphasize the need for standardized carbon disclosure, which would enhance market efficiency and assist in better investment decisions (Busch, Johnson, & Pioch, 2020; Liesen et al., 2017). In addition, there is a concern relating to the reported GHG data quality under voluntary reporting regimes, which challenges the usefulness and comparability of the results of these studies (Busch, 2011; Busch, Johnson, & Pioch, 2020). Therefore, following the criticisms from researchers about the effectiveness of voluntary emission data (Busch, 2011; Kolk et al., 2008; Liesen et al., 2015; Tang & Demeritt, 2018) and demand for increased standardized GHG reporting to show the actual and potential contributions of the business firms towards tackling climate change, the UK government introduced mandatory nonfinancial carbon reporting for its listed firms since 2013 under the UK Companies Act 2006 (Strategic and Directors' Reports) Regulations 2013 (DEFRA, 2013). This regulation requires reporting of scope-1 and scope-2 emissions only.

Arguably, the introduction of mandatory NFR of carbon has led to increased visibility of the carbon performance of listed firms, which ultimately puts them under more public attention and scrutiny (Baboukardos, 2017; Jouvenot & Krueger, 2021). Jackson et al. (2020) argue that mandatory nonfinancial disclosure regulation could lead to stringency around minimum standards. We further argue that corporate boards would then see meeting and/or exceeding these minimum standards as a signal of outperforming competitors and providing stakeholder value. Therefore, we expect that following the adoption of carbon reporting regulation, to achieve the long-run sustainable competitive advantage of the firm, corporate boards would play a more proactive role in reducing the carbon emission level.

2.3 | Board composition diversity and emission performance

The composition of corporate boards has a profound influence on environmental performance due to the social capital created by the shared skills and knowledge of board members (Ortiz de Mandojana & Aragon Correa, 2015). However, little corporate governance (CG) research explicitly examines organizations and their broader environment, specifically the firm's coevolution towards a sustainable and win–win relationship with stakeholders (Filatotchev et al., 2020). Researchers argue that the fiduciary duty of investment managers in terms of pure financial interpretation will risk the interest of their investors. Hence, a more holistic interpretation of fiduciary duty should be considered while incorporating their beneficiaries' nonfinancial interests, given that these are not disadvantageous to fund performance (Hoepner & Schopohl, 2020). The board of directors can ensure better sustainable performance through the acquisition of necessary resources and capabilities, which is crucial for achieving a competitive advantage and long-term value creation (Barney, 1996; Barney et al., 2001; Wernerfelt, 1984).

Moreover, the incorporation of carbon management into board structures not only improves carbon performance but also ensures the accountability of boards to their stakeholders (Bui et al., 2020). Prior studies also widely highlighted the importance of board composition with sustainable business practices by showing that the performance of the firm may largely depend on the composition and characteristics of the board (Johnson et al., 2013). These studies highlighted that the board's composition diversity can be defined mainly in terms of board size, diversity in gender, and proportion of insider and outsider directors, which are instrumental for better corporate social performance (Hillman et al., 2001; Hussain et al., 2018; Jizi, 2017; Post et al., 2015; Shaukat et al., 2016; Sundarasen et al., 2016; Zhang, 2012).

2.3.1 | Gender diversity

Applying the RBV, our study argues that a gender-diverse corporate board could provide a firm with a resource that allows them to gain a sustainable competitive advantage. Gender representation on boards has been a topic of great debate where previous studies attempted to establish an association between the presence of women on the board and environmental performance. Palmer et al. (2012) find that incorporating women within the board results in superior environmental performance. Hafsi and Turgut (2013) and Galia et al. (2015) argue that as woman board members are sensitive to specific issues like environmental or societal ones, they can better pursue the board in addressing the environmental goals within its strategic policy.

Braun (2010) argues that woman entrepreneurs are likely to be more involved in green and sustainability-related issues than man entrepreneurs. This was supported by Kassinis et al. (2016) and Li et al. (2017), who find a positive association between the increased percentage of woman board members and environmental emission reduction policy. On the other hand, Ben-Amar et al. (2017) report that the probability of carbon disclosure increases with a higher proportion of females on the board. Similarly, Liao et al. (2015) show a positive influence of gender diversity on the disclosure of carbon emission data. Nuber and Velte (2021) also report a positive and significant relationship between board gender diversity and the carbon performance of European firms. Therefore, we hypothesize that women directors can play a significant role in the carbon performance of the firms and hence,

Hypothesis 1. Gender diversity is negatively related to the firms' carbon emissions under mandatory NFR.

2.3.2 | Board independence

Under stakeholder theory, it is expected that corporate boards should act independently of management, and thus, the inclusion of non-executive board members is associated with better stakeholder responsibility (Barratt & Korac-Kakabadse, 2002). In addition to influencing key decisions, the non-executive directors' interests can be closely matched to stakeholders' interests, as both may not be aligned with management (Fama & Jensen, 1983). Haque (2017) argues that the increased share of non-executive directors can reduce the potential agency conflict arising from the long-term commitment to environmental-related investment. Being outsiders, non-executive directors have a better ability to balance the interest of all stakeholders and can promote the socially responsible behaviour of their firms (O'Neill et al., 1989). Post et al. (2011) state that contrasting to the short-term profit maximization interest of inside directors, outside directors are more committed to investment in the environmental activities of the firm as a means of maximizing the long-term interest of shareholders. The empirical evidence of prior studies largely shows that an increased proportion of independent directors exerts a positive influence on environmental sustainability performance (Ben-Amar et al., 2022; Hussain et al., 2018; Jizi et al., 2014; Shaukat et al., 2016). Hence,

Hypothesis 2. Proportion of non-executive directors on board is negatively related to the firms' carbon emissions under mandatory NFR.

2.3.3 | Board size

From the point of the RBV, due to the benefit of more diversified knowledge and skills, larger boards will have more opportunities to contribute to better decision-making (Singh, 2007). Besides sharing expertise and knowledge, a larger board can facilitate greater access to crucial financial and technological resources concerning environmental-related initiatives (Villiers et al., 2011). Jizi (2017) argues that due to the larger and more complex nature, an increased board size could ensure a better allocation of responsibility in terms of social performance. Chen and Jaggi (2000) find that a larger board size could reduce the information asymmetry problem. Guest (2009) further finds that small boards suffer from a lack of diversified experience and backgrounds, and therefore, a larger board can respond better to societal needs. Apart from the extended monitoring benefit of a larger board, Giannarakis (2014) also highlights the benefit of the greater exchange of ideas and experience among board members. Similarly, other authors report a significant and positive impact of board size on the sustainability performance of the firms (Htay et al., 2012; Rao et al., 2012).

On the contrary, research also shows that a larger board can result in greater conflicts in decisions regarding environmental initiatives because of free riders, communication, and harmonization problems (Boone et al., 2007; Haque & Ntim, 2018; Lipton & Lorsch, 1992). Prado-Lorenzo and Garcia-Sanchez (2010) report that larger boards are less effective in improving environmental performance and tend to divulge less information on the GHG effect. Similarly, Hillman et al. (2001) show that in terms of environmental policy, a larger board is negatively correlated with stakeholder performance (Figure 1).

Thus, considering these contradictory views, we propose the following competing hypotheses:

Hypothesis 3a. Board size is negatively related to the firms' carbon emissions under mandatory NFR.

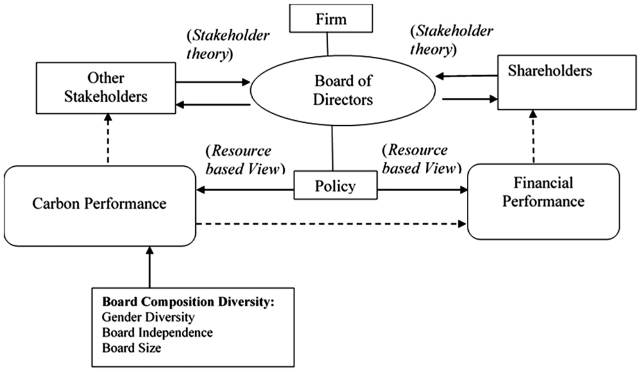

FIGURE 1 Theoretical model.

Hypothesis 3b. Board size is positively related to the firms' carbon emissions under mandatory NFR.

3 | DATA AND METHOD

3.1 | Data and sample selection

This study uses a sample of UK-listed firms on the FTSE All-Share index which is consistent with the approach undertaken by Brammer and Pavelin (2008). The mandatory NFR regulation of carbon emission reporting for UK-listed firms was introduced in 2013; hence, this study covers a sample period from 2013 to 2019 for the baseline model. Since the regulation applies to all listed firms in the United Kingdom, we chose the FTSE All-Share index as this represents 98% of all companies listed on the London Stock Exchange. All the study data were collected from the Thomson Reuters Refinitiv Eikon database (hereafter, Refinitiv Eikon). As a reliable database for widely covered financial and firm-specific variables, Refinitiv Eikon is now being used by the wider research community (e.g., Altunbas et al., 2022; Fasan et al., 2021; Havlinova & Kukacka, 2021; Uyar et al., 2023; Zaman et al., 2021). Table 1 provides a summary of the sample selection.

Our initial sample consists of 867 unique firms, which results in a total of 5590 firm-year observations. We exclude firms with missing data for variables relevant to this study. Hence, our final unbalance panel dataset consists of 1951 firm-year observations for 382 unique firms. The distribution of the sample according to year and industry is shown in Table 2. The sample firms are distributed among a total of 10 different sectors according to the TRBC industry category. As a standard academic practice, all continuous variables are winsorized at their 1st and 99th percentiles to reduce the influence of outliers.

3.2 | Model and variables

To test the research hypotheses, the baseline empirical model is developed as follows:

TABLE 1 Sample construction for baseline model.

Steps	Unique firms	Firm-year observations
(1) FTSE All-Share Index constituents	867	5590
(2) Less: Firms with missing data of variables used in analysis	(485)	3639
(3) Final sample	382	1951

Note: This table shows sample construction process.

$$\begin{aligned} GHG(Carbon)\ Emissions_{it} = \alpha_0 &+ \beta_1\, Gender_{it} + \beta_2 BoD\_Independence_{it} \\ &+ \beta_3 BoD\_Size_{it} + + \beta_4\, TotalAssets_{it} \\ &+ \beta_5 ROA_{it} + \beta_6\, Leverage_{it} + \beta_7 Cash_{it} \\ &+ \beta_8\, New\ Technology_{it} \\ &+ \beta_9 ESG\_Compensation_{it} \\ &+\ \beta_{10} Sust\_Committee_{it} + \varepsilon_{it}. \end{aligned} \quad (1)$$

The control variables included in the model are total assets, return on asset (*ROA*), leverage, cash ratio (*Cash*), new technology, environmental, social, and governance-based compensation (*ESG_Compensation*), and sustainability committee (*Sust_Committee*). A description of all the study variables and measurements is provided in Table 3. In the next section, we discuss in detail about the appropriateness and selection of the variables for our empirical model.

As the sample is composed of several firms and periods, panel data regression has been performed, as it minimizes the risk of omitted variables and allows to control for unobservable heterogeneity (Qian & Schaltegger, 2017; Wooldridge, 2010). Based on the Hausman test, we use a fixed effect (FE) model, which can control the effects of time-invariant variables.

The FE regression is performed to form our baseline mode. Next, in order to better understand the regulatory impact on the board's effectiveness, we perform a triple difference in difference (DID). This analysis is undertaken between UK- and US-listed firms in the pre- and post-regulatory period to show the impact of board diversity on carbon performance. The triple difference estimator (Wooldridge, 2020, p. 436) is a widely used regression method in economics research that describes causal inference by taking multiple differences (Olden & Møen, 2022; Yelowitz, 1995). Thus, the DID approach is a quasi-experimental analysis technique, which is more appropriate to determine the effect of changes in government policy (in our case, carbon reporting) when certain groups (in our case, UK firms) are exposed to a change and others (in our case, US firms) are not (Angrist & Krueger, 1999).

Further, we estimate another regression model to explore the channels by which board diversity may affect carbon performance under the NFR period. Particularly, we regressed four potential channels, that is, emission policy, environmental innovation, environmental impact management capacity, and environmental investment on our board diversity variables.

Finally, we perform a set of robustness tests including the generalized method of moments (GMM) to address the endogeneity and to ensure the inference of structural validity of the regression models.

TABLE 2 Sample distribution by year and industry.

Industry	Year 2013	2014	2015	2016	2017	2018	2019	Total obs.	Unique firms
Basic materials	29	33	34	34	33	35	30	228	39
Consumer cyclicals	51	62	74	76	72	67	62	464	94
Consumer noncyclicals	20	20	22	23	25	23	23	156	27
Energy	20	20	20	18	18	18	17	131	27
Financials	25	31	37	38	36	40	42	249	53
Healthcare	7	8	14	14	14	15	14	86	19
Industrials	57	62	63	66	65	59	60	432	79
Technology	15	17	20	20	21	18	19	130	30
Telecommunications	4	3	4	4	5	4	4	28	6
Utilities	6	6	7	7	6	7	8	47	8
Total	234	262	295	300	295	286	279	1951	382

Note: This table shows distribution of final study sample according to year and industry.

TABLE 3 Variables description (in order of appearances).

Variables	Description
GHG_Emissions	Natural logarithm of total GHG emissions (scopes 1 and 2). In the summary statistics, we represent it in million tons
Gender	The percentage of woman directors on the board
BoD_Independence	Board independence, measured as the proportion of non-executive directors on the board
BoD_Size	Board size, measured as total number of board of directors
Total_Assets	Natural logarithm of total assets. In the summary statistics, we represent it in million pounds (£)
ROA	The percentage of net profit after tax to total assets
Leverage	The percentage of debt to equity
Cash	The ratio of cash and short-term investments to total assets
New_Technology	The ratio of net property, plant, and equipment (PPE) to gross PPE
ESG_Compensation	A dummy coding 1, if the firm has ESG/sustainability-based compensation policy, otherwise 0
Sust_Committee	A dummy coding 1, if the firm has sustainability/CSR committee, otherwise 0
Capital_Intensity	The ratio of PPE to total assets.
Market_to_Book	The ratio of market value to book value of equity
Ownership	Total percentage of the shares held by institutional shareholders
Governance_Score	Governance pillar score that measures a company's systems and processes
Board tenure	The average number of years of member on the board
Treat	A dummy coding 1, if UK firm, and 0, if US firm
Post	A dummy coding 1 indicating post-regulatory period (i.e., 2013–2019), and 0 for pre-regulatory period (i.e., 2009–2012)
Policy Emissions	A dummy coding 1, if the firm has a policy to improve emission reduction, otherwise 0
Environmental Innovation	Score, reflecting a company's capacity to reduce the environmental costs and burdens for its customers through new environmental technologies and processes or eco-designed products
EnironmentImpactMgtCapacity	Score, reflecting how well a company uses best management practices to avoid environmental risks and capitalize on environmental opportunities in order to generate long-term shareholder value
Environmental Investment	A dummy coding 1, if the firm makes proactive environmental investments or expenditures to reduce future risks or increase future opportunities, otherwise 0

Note: All data sources are from Refinitiv Eikon.

3.2.1 | Dependent variable

Although the literature suggests different proxy variables to measure environmental performance, this study uses actual carbon emission levels in terms of GHG (García Martín & Herrero, 2020; Haque & Ntim, 2020). GHG emission is the most significant factor for climate change and a better indicator of carbon performance (Giannarakis et al., 2017; Konadu, 2017). Therefore, studies mostly use GHG emissions as a better proxy to estimate the carbon performance of firms (Baboukardos, 2017; Benz et al., 2021; Bolton & Kacperczyk, 2021; Chapple et al., 2013; Griffin et al., 2017; Haque, 2017; Matsumura et al., 2014). The GHG emissions data can be reported under three scopes. However, the Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013 made it mandatory to report direct and indirect emissions from purchased electricity and gas under scopes 1 and 2 only, where the reporting of GHG data under scope 3 is voluntary (DEFRA, 2013). Therefore, the natural log of the total GHG emissions under scopes 1 and 2 is used as a dependent variable for this study.

3.2.2 | Independent variables

For our study, three main governance variables are identified through the review of related literature to determine their influence on carbon emission performance. The first independent variable is gender diversity as studies show that a board with a higher proportion of women can lead to greater environmental performance (e.g., Galbreath, 2011; Li et al., 2017; Nuber & Velte, 2021). The second is board independence as literature shows that boards having more non-executive directors can better ensure the interest of the stakeholders (e.g., Hussain et al., 2018; Shaukat et al., 2016). The third is board size as larger boards can be associated with a better allocation of responsibility in terms of environmental and social performance (e.g., Giannarakis, 2014; Jizi, 2017). However, a larger board beyond the optimum level may also suffer coordination problems which can negatively affect environment performance (Elsayih et al., 2018; Kılıç & Kuzey, 2019).

3.2.3 | Control variables

We control for other factors that the prior studies have linked to environmental performance (De Villiers et al., 2011; Haque, 2017; Li et al., 2018; Liao et al., 2015; Qian & Schaltegger, 2017). We control the effect of the firm size measured in terms of total assets (Haniffa & Cooke, 2005; Li et al., 2018). Although there are some other proxies for firm size, within corporate governance literature, total assets are actively used as a better proxy for firm size (e.g., Haque & Ntim, 2020; Lu & Herremans, 2019; Moussa et al., 2020; Orazalin & Mahmood, 2021). Moreover, firm-level GHG emission is more related to the property, plant, or equipment-based fixed assets. Goldhammer et al. (2017) argue that two firms produce the same goods with the same processes under the same circumstances, the one with a larger size will, all other aspects being equal, have larger emissions. Additionally, by expanding size, the firm will have more assets which may consume more energy and release more GHG (Konadu, 2017). Therefore, firm size is expected to have a positive relationship with the dependent variable.

It is argued that investors are more interested in profitable firms which are also under more public attention and more political pressure, and therefore, they tend to show more commitment towards social expectation to avoid negative public views about their legitimacy performance (Li et al., 2018; Zimmerman, 1983). This is consistent with the findings of Liesen et al. (2015) and the stakeholder theory that stakeholder pressure influences environmental reporting. To address this, ROA is used as a proxy control variable for profitability.

Another firm-specific characteristic related to environmental performance is leverage, measured in terms of debt-to-equity ratio (Cho et al., 2012; Hart & Ahuja, 1996). Highly levered firms may pay more attention to accumulating cash due to interest and debt repayment obligations, and therefore, these firms are expected to have less commitment to investment in environmental activities (Haque, 2017). We also control for liquidity, measured by the cash ratio. Firms with more cash holdings are better equipped to manage environmental performance as they can allocate more resources for environmental activities and initiatives (De Villiers et al., 2011; Dowell & Muthulingam, 2017). Another control variable is new technology, which is the ratio of net PPE to gross PPE. Firms with more-advanced equipment are likely to achieve better environmental performance as newer equipment is more energy efficient with less GHG emissions (Goldhammer et al., 2017; Qian & Schaltegger, 2017).

Further, we also control the potential impact of environmental, social, and governance (ESG)-based compensation and sustainability committee on carbon performance. ESG-based compensation can motivate management to address social and environmental concerns and can benefit the firm to reduce carbon emissions (Campbell et al., 2007; Flammer et al., 2019). Eccles et al. (2014) argue that ESG-based compensation policy can work as an explicit incentive for the management to ensure better social performance while holding them accountable for social responsibility. Prior studies also empirically show a positive impact of ESG-based compensation policy on the environmental performance of the firms (Berrone & Gomez-Mejia, 2009; Cordeiro & Sarkis, 2008; Haque, 2017; Haque & Ntim, 2020). On the other hand, the presence of a sustainability committee indicates a better commitment and responsiveness of the firm to its stakeholders in terms of social responsibility (Lam & Li, 2008). Previous studies also show that the existence of an environmental committee can lead to greater environmental sustainability disclosure and better environmental performance (Cucari et al., 2018; Haque, 2017; Helfaya & Moussa, 2017; Liao et al., 2015; Orazalin & Mahmood, 2021).

4 | RESULTS

4.1 | Descriptive statistics and univariate analysis

We first show the carbon performance profile of firms in Table 4, categorised by industry and by the sample period of 2013–2019. Panel A in Table 4 indicates that sample firms account for a total of 4279.20 million tons of GHG emissions during 2013–2019, on an average of 188.64 million tons per year. Energy sector firms account for almost half of total emissions (44%). And there is a decreasing trend of GHG emissions during this period.

Panel B in Table 4 presents the descriptive statistics of the study variables included in the baseline estimation. For ease of interpretation, although the summary statistics represent both GHG emission and total assets data in million figures, we use log-transformed data in our multivariate analysis. Moreover, all scale variables are winsorized to control the effect of outliers (Leone et al., 2019). The mean GHG emission by the sample UK-listed firms is 2.19 million tons which indicates that the UK firms are largely liable for carbon-related environmental degradation. In terms of board composition, we find that, on average, only about 21% of board members are women. Although some firms ensured an equal proportion of men and women board members, there were still some firms which had not appointed any women board members. We find on average 58% of directors on the board are non-executive directors. This ranges between 4 and 16 members, where on average board size consists of nine members. About 36% of firms have an ESG-linked compensation policy, whereas about 71% of firms have a sustainability/CSR committee. Therefore, the average number of women on the average board size would be around two out of nine directors. While a dummy variable here could have been used for the presence of women on the board, the scale variable provides opportunity for a richer analysis on the impact of a larger representation of women on board.

Panel C in Table 4 reports the correlation matrix between the study variables. For most of the study variables, low to moderate correlations are observed. Moreover, no correlation value below .80 exists, indicating that the study variables do not suffer a multicollinearity problem (Gujarati, 2003). This is further confirmed by the VIF test during the regression analysis.

4.2 | Multivariate analysis

Table 5 presents the fixed effect regression results where column (1) includes only control variables, columns (2)–(4), each of the independent variables (on its own) is included one at a time, and column (5) shows our baseline regression model incorporating all the independent variables. Our panel regression results are based on a fixed effect model where we control the firm effect. This controls any time-invariant variable in the model including industry as the firm is unlikely to change its industry over time. The results show that board gender diversity has a negative and significant impact on carbon emissions ($p = 0.03$). Another significant governance variable is board size which is positively related to carbon performance ($p = 0.02$). Additionally, among control variables, firm size and liquidity show a significant influence on carbon performance.

4.2.1 | Robustness test

The estimated regression result with robustness tests is provided in Table 6. First, we performed a random effects model estimation. Although the Hausman test suggests a fixed effect model, the appropriateness of this test is arguable due to some problematic assumptions and limitations (see Hill et al., 2020; Wooldridge, 2010). The random effects result is presented in column (1), which confirms the former conclusions regarding our developed hypotheses.

The regression model is re-estimated by using an alternative dependent variable as GHG intensity (in terms of profitability and firm size) to incorporate growth and size-related effects of the firms (Busch, Bassen, et al., 2020; Sullivan, 2009). The output of the regression, scaling GHG emissions by EBIT and gross PPE, is reported in columns (2) and (3), respectively. The outputs substantiated the former results. Column (4) shows the regression result based on standard errors clustered at the industry level to account for within-industry correlations. The results confirm prior findings. Although carbon reporting regulation has been made mandatory for all types of industries, financial firms are typically studied separately due to specific financial regulations and unique financial structures compared with other firms (Baboukardos, 2017). Therefore, we re-estimate our baseline regression excluding financial firms and show the results in column (5). The new estimated model shows the same findings for independent variables.

In columns (6) and (7), we used a 1-year lag of regressors because board effectiveness may need time before influencing carbon performance. Colum (6) is based on FE, and column (7) is based on the RE model. There is no change in our initial findings. However, the coefficient of board independence becomes significant and negative in these models.

To address omitted variable biases, the model is re-estimated by including some additional control variables as reported in column (8). Literature suggests that environmental performance is related to capital spending as it helps firms to generate adequate revenue that can be allocated for environmental matters (Clarkson et al., 2011; Qian & Schaltegger, 2017). Moreover, firms need significant capital investment in advanced technology and machinery to reduce the level of carbon emissions (Gillingham & Stock, 2018). Goldhammer et al. (2017) argue that facilities undergone large investments in recent years will have lower specific emissions than those installed years ago. Therefore, we include capital intensity as a variable to control its potential impact. Another additional control variable is market-to-book value ratio, which is an indicator of the growth opportunity of the firm. A firm with higher growth opportunity has greater investment opportunity and, thus, can achieve better environmental performance (Artiach et al., 2010).

TABLE 4 Descriptive statistics of variables.

Panel A. Total GHG emissions (million tons) by industry and year								
	Year							
Industry	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Basic materials	236.04	216.608	221.865	184.46	164.829	166.757	129.918	1320.477
Consumer cyclicals	27.444	41.345	37.684	25.258	36.628	35.755	15.753	219.867
Consumer noncyclicals	21.697	22.45	22.974	20.033	17.906	16.985	17.044	139.089
Energy	282.215	282.966	270.596	260.163	265.166	254.421	248.74	1864.267
Financials	0.292	0.321	0.467	0.448	0.39	0.389	0.363	2.67
Healthcare	2.705	2.612	2.918	3.032	1.484	2.494	2.34	17.585
Industrials	60.454	62.676	64.001	59.534	67.212	58.458	29.868	402.203
Technology	0.418	0.431	0.242	0.234	0.23	0.15	0.177	1.882
Telecommunications services	2.515	2.425	0.297	3.489	2.291	3.024	2.574	16.615
Utilities	63.508	58.524	51.771	35.992	27.613	27.691	29.441	294.54
Total	697.288	690.358	672.815	592.643	583.749	566.124	476.218	4279.195

Panel B. Summary statistics								
Variables	**N**	**Mean**	**Std. deviation**	**Min**	**p25**	**Median**	**p75**	**Max**
GHG_Emissions (million tons)	1951	2.19	9.32	0.0000139	0.012	0.06	0.33	86
Gender	1947	21.16	10.71	0	14.29	22.22	28.57	50
BoD_Independence	1935	58.28	13.53	18.18	50	58.33	66.67	100
BoD_Size	1947	8.96	2.25	4	7	9	10	16
ESG_Compensation	1951	0.36	0.48	0	0	0	1	1
Sust_Committee	1951	0.71	0.45	0	0	1	1	1
Total_Assets (million £)	1951	11,000	46,050	7.67	786.6	1794	4913	843,000
ROA	1951	5.52	8.67	−36.52	2.05	5.01	9.21	36.34
Leverage	1951	101.96	158.19	0	19.09	55.71	112.62	986.53
Cash	1951	0.1	0.1	0	0.04	0.07	0.13	0.89
New_Technology	1951	0.52	0.18	0.07	0.39	0.5	0.62	1.06

Panel C. Pearson correlations											
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
(1) *GHG_Emissions*	1.000										
(2) *Gender*	.059***	1.000									
	(.009)										
(3) *BoD_Independence*	.250***	.279***	1.000								
	(.000)	(.000)									
(4) *BoD_Size*	.332***	.142***	.065***	1.000							
	(.000)	(.000)	(.004)								
(5) *ESG_Compensation*	.222***	−.019	.108***	.100***	1.000						
	(.000)	(.397)	(.000)	(.000)							
(6) *Sust_Committee*	.370***	.107***	.165***	.242***	.140***	1.000					
	(.000)	(.000)	(.000)	(.000)	(.000)						
(7) *Total_Assets*	.614***	.229***	.328***	.555***	.159***	.350***	1.000				
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)					
(8) *ROA*	−.176***	.123***	.022	−.030	−.055**	−.053**	−.150***	1.000			
	(.000)	(.000)	(.334)	(.191)	(.015)	(.020)	(.000)				
(9) *Leverage*	.125***	.009	.000	.035	.051**	.044**	.148***	−.161***	1.000		
	(.000)	(.705)	(.985)	(.127)	(.026)	(.050)	(.000)	(.000)			

(Continues)

TABLE 4 (Continued)

Panel C. Pearson correlations											
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(10) *Cash*	−.194***	−.017	−.024	−.036	.001	−.119***	−.206***	.135***	−.011	1.000	
	(.000)	(.465)	(.283)	(.115)	(.961)	(.000)	(.000)	(.000)	(.644)		
(11) *New_Technology*	.110***	−.054**	−.086***	.102***	.030	−.058***	.162***	−.023	.011	−.135***	1.000
	(.000)	(.017)	(.000)	(.000)	(.185)	(.010)	(.000)	(.314)	(.629)	(.000)	

Note: This table shows the descriptive statistics. Table 3 provides a detailed definition of the variables. Panel A provides GHG emissions of sample firms distributed by year and industry. Panel B provides summary statistics of each variable. Panel C provides pairwise Pearson correlations used in baseline regression model (*N* = 1935). The *p*-values of correlation coefficients are in parentheses.
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

TABLE 5 Base model regression results.

	Parameter estimate (*t*-statistic)				
Variables	(1)	(2)	(3)	(4)	(5)
Intercept	5.233***	4.567***	5.253***	5.219***	4.567***
	(3.507)	(2.916)	(3.510)	(3.456)	(2.891)
Gender		−0.00406***			−0.00371**
		(−2.589)			(−2.197)
BoD_Independence			−0.00191		−0.000954
			(−1.391)		(−0.652)
BoD_Size				0.0227**	0.0219**
				(2.442)	(2.343)
Total_Assets	0.281***	0.315***	0.285***	0.273***	0.309***
	(3.951)	(4.214)	(3.990)	(3.800)	(4.120)
ROA	0.000130	9.77e−06	0.000263	0.000168	0.000131
	(0.0603)	(0.00456)	(0.122)	(0.0779)	(0.0614)
Leverage	−0.000204	−0.000214	−0.000204	−0.000190	−0.000198
	(−1.266)	(−1.291)	(−1.250)	(−1.197)	(−1.209)
Cash	−0.635*	−0.636*	−0.649*	−0.628*	−0.628*
	(−1.688)	(−1.700)	(−1.728)	(−1.661)	(−1.673)
New_Technology	−0.0516	−0.0508	−0.0505	−0.0792	−0.0727
	(−0.334)	(−0.332)	(−0.328)	(−0.518)	(−0.480)
ESG_Compensation	0.0126	0.0128	0.0126	0.00804	0.00954
	(0.593)	(0.606)	(0.592)	(0.382)	(0.452)
Sust_Committee	0.0320	0.0432	0.0353	0.0289	0.0411
	(0.690)	(0.887)	(0.760)	(0.629)	(0.853)
Observations	1951	1947	1935	1947	1935
No. of firms	382	382	380	382	380
Adjusted R^2 (%)	7.8	8.5	7.9	8.2	9
Max VIF	1.27	1.35	1.41	1.72	2

Note: This table presents results of fixed effect panel regression of the impact of board composition diversity on carbon performance under mandatory carbon reporting regulation. Table 3 provides a detailed definition of the variables. *t*-statistics are in parentheses based on robust standard errors, clustered at the firm level.
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

TABLE 6 Regression model for robustness tests.

Variables	Random effect (RE) model (1)	GHG intensity (scaled by EBIT) (2)	GHG intensity (scaled by PPE) (3)	Industry cluster (4)	Excluding financial firms (5)	Lagged variables FE (6)	Lagged variables RE (7)	Additional control variables (8)
	Parameter estimate (*t*-statistic)							
Intercept	1.815	−0.00715	0.00295**	4.567**	3.818**	6.219***	3.205**	4.228**
	(1.340)	(−0.585)	(2.131)	(2.531)	(2.067)	(4.074)	(2.266)	(2.560)
Gender	−0.00525***	−0.0004***	−0.000004*	−0.00371**	−0.00345*	−0.00286*	−0.00454***	−0.00367**
	(−3.137)	(−3.101)	(−1.894)	(−2.521)	(−1.950)	(−1.634)	(−2.657)	(−2.304)
BoD_Independence	−0.000461	0.000004	−0.000002	−0.000954	−0.000456	−0.00287**	−0.00224*	−0.00112
	(−0.315)	(0.367)	(−0.878)	(−1.078)	(−0.313)	(−2.060)	(−1.660)	(−0.695)
BoD_Size	0.0247***	0.000261***	0.000026**	0.0219**	0.0207**	0.0242**	0.0282**	0.0174*
	(2.620)	(3.091)	(2.580)	(2.553)	(2.047)	(2.061)	(2.451)	(1.855)
Total_Assets	0.426***	0.000375	−0.000134*	0.309***	0.363***	0.231***	0.360***	0.324***
	(6.572)	(0.676)	(−1.924)	(3.646)	(4.093)	(3.255)	(5.494)	(4.077)
ROA	5.06e−05	−0.00003	−0.00000095	0.000131	0.00003	−0.00208	−0.00197	0.00131
	(0.0241)	(−0.948)	(−0.382)	(0.0670)	(0.0131)	(−0.762)	(−0.718)	(0.622)
Leverage	−0.000154	0.000003**	−0.00000014	−0.000198	−0.000183	−0.000027	1.90e−05	−0.000178
	(−0.943)	(2.314)	(−0.966)	(−1.045)	(−1.123)	(−0.199)	(0.135)	(−1.082)
Cash	−0.628*	−0.00314*	−0.00005	−0.628	−0.611	−0.678***	−0.683***	−0.677
	(−1.700)	(−1.809)	(−0.473)	(−1.521)	(−1.492)	(−3.365)	(−3.524)	(−1.571)
New_Technology	−0.120	−0.000403	0.000594	−0.0727	−0.124	0.163	0.125	−0.0528
	(−0.821)	(−0.247)	(1.485)	(−0.551)	(−0.608)	(1.033)	(0.814)	(−0.295)
ESG_Compensation	0.0224	0.000193	−0.00000047	0.00954	0.0167	0.0157	0.0311	0.0116
	(1.054)	(0.647)	(−0.0169)	(0.510)	(0.756)	(0.777)	(1.495)	(0.548)
Sust_Committee	0.0839*	0.000133	−0.00002	0.0411	0.0323	0.0205	0.0642	0.0624
	(1.740)	(0.219)	(−0.625)	(1.487)	(0.602)	(0.384)	(1.179)	(1.228)
Capital_Intensity								−0.0198
								(−0.160)
Market_to_Book								0.00290
								(0.335)
Ownership								−0.000389
								(−0.308)
Governance_Score								−0.000376
								(−0.438)
Board tenure								0.0167
								(1.522)
Observations	1935	1935	1935	1935	1686	1647	1647	1857
No. of firms	380	380	380	380	327	365	365	370
Adjusted R^2 (%)	8.82	1.5	3.7	9.01	10	7.91	7.50	9.33

Note: This table presents regression results of additional robustness tests of the impact of board composition diversity on carbon performance under mandatory carbon reporting regulation. Table 3 provides a detailed definition of the variables. *t*-statistics are in parentheses based on robust standard errors, clustered at the firm level.

*Statistical significance at 10% level.

**Statistical significance at 5% level.

***Statistical significance at 1% level.

We control the effect of ownership, represented by institutional shareholdings (Walls et al., 2012), as their significant and powerful ownership position also gives them more incentive to pursue the firms for sustainable business practice (Benlemlih et al., 2023; Chen et al., 2020; Meng & Wang, 2019). Further, we include a governance pillar score, a Refinitiv Eikon variable, which rates the firm in comparison with its industry peers in terms of the company's systems and processes ensuring that the board acts in the best interest of its stakeholders (Uyar et al., 2020). Finally, we also additionally control board tenure as prior studies also argue that board tenure is a driving factor of CSR or environmental performance of the firm (Harjoto et al., 2015; Galbreath, 2018; Phung et al., 2023). These additional control variables leave our conclusion unaffected. There is increasing debate on the effect of CEO duality and director age. We do not include this as a control variable in our study as CEO duality in the United Kingdom is considered poor practice under the UK Corporate governance code, and hence, there would not be sufficient representation in the data to draw any conclusions. In addition, Refinitiv Eikon does not provide CEO or director age data during this entire period. Hence, it would once again not provide sufficient representation for valid findings.

4.2.2 | Addressing endogeneity

Using panel data regression, primarily, we have addressed the endogeneity of unobservable firm-specific variables. Further, we perform a two-step system generalized method of moments (GMM) as proposed by Arellano and Bond (1991) to address endogeneity arising from a possible dynamic relationship, unobserved heterogeneity, or simultaneity (Ullah et al., 2018; Wintoki et al., 2012). The result of GMM estimation is provided in columns (1)–(3) of Table 7 with a different combination of year and industry fixed effect. These results show that there is no qualitative difference from previous findings.

4.2.3 | Quasi-natural experiment of regulatory shocks

So far, we document the effect of board composition diversity on carbon performance under mandatory NFR regulation. However, the next apparent question is whether such an effect is reinforced by the adoption of carbon reporting regulation. Therefore, we perform triple difference-in-differences (DID) analysis to see the regulatory impact of board composition diversity on carbon performance between treated and a control group of firms. Particularly, we want to test whether the impact of board composition diversity on GHG emission is moderated by the regulatory shock of mandatory carbon reporting in a quasi-natural experiment setting. We reconstructed our sample period from 2009 to 2019. Considering the adoption of mandatory carbon regulation in 2013, we divide the sample period as post-regulatory (2013–2019) and pre-regulatory (2009–2012). We assign all UK-quoted firms to the treatment group, which is subject to mandatory carbon reporting regulation. The control group is S&P 500 listed US firms, which are out of mandatory carbon reporting regulation. We chose the United States as the control group because there is less nonfinancial regulatory disclosure and more similarity in market structure (Ioannou & Serafeim, 2019; Nyombi, 2018). We estimate the following triple difference equation for regression:

$$\begin{aligned} \mathit{Carbon\ Emissions}_{it} = {} & \alpha_0 + \beta_1 \mathit{Treat}_{it} * \mathit{Post}_{it} * \mathit{BoardDiversity}_{it} + \beta_2 X_{it} \\ & + (\mathit{Year\&Industry})FE + \varepsilon_{it}, \end{aligned} \tag{2}$$

where *Carbon Emissions* is a natural log of the total GHG emissions. *Treat* is a dummy variable marking all UK-quoted firms (against US quoted firms as control). *Post* is a dummy variable indicating the post-regulatory period (i.e., 2013–2019). *BoardDiversity* is a board composition diversity variable in terms of gender, board independence, and board size. X_{it} is a firm-level control variable. We also control industry and year-fixed effect. ε_{it} is the error term.

Table 8 provides the results where our main variable of interest is the coefficients of *TREATED* * *POST* * *BoardDiversity* triple interaction, which captures the impact of board composition diversity on the carbon performance of UK firms in contrast to US firms between the pre- and post-regulatory shock period. The negative and significant coefficient of this triple interaction (columns (1)–(3)) indicates that compared with the pre-regulatory period, after the adoption of mandatory carbon reporting regulation, increased board diversity leads to a greater decrease in GHG emissions for UK listed firms relative to control US firms. As robustness, we rerun our DID model using a propensity score matching (PSM) method, where our control group is size and industry-matched US firms. Our findings in columns (4)–(6) also remain robust in this estimation.

4.2.4 | Effect of channels and mechanisms

To understand the channels causing a carbon emission effect of board composition diversity, we examine the four potential drives: emission reduction policy, environmental innovation, environmental impact management capacity, and environmental investment provision.

Our first channel variable is the existence of an emission reduction policy. The existence of climate change and related policy enhances the social legitimacy of the firm where it also conveys a positive signal about better commitment in terms of environmental performance (Galán-Valdivieso et al., 2019; Giannarakis et al., 2017). At the firm level, emission reduction policy can be formulated in different aspects, from product or process innovation to green financing or even political lobbying (Bumpus, 2015; Fatica & Panzica, 2021; Zhang et al., 2017). Although firm-level carbon reduction policy initiative depends on marginal costs and benefits, the ultimate objective of such policy is to reduce carbon emissions.

Another potential channel is environmental innovation, which not only ensures the efficient use of resources but also reduces energy consumption through process improvement, better utilization of

TABLE 7 GMM estimation.

Variables	Parameter estimate (Z-statistic) Dynamic GMM-1 (1)	Dynamic GMM-2 (2)	Dynamic GMM-3 (3)
Intercept	−0.045	0.989	0.255
	(−0.076)	(1.457)	(0.441)
GHG_{t-1}	0.919***	0.767***	0.807***
	(40.092)	(23.882)	(27.652)
GHG_{t-2}	0.063***	0.060***	0.066***
	(3.653)	(2.912)	(3.756)
Gender	−0.004***	−0.005***	−0.005***
	(−4.221)	(−5.222)	(−5.402)
BoD_Independence	−0.001	−0.000	0.000
	(−0.624)	(−0.095)	(0.180)
BoD_Size	0.013*	0.016**	0.021***
	(1.611)	(1.996)	(2.647)
Total_Assets	0.002	0.051	0.056
	(0.058)	(1.360)	(1.604)
ROA	0.008***	0.005***	0.005***
	(5.887)	(4.187)	(4.050)
Leverage	0.000	0.000	0.000
	(1.628)	(0.308)	(0.203)
Cash	−0.137	−0.042	−0.002
	(−0.756)	(−0.216)	(−0.011)
New_Technology	0.261*	0.291**	0.191
	(1.885)	(2.017)	(1.464)
ESG_Compensation	−0.018	−0.031**	−0.031**
	(−1.169)	(−1.993)	(−2.016)
Sust_Committee	0.070**	0.124***	0.124***
	(2.044)	(2.891)	(3.151)
Industry fixed effects	No	Yes	Yes
Year fixed effects	Yes	No	Yes
Observations	1243	1243	1243
No. of firms	327	327	327
Hansen (*p*-value)	.12	.26	.21
AR (2) serial correlation (*p*-value)	.23	.22	.24

Note: Using dynamic panel data approach, this table presents regression results of the impact of board composition diversity on carbon performance under mandatory carbon reporting regulation. *z*-statistics are in parentheses.
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

materials, or energy-efficient product development (Costantini et al., 2017; Long et al., 2017). Moreover, prior studies show that environmental innovation leads to a substantial reduction in emissions (Carrión-Flores & Innes, 2010; Lee & Min, 2015; Li, 2014; Toebelmann & Wendler, 2020; Weina et al., 2016).

Environmental management capacity is another key driver that may help to reduce carbon emissions. Firm-level approach to reducing carbon emissions also depends on managerial capabilities by ensuring best management practices for addressing carbon risk (Lee & Klassen, 2016; Luo & Tang, 2021).

The literature further shows that firms with separate environmental investment provisions are more capable to reduce carbon emissions because such provision facilitates the use of advanced and innovative technology, which helps to achieve energy-efficient

TABLE 8 Effects of carbon reporting regulation on carbon performance.

Variables	Parameter estimate (*t*-statistic)					
	Full sample			PSM size and industry matched sample		
	(1)	(2)	(3)	(4)	(5)	(6)
*Treat * Post * Gender*	−0.00969***			−0.00986**		
	(−2.691)			(−2.199)		
*Treat * Post * BoD_Independence*		−0.00463***			−0.00468**	
		(−2.843)			(−2.524)	
*Treat * Post * BoD_Size*			−0.0348***			−0.0293**
			(−3.202)			(−2.341)
Total_Assets	1.018***	1.011***	1.009***	0.992***	0.991***	0.993***
	(33.25)	(32.15)	(32.16)	(21.51)	(21.49)	(21.51)
ROA	0.00137	0.000480	0.000252	−0.00357	−0.00417	−0.00406
	(0.291)	(0.103)	(0.0543)	(−0.510)	(−0.598)	(−0.581)
Leverage	0.000165	0.000158	0.000157	1.62e−05	1.19e−05	1.49e−05
	(0.622)	(0.601)	(0.596)	(0.0538)	(0.0398)	(0.0499)
Cash	−0.580	−0.566	−0.593*	0.0690	0.0398	0.0588
	(−1.618)	(−1.565)	(−1.657)	(0.145)	(0.0837)	(0.124)
New_Technology	0.475*	0.480*	0.512*	0.565	0.568	0.582
	(1.755)	(1.772)	(1.891)	(1.481)	(1.497)	(1.529)
Constant	−10.52***	−10.36***	−10.32***	−10.21***	−10.17***	−10.23***
	(−15.32)	(−14.67)	(−14.65)	(−10.03)	(−9.924)	(−10.01)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6128	6111	6128	2815	2808	2814
Adjusted R^2 (%)	74.2	74.2	74.3	69.5	69.6	69.6

Note: This table shows triple difference-in-differences (DID) estimates of the impact of board composition diversity on carbon performance in pre- and post-regulatory shock of mandatory carbon reporting in 2013. *Treat* is a dummy variable indicating UK quoted firms, which need to comply the regulation. The control group is US listed firms. *Post* is a dummy variable indicating the post-regulation period, that is, years 2013–2019, against 2009–2012. Column (1)–(3) shows the results of full sample. Column (4)–(6) shows the results based on propensity score matching (PSM) in terms of size and industry matched samples. *t*-statistics are in parentheses based on robust standard errors, clustered at the firm level.
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

products or production processes (Alam et al., 2019). Moreover, pro-active environmental practice through environmental investment also enhances a firm's competitiveness through improved productivity, better operational performance, and cost efficiency, and therefore, such firms are also benefited from both environmental and financial return in the long run (Hart & Ahuja, 1996; King & Lenox, 2001).

To investigate the impact of board diversity on these channels, we estimate the following equation:

$$\textit{Emission Reduction Channel}_{it} = \alpha_0 + \beta_1 \textit{BoardDiversity}_{it} + \beta_2 X_{it} + \varepsilon_{it}. \quad (3)$$

Our dependent variable is the carbon reduction channel in terms of emission reduction policy, environmental innovation, environmental impact management capacity, and environmental investment provision. *BoardDiversity* is a board composition diversity variable in terms of gender, board independence, and board size. X_{it} is a firm-level control variable. ε_{it} is the error term. All channel variables are obtained from Refinitiv Eikon, and a detailed definition is provided in the variable description table.

Our results are presented in Table 9, based on fixed effect panel regression. We find that board gender diversity and independence significantly and positively affect all our channels. Previously, our baseline results showed that increased board size leads to increased carbon emission; hence, it would be natural to assume the impact on the channel should be negative. While board size negatively affects policy emission, we however find a positive impact on environmental investment. This indicates that larger firms make larger investments;

TABLE 9 Fixed effect panel regression of channel.

Parameter estimate (*t*/*Z*-statistic)				
Variables	**(1)** ***Policy Emissions***	**(2)** ***Environmental Innovation***	**(3)** ***EnvironmentImpactMgtCapacity***	**(4)** *Environmental Investment*
Gender	0.0522***	0.115*	0.121***	0.0524**
	(3.182)	(1.940)	(2.874)	(2.033)
BoD_Independence	0.0275**	0.100**	0.0720**	0.0554**
	(2.025)	(2.474)	(2.237)	(2.124)
BoD_Size	−0.160*	−0.460	−0.334	0.356**
	(−1.626)	(−1.273)	(−1.412)	(2.380)
Total_Assets	0.820*	1.972	2.747**	0.214
	(1.794)	(1.109)	(2.107)	(0.288)
ROA	−0.0316	−0.0153	−0.0308	0.0368
	(−1.407)	(−0.306)	(−0.954)	(1.047)
Leverage	0.000207	−0.00458	−0.0101***	0.00328**
	(0.154)	(−0.867)	(−5.435)	(2.118)
Cash	0.939	8.063	1.042	−2.425
	(0.425)	(0.872)	(0.174)	(−0.614)
New_Technology	−0.533	3.601	0.101	5.328**
	(−0.478)	(0.796)	(0.0288)	(2.396)
ESG_Compensation	−0.156	0.562	0.246	1.076**
	(−0.532)	(0.603)	(0.413)	(2.314)
Sust_Committee	1.722***	4.765***	6.313***	1.144
	(3.679)	(2.691)	(4.937)	(1.408)
Observations	495	2051	2051	236
Pseudo/adjusted R^2 (%)	16.6	2.85	9.60	20.3

Note: This table presents results of fixed effect panel regression, showing the impact of board composition diversity on potential channel for carbon performance. Table 3 provides a detailed definition of the variables. *t*-statistics are in parentheses based on robust standard errors, clustered at the firm level.
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

however, bigger boards were resulting in a lack of efficient allocation of the funds to result in a positive impact on the firm's environmental performance.

5 | DISCUSSION AND CONCLUSION

We find that board gender diversity is associated with greater environmental performance by lowering GHG emissions.

This supports the arguments for the benefit of a higher proportion of women directors on the board according to the resource provisioning role (Liao et al., 2015). Having a minority position on the board, women directors are more sensitive to the protection of the interest of lower-priority stakeholder groups (Galia et al., 2015). Overall, our study suggests that females are characterized by more social orientation, and therefore, they can have a higher influence on board decisions to adopt environmentally sustainable business practices (Boulouta, 2013; Glass et al., 2016).

Another significant determinant is board size, which is associated with poor environmental performance by increasing GHG emissions. This is broadly in line with the prior findings of Haque and Ntim (2018) and Prado-Lorenzo and Garcia-Sanchez (2010). Although larger boards can be benefitted from better monitoring and sharing of diversified skills and knowledge, they may also suffer from coordination and controlling problems (Hussain et al., 2018; Jizi, 2017). Moreover, increased board size does not mean more concern from directors for environmental performance as Rodrigue et al. (2013) show that on average, only about 10% of the board of directors are environmentally aware. It is reported that less percentage of board members are interested in social performance as they are more interested in value creation for shareholders (Rose, 2007). Therefore, the increased size of the board above the optimum level may fail to bring any positive change to the social performance of the firm, although the optimum board size argument demands further investigation.

We also find evidence of a significant and negative lag relationship between board independence and carbon performance in terms of GHG emissions. This suggests that non-executive directors need some time before making any significant impact on the firm's carbon performance.

The difference-in-differences estimation shows the impact of regulatory shocks of mandatory carbon reporting on the board's effectiveness towards addressing carbon performance. Our study reveals that the effect of board composition diversity on carbon emissions performance is reinforced by NFR regulation. Additionally, our study also reveals the significant impact of board diversity on the potential channels towards carbon performance.

Our findings have implications at a regulatory level for formulating relevant policy frameworks to reduce firm-level carbon emissions. Overall, the results have implications in other jurisdictions, for example, the United States, Australia, or European countries, since our results suggest that mandating carbon reporting may result in more responsiveness of the corporate board towards the management of the carbon performance of the firms.

Although our study uses the United Kingdom as a context, due to the only mandatory NFR regulation of carbon for listed firms, it has implications for other globally listed firms. Concerns regarding carbon emissions have been addressed in many countries especially following Kyoto Protocol and Paris Agreement. Firms of these countries follow several emission reduction programmes including Emissions Trading Scheme (ETS), Carbon Disclosure Project (CDP), and Regional Greenhouse Gas Initiative (RGGI) (Brouwers et al., 2016; Freedman & Park, 2014; Stanny, 2013). Although not mandatory for all listed firms, many countries also made compulsory reporting rules for large and specific sector polluters (Chapple et al., 2013; Cong et al., 2020; Saka & Oshika, 2014). Moreover, many multinational corporations (MNCs) are listed on different stock markets and hence may be required to comply with mandatory NFR regulation. Therefore, our study will also benefit the MNCs' understanding of the responsiveness of their board towards carbon performance from the regulatory perspective of the country of operation.

Moreover, Jackson et al. (2020) found that variations in CSR activity, between firms self-regulating nonfinancial disclosure versus those influenced by government regulation, declined over time. Hence, it would be also interesting for future studies to extend our empirical framework towards a comparative study in terms of the country as well as the regulatory context of environmental reporting. This would also allow for the study to include the effects of CEO duality and director age as under different jurisdictions, the representation in data is likely to provide more valid results.

To conclude, we show that carbon emission performance in terms of GHG emissions is negatively related to board gender diversity, positively related to board size, and a lagged negative effect of board independence on carbon emission performance. Our quasi-natural experiment setting of US and UK firms between 2009 and 2019 shows that following a regulatory shock, board composition diversity is more negatively associated with GHG emissions for the regulatory affected UK firms in contrast to nonregulatory compliant US firms. Finally, examining the channels causing the carbon emission effect of board composition diversity, we find that board gender diversity and board independence significantly and positively affect all our potential channels. However, board size significantly and positively affects environmental investment but negatively on policy emissions. This indicates that large investments from bigger firms may not always improve carbon performance as larger boards may suffer from inefficiency in policy implementation.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the editor and reviewers of the Business Strategy and the Environment Journal for their comments.

CONFLICT OF INTEREST STATEMENT

We confirm that there is no interest or relationship, financial, or otherwise that might be perceived as influencing our objectivity. We confirm that there are no disclosures that are directly relevant or directly related to the work we describe in our manuscript. There are no potential sources of conflict of interest included but are not limited to patent or stock ownership, membership of a company board of directors, membership of an advisory board or committee for a company, and consultancy for or receipt of speaker's fees from a company. We can confirm that we have no conflict of interest to declare.

ORCID

Firoz Haroon Bhaiyat https://orcid.org/0000-0003-4211-3591

REFERENCES

Aggarwal, R., & Dow, S. (2012). Corporate governance and business strategies for climate change and environmental mitigation. *The European Journal of Finance*, *18*(3–4), 311–331. https://doi.org/10.1080/1351847X.2011.579745

Alam, M. S., Atif, M., Chien-Chi, C., & Soytaş, U. (2019). Does corporate R&D investment affect firm environmental performance? Evidence from G-6 countries. *Energy Economics*, *78*, 401–411. https://doi.org/10.1016/j.eneco.2018.11.031

Altunbas, Y., Gambacorta, L., Reghezza, A., & Velliscig, G. (2022). Does gender diversity in the workplace mitigate climate change? *Journal of Corporate Finance*, *77*, 102303. https://doi.org/10.1016/j.jcorpfin.2022.102303

Angrist, J. D., & Krueger, A. B. (1999). Empirical strategies in labor economics. In *Handbook of labor economics* (Vol. 3) (pp. 1277–1366). Elsevier. https://doi.org/10.1016/S1573-4463(99)03004-7

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277–297. https://doi.org/10.2307/2297968

Artiach, T., Lee, D., Nelson, D., & Walker, J. (2010). The determinants of corporate sustainability performance. *Accounting and Finance*, *50*(1), 31–51. https://doi.org/10.1111/j.1467-629X.2009.00315.x

Baboukardos, D. (2017). Market valuation of greenhouse gas emissions under a mandatory reporting regime: Evidence from the UK. *Accounting Forum*, *41*(3), 221–233. https://doi.org/10.1016/j.accfor.2017.02.003

Barney, J., Wright, M., & Ketchen, D. J. Jr. (2001). The resource-based view of the firm: Ten years after 1991. *Journal of Management*, *27*(6), 625–641. https://doi.org/10.1177/014920630102700601

Barney, J. B. (1996). The resource-based theory of the firm. *Organization Science*, *7*(5), 469. https://doi.org/10.1287/orsc.7.5.469

Barratt, R., & Korac-Kakabadse, N. (2002). Developing reflexive corporate leadership: The role of the non-executive director. *Corporate Governance: The International Journal of Business in Society*, *2*(3), 32–36. https://doi.org/10.1108/14720700210440071

Ben-Amar, W., Chang, M., & McIlkenny, P. (2017). Board gender diversity and corporate response to sustainability initiatives: Evidence from the carbon disclosure project. *Journal of Business Ethics*, *142*(2), 369–383. https://doi.org/10.1007/s10551-015-2759-1

Ben-Amar, W., Gomes, M., Khursheed, H., & Marsat, S. (2022). Climate change exposure and internal carbon pricing adoption. *Business Strategy and the Environment*, *31*, 2854–2870. https://doi.org/10.1002/bse.3051

Benlemlih, M., Arif, M., & Nadeem, M. (2023). Institutional ownership and greenhouse gas emissions: A comparative study of the UK and the USA. *British Journal of Management*, *34*, 623–647. https://doi.org/10.1111/1467-8551.12613

Benz, L., Paulus, S., Scherer, J., Syryca, J., & Trück, S. (2021). Investors' carbon risk exposure and their potential for shareholder engagement. *Business Strategy and the Environment*, *30*(1), 282–301.

Berrone, P., & Gomez-Mejia, L. R. (2009). Environmental performance and executive compensation: An integrated agency-institutional perspective. *Academy of Management Journal*, *52*(1), 103–126. https://doi.org/10.5465/amj.2009.36461950

Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of Financial Economics*, *142*(2), 517–549. https://doi.org/10.1016/j.jfineco.2021.05.008

Bonetti, P., Cho, C. H., & Michelon, G. (2015). Environmental disclosure and the cost of capital: Evidence from the Fukushima nuclear disaster. Available at SSRN 2373877.

Boone, A. L., Field, L. C., Karpoff, J. M., & Raheja, C. G. (2007). The determinants of corporate board size and composition: An empirical analysis. *Journal of Financial Economics*, *85*(1), 66–101. https://doi.org/10.1016/j.jfineco.2006.05.004

Boulouta, I. (2013). Hidden connections: The link between board gender diversity and corporate social performance. *Journal of Business Ethics*, *113*(2), 185–197. https://doi.org/10.1007/s10551-012-1293-7

Bouten, L., Everaert, P., Van Liedekerke, L., De Moor, L., & Christiaens, J. (2011). Corporate social responsibility reporting: A comprehensive picture? *Accounting Forum*, *35*(3), 187–204. https://doi.org/10.1016/j.accfor.2011.06.007

Brammer, S., & Pavelin, S. (2008). Factors influencing the quality of corporate environmental disclosure. *Business Strategy and the Environment*, *17*(2), 120–136. https://doi.org/10.1002/bse.506

Braun, P. (2010). Going green: Women entrepreneurs and the environment. *International Journal of Gender and Entrepreneurship*, *2*(3), 245–259. https://doi.org/10.1108/17566261011079233

Brouwers, R., Schoubben, F., Van Hulle, C., & Van Uytbergen, S. (2016). The initial impact of EU ETS verification events on stock prices. *Energy Policy*, *94*, 138–149. https://doi.org/10.1016/j.enpol.2016.04.006

Bui, B., & De Villiers, C. (2017). Business strategies and management accounting in response to climate change risk exposure and regulatory uncertainty. *The British Accounting Review*, *49*(1), 4–24. https://doi.org/10.1016/j.bar.2016.10.006

Bui, B., Houqe, M. N., & Zaman, M. (2020). Climate governance effects on carbon disclosure and performance. *The British Accounting Review*, *52*(2), 100880. https://doi.org/10.1016/j.bar.2019.100880

Bumpus, A. G. (2015). Firm responses to a carbon price: Corporate decision making under British Columbia's carbon tax. *Climate Policy*, *15*(4), 475–493. https://doi.org/10.1080/14693062.2014.937389

Busch, T. (2011). Which emissions do we need to account for in corporate carbon performance? Response to Murray and colleagues. *Journal of Industrial Ecology*, *15*(1), 160–163. https://doi.org/10.1111/j.1530-9290.2010.00321.x

Busch, T. (2019). Markets must back climate mitigation. *Nature*, *571*, 36. https://doi.org/10.1038/d41586-019-02029-1

Busch, T., Bassen, A., Lewandowski, S., & Sump, F. (2020). Corporate carbon and financial performance revisited. *Organization and Environment*, *35*, 1–18. https://doi.org/10.1177/1086026620935638

Busch, T., Bauer, R., & Orlitzky, M. (2016). Sustainable development and financial markets: Old paths and new avenues. *Business and Society*, *55*(3), 303–329. https://doi.org/10.1177/0007650315570701

Busch, T., Johnson, M., & Pioch, T. (2020). Corporate carbon performance data: Quo vadis? *Journal of Industrial Ecology*, *26*, 350–363. https://doi.org/10.1111/jiec.13008

Campbell, K., Johnston, D., Sefcik, S. E., & Soderstrom, N. S. (2007). Executive compensation and non-financial risk: An empirical examination. *Journal of Accounting and Public Policy*, *26*(4), 436–462. https://doi.org/10.1016/j.jaccpubpol.2007.05.001

Carrión-Flores, C. E., & Innes, R. (2010). Environmental innovation and environmental performance. *Journal of Environmental Economics and Management*, *59*(1), 27–42. https://doi.org/10.1016/j.jeem.2009.05.003

Carroll, A. B. (2016). Carroll's pyramid of CSR: Taking another look. *International Journal of Corporate Social Responsibility*, *1*(1), 3. https://doi.org/10.1186/s40991-016-0004-6

Chabowski, B., Chiang, W. C., Deng, K., & Sun, L. (2019). Environmental inefficiency and bond credit rating. *Journal of Economics and Business*, *101*, 17–37. https://doi.org/10.1016/j.jeconbus.2018.08.003

Chapple, L., Clarkson, P. M., & Gold, D. L. (2013). The cost of carbon: Capital market effects of the proposed emission trading scheme (ETS). *Abacus*, *49*(1), 1–33. https://doi.org/10.1111/abac.12006

Chen, C. J., & Jaggi, B. (2000). Association between independent non-executive directors, family control and financial disclosures in Hong Kong. *Journal of Accounting and Public Policy*, *19*(4–5), 285–310. https://doi.org/10.1016/S0278-4254(00)00015-6

Chen, T., Dong, H., & Lin, C. (2020). Institutional shareholders and corporate social responsibility. *Journal of Financial Economics*, *135*(2), 483–504. https://doi.org/10.1016/j.jfineco.2019.06.007

Chithambo, L., Tingbani, I., Agyapong, G. A., Gyapong, E., & Damoah, I. S. (2020). Corporate voluntary greenhouse gas reporting: Stakeholder pressure and the mediating role of the chief executive officer. *Business Strategy and the Environment*, *29*(4), 1666–1683. https://doi.org/10.1002/bse.2460

Cho, C. H., Guidry, R. P., Hageman, A. M., & Patten, D. M. (2012). Do actions speak louder than words? An empirical investigation of corporate environmental reputation. *Accounting, Organizations and Society*, *37*(1), 14–25. https://doi.org/10.1016/j.aos.2011.12.001

Chung, J., & Cho, C. H. (2018). Current trends within social and environmental accounting research: A literature review. *Accounting Perspectives*, *17*(2), 207–239. https://doi.org/10.1111/1911-3838.12171

Clarkson, P. M., Overell, M. B., & Chapple, L. (2011). Environmental reporting and its relation to corporate environmental performance. *Abacus*, *47*(1), 27–60. https://doi.org/10.1111/j.1467-6281.2011.00330.x

Cong, Y., Freedman, M., & Park, J. D. (2020). Mandated greenhouse gas emissions and required SEC climate change disclosures. *Journal of Cleaner Production*, *247*, 119111. https://doi.org/10.1016/j.jclepro.2019.119111

Consolandi, C., Eccles, R. G., & Gabbi, G. (2022). How material is a material issue? Stock returns and the financial relevance and financial intensity of ESG materiality. *Journal of Sustainable Finance & Investment*, *12*, 1045–1068. https://doi.org/10.1080/20430795.2020.1824889

Cordeiro, J. J., & Sarkis, J. (2008). Does explicit contracting effectively link CEO compensation to environmental performance? *Business Strategy* *and the Environment*, *17*(5), 304–317. https://doi.org/10.1002/bse.621

Costantini, V., Crespi, F., Marin, G., & Paglialunga, E. (2017). Eco-innovation, sustainable supply chains and environmental performance in European industries. *Journal of Cleaner Production*, *155*, 141–154. https://doi.org/10.1016/j.jclepro.2016.09.038

Cotter, J., & Najah, M. M. (2012). Institutional investor influence on global climate change disclosure practices. *Australian Journal of Management*, *37*(2), 169–187. https://doi.org/10.1177/0312896211423945

Cucari, N., Falco, E. D. S., & Orlando, B. (2018). Diversity of board of directors and environmental social governance: Evidence from Italian listed companies. *Corporate Social Responsibility and Environmental Management*, *25*(3), 250–266. https://doi.org/10.1002/csr.1452

Dafermos, Y., Nikolaidi, M., & Galanis, G. (2018). Climate change, financial stability and monetary policy. *Ecological Economics*, *152*, 219–234. https://doi.org/10.1016/j.ecolecon.2018.05.011

De Villiers, C., Naiker, V., & Van Staden, C. J. (2011). The effect of board characteristics on firm environmental performance. *Journal of Management*, *37*(6), 1636–1663. https://doi.org/10.1177/0149206311411506

DEFRA. (2013). Environmental reporting guidelines. Available at: https://www.gov.uk/guidance/measuring-and-reporting-environmental-impacts-guidance-for-businesses

Donaldson, T., & Preston, L. E. (1995). The stakeholder theory of the corporation: Concepts, evidence, and implications. *Academy of Management Review*, *20*(1), 65–91. https://doi.org/10.2307/258887

Dowell, G. W. S., & Muthulingam, S. (2017). Will firms go green if it pays? The impact of disruption, cost, and external factors on the adoption of environmental initiatives. *Strategic Management Journal*, *38*(6), 1287–1304. https://doi.org/10.1002/smj.2603

Eccles, R. G., Ioannou, I., & Serafeim, G. (2014). The impact of corporate sustainability on organizational processes and performance. *Management Science*, *60*(11), 2835–2857. https://doi.org/10.1287/mnsc.2014.1984

Elsayih, J., Tang, Q., & Lan, Y. C. (2018). Corporate governance and carbon transparency: Australian experience. *Accounting Research Journal*, *31*(3), 405–422. https://doi.org/10.1108/ARJ-12-2015-0153

Fama, E. F., & Jensen, M. C. (1983). Separation of ownership and control. *The Journal of Law and Economics*, *26*(2), 301–325. https://doi.org/10.1086/467037

Fasan, M., Soerger Zaro, E., Soerger Zaro, C., Porco, B., & Tiscini, R. (2021). An empirical analysis: Did green supply chain management alleviate the effects of COVID-19? *Business Strategy and the Environment*, *30*(5), 2702–2712. https://doi.org/10.1002/bse.2772

Fatica, S., & Panzica, R. (2021). Green bonds as a tool against climate change? *Business Strategy and the Environment*, *30*(5), 2688–2701. https://doi.org/10.1002/bse.2771

Fernández-Guadaño, J., & Sarria-Pedroza, J. H. (2018). Impact of corporate social responsibility on value creation from a stakeholder perspective. *Sustainability*, *10*(6), 2062. https://doi.org/10.3390/su10062062

Filatotchev, I., Aguilera, R. V., & Wright, M. (2020). From governance of innovation to innovations in governance. *Academy of Management Perspectives*, *34*(2), 173–181. https://doi.org/10.5465/amp.2017.0011

Finster, M. P., & Hernke, M. T. (2014). Benefits organizations pursue when seeking competitive advantage by improving environmental performance. *Journal of Industrial Ecology*, *18*(5), 652–662. https://doi.org/10.1111/jiec.12106

Flammer, C., Hong, B., & Minor, D. (2019). Corporate governance and the rise of integrating corporate social responsibility criteria in executive compensation: Effectiveness and implications for firm outcomes. *Strategic Management Journal*, *40*(7), 1097–1122. https://doi.org/10.1002/smj.3018

Freedman, M., & Park, J. D. (2014). Mandated climate change disclosures by firms participating in the regional greenhouse gas initiative. *Social and Environmental Accountability Journal*, *34*(1), 29–44. https://doi.org/10.1080/0969160X.2013.852988

Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Boston, Pitman Publishing.

Freeman, R. E., Harrison, J. S., Wicks, A. C., Parmar, B. L., Purnell, L., & De Colle, S. (2010). *Stakeholder theory: The state of the art*. Cambridge University Press. https://doi.org/10.1017/CBO9780511815768

Galán-Valdivieso, F., Saraite-Sariene, L., Alonso-Cañadas, J., & Caba-Pérez, M. D. C. (2019). Do corporate carbon policies enhance legitimacy? A social media perspective. *Sustainability*, *11*(4), 1161. https://doi.org/10.3390/su11041161

Galbreath, J. (2011). Are there gender-related influences on corporate sustainability? A study of women on boards of directors. *Journal of Management & Organization*, *17*(1), 17–38. https://doi.org/10.5172/jmo.2011.17.1.17

Galbreath, J. (2018). Do boards of directors influence corporate sustainable development? An attention-based analysis. *Business Strategy and the Environment*, *27*(6), 742–756. https://doi.org/10.1002/bse.2028

Galia, F., Zenou, E., & Ingham, M. (2015). Board composition and environmental innovation: Does gender diversity matter. *International Journal of Entrepreneurship and Small Business*, *24*(1), 117–141. https://doi.org/10.1504/IJESB.2015.066152

García Martín, C. J., & Herrero, B. (2020). Do board characteristics affect environmental performance? A study of EU firms. *Corporate Social Responsibility and Environmental Management*, *27*(1), 74–94. https://doi.org/10.1002/csr.1775

Giannarakis, G. (2014). The determinants influencing the extent of CSR disclosure. *International Journal of Law and Management*, *56*(5), 393–416. https://doi.org/10.1108/IJLMA-05-2013-0021

Giannarakis, G., Zafeiriou, E., & Sariannidis, N. (2017). The impact of carbon performance on climate change disclosure. *Business Strategy and the Environment*, *26*(8), 1078–1094. https://doi.org/10.1002/bse.1962

Gillingham, K., & Stock, J. H. (2018). The cost of reducing greenhouse gas emissions. *Journal of Economic Perspectives*, *32*(4), 53–72. https://doi.org/10.1257/jep.32.4.53

Glass, C., Cook, A., & Ingersoll, A. R. (2016). Do women leaders promote sustainability? Analyzing the effect of corporate governance composition on environmental performance. *Business Strategy and the Environment*, *25*(7), 495–511. https://doi.org/10.1002/bse.1879

Goldhammer, B., Busse, C., & Busch, T. (2017). Estimating corporate carbon footprints with externally available data. *Journal of Industrial Ecology*, *21*(5), 1165–1179. https://doi.org/10.1111/jiec.12522

Griffin, P. A., Lont, D. H., & Sun, E. Y. (2017). The relevance to investors of greenhouse gas emission disclosures. *Contemporary Accounting Research*, *34*(2), 1265–1297. https://doi.org/10.1111/1911-3846.12298

Guest, P. M. (2009). The impact of board size on firm performance: Evidence from the UK. *The European Journal of Finance*, *15*(4), 385–404. https://doi.org/10.1080/13518470802466121

Gujarati, D. N. (2003). *Basic econometrics*. McGraw-Hill.

Hafsi, T., & Turgut, G. (2013). Boardroom diversity and its effect on social performance: Conceptualization and empirical evidence. *Journal of Business Ethics*, *112*(3), 463–479. https://doi.org/10.1007/s10551-012-1272-z

Haniffa, R. M., & Cooke, T. E. (2005). The impact of culture and governance on corporate social reporting. *Journal of Accounting and Public Policy*, *24*(5), 391–430. https://doi.org/10.1016/j.jaccpubpol.2005.06.001

Haque, F. (2017). The effects of board characteristics and sustainable compensation policy on carbon performance of UK firms. *The British Accounting Review*, *49*(3), 347–364. https://doi.org/10.1016/j.bar.2017.01.001

Haque, F., & Ntim, C. G. (2018). Environmental policy, sustainable development, governance mechanisms and environmental performance.

Business Strategy and the Environment, *27*(3), 415–435. https://doi.org/10.1002/bse.2007
Haque, F., & Ntim, C. G. (2020). Executive compensation, sustainable compensation policy, carbon performance and market value. *British Journal of Management*, *31*(3), 525–546. https://doi.org/10.1111/1467-8551.12395
Harjoto, M., Laksmana, I., & Lee, R. (2015). Board diversity and corporate social responsibility. *Journal of Business Ethics*, *132*(4), 641–660. https://doi.org/10.1007/s10551-014-2343-0
Hart, S. L. (1995). A natural-resource-based view of the firm. *Academy of Management Review*, *20*(4), 986–1014. https://doi.org/10.2307/258963
Hart, S. L., & Ahuja, G. (1996). Does it pay to be green? An empirical examination of the relationship between emission reduction and firm performance. *Business Strategy and the Environment*, *5*(1), 30–37. https://doi.org/10.1002/(SICI)1099-0836(199603)5:1<30::AID-BSE38>3.0.CO;2-Q
Havlinova, A., & Kukacka, J. (2021). Corporate social responsibility and stock prices after the financial crisis: The role of strategic CSR activities. *Journal of Business Ethics*, *1*, 1–20.
Helfaya, A., & Moussa, T. (2017). Do board's corporate social responsibility strategy and orientation influence environmental sustainability disclosure? UK evidence. *Business Strategy and the Environment*, *26*(8), 1061–1077. https://doi.org/10.1002/bse.1960
Hill, T. D., Davis, A. P., Roos, J. M., & French, M. T. (2020). Limitations of fixed-effects models for panel data. *Sociological Perspectives*, *63*(3), 357–369. https://doi.org/10.1177/0731121419863785
Hillman, A. J., Cannella, A. A., & Paetzold, R. L. (2000). The resource dependence role of corporate directors: Strategic adaptation of board composition in response to environmental change. *Journal of Management Studies*, *37*(2), 235–256. https://doi.org/10.1111/1467-6486.00179
Hillman, A. J., Keim, G. D., & Luce, R. A. (2001). Board composition and stakeholder performance: Do stakeholder directors make a difference? *Business and Society*, *40*(3), 295–314. https://doi.org/10.1177/000765030104000304
Hoepner, A. G., & Schopohl, L. (2020). State pension funds and corporate social responsibility: Do beneficiaries' political values influence funds' investment decisions? *Journal of Business Ethics*, *165*(3), 489–516. https://doi.org/10.1007/s10551-018-4091-z
Homroy, S., & Slechten, A. (2019). Do board expertise and networked boards affect environmental performance? *Journal of Business Ethics*, *158*(1), 269–292. https://doi.org/10.1007/s10551-017-3769-y
Htay, S. N. N., Rashid, H. M. A., Adnan, M. A., & Meera, A. K. M. (2012). Impact of corporate governance on social and environmental information disclosure of Malaysian listed banks: Panel data analysis. *Asian Journal of Finance and Accounting*, *4*(1), 1–24. https://doi.org/10.5296/ajfa.v4i1.810
Hussain, N., Rigoni, U., & Orij, R. P. (2018). Corporate governance and sustainability performance: Analysis of triple bottom line performance. *Journal of Business Ethics*, *149*(2), 411–432. https://doi.org/10.1007/s10551-016-3099-5
Ioannou, I., & Serafeim, G. (2019). The consequences of mandatory corporate sustainability reporting. In A. McWilliams (Ed.), and others*The Oxford handbook of corporate social responsibility: Psychological and organizational perspectives*. Oxford. https://doi.org/10.1093/oxfordhb/9780198802280.013.20
Ivanova, M. R. (2017). Institutional investors as stewards of the corporation: Exploring the challenges to the monitoring hypothesis. *Business Ethics: a European Review*, *26*(2), 175–188. https://doi.org/10.1111/beer.12142
Jackson, G., Bartosch, J., Avetisyan, E., Kinderman, D., & Knudsen, J. S. (2020). Mandatory non-financial disclosure and its influence on CSR: An international comparison. *Journal of Business Ethics*, *162*(2), 323–342. https://doi.org/10.1007/s10551-019-04200-0
Jizi, M. (2017). The influence of board composition on sustainable development disclosure. *Business Strategy and the Environment*, *26*(5), 640–655. https://doi.org/10.1002/bse.1943
Jizi, M. I., Salama, A., Dixon, R., & Stratling, R. (2014). Corporate governance and corporate social responsibility disclosure: Evidence from the US banking sector. *Journal of Business Ethics*, *125*(4), 601–615. https://doi.org/10.1007/s10551-013-1929-2
John, K., & Senbet, L. W. (1998). Corporate governance and board effectiveness. *Journal of Banking and Finance*, *22*(4), 371–403. https://doi.org/10.1016/S0378-4266(98)00005-3
Johnson, S. G., Schnatterly, K., & Hill, A. D. (2013). Board composition beyond independence: Social capital, human capital, and demographics. *Journal of Management*, *39*(1), 232–262. https://doi.org/10.1177/0149206312463938
Jouvenot, V., & Krueger, P. (2021). Mandatory corporate carbon disclosure: Evidence from a natural experiment. Available at SSRN 3434490.
Kassinis, G., Panayiotou, A., Dimou, A., & Katsifaraki, G. (2016). Gender and environmental sustainability: A longitudinal analysis. *Corporate Social Responsibility and Environmental Management*, *23*(6), 399–412. https://doi.org/10.1002/csr.1386
Kassinis, G., & Vafeas, N. (2006). Stakeholder pressures and environmental performance. *Academy of Management Journal*, *49*(1), 145–159. https://doi.org/10.5465/amj.2006.20785799
Kılıç, M., & Kuzey, C. (2019). The effect of corporate governance on carbon emission disclosures. *International Journal of Climate Change Strategies and Management*, *11*(1), 35–53. https://doi.org/10.1108/IJCCSM-07-2017-0144
King, A. A., & Lenox, M. J. (2001). Does it really pay to be green? An empirical study of firm environmental and financial performance: An empirical study of firm environmental and financial performance. *Journal of Industrial Ecology*, *5*(1), 105–116. https://doi.org/10.1162/108819801753358526
Kock, C. J., Santalo, J., & Diestre, L. (2012). Corporate governance and the environment: What type of governance creates greener companies? *Journal of Management Studies*, *49*(3), 492–514. https://doi.org/10.1111/j.1467-6486.2010.00993.x
Kolk, A., Levy, D., & Pinkse, J. (2008). Corporate responses in an emerging climate regime: The institutionalization and commensuration of carbon disclosure. *The European Accounting Review*, *17*(4), 719–745. https://doi.org/10.1080/09638180802489121
Konadu, R. (2017). Gender diversity impact on corporate social responsibility (CSR) and greenhouse gas emissions in the UK. *Economics and Business Review*, *3*(17), 127–148. https://doi.org/10.18559/ebr.2017.1.7
Krishnamurti, C., & Velayutham, E. (2018). The influence of board committee structures on voluntary disclosure of greenhouse gas emissions: Australian evidence. *Pacific-Basin Finance Journal*, *50*, 65–81. https://doi.org/10.1016/j.pacfin.2017.09.003
Krueger, P. (2015). Climate change and firm valuation: Evidence from a quasi-natural experiment. In Swiss finance institute research paper (15-40).
Krueger, P., Sautner, Z., & Starks, L. T. (2020). The importance of climate risks for institutional investors. *Review of Financial Studies*, *33*(3), 1067–1111. https://doi.org/10.1093/rfs/hhz137
Lam, K., & Li, Y. (2008). Does corporate governance matter? The case of environmental and social responsibility committees in the board. In Canadian Academic Accounting Association conference. Halifax, Canada.
Lee, K. H., & Min, B. (2015). Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *Journal of Cleaner Production*, *108*, 534–542. https://doi.org/10.1016/j.jclepro.2015.05.114
Lee, S. Y., & Klassen, R. D. (2016). Firms' response to climate change: The interplay of business uncertainty and organizational capabilities. *Business Strategy and the Environment*, *25*(8), 577–592. https://doi.org/10.1002/bse.1890

Leone, A. J., Minutti-Meza, M., & Wasley, C. E. (2019). Influential observations and inference in accounting research. *The Accounting Review*, *94*(6), 337–364. https://doi.org/10.2308/accr-52396

Li, D., Huang, M., Ren, S., Chen, X., & Ning, L. (2018). Environmental legitimacy, green innovation, and corporate carbon disclosure: Evidence from CDP China 100. *Journal of Business Ethics*, *150*(4), 1089–1104. https://doi.org/10.1007/s10551-016-3187-6

Li, J., Zhao, F., Chen, S., Jiang, W., Liu, T., & Shi, S. (2017). Gender diversity on boards and firms' environmental policy. *Business Strategy and the Environment*, *26*(3), 306–315. https://doi.org/10.1002/bse.1918

Li, Y. (2014). Environmental innovation practices and performance: Moderating effect of resource commitment. *Journal of Cleaner Production*, *66*, 450–458. https://doi.org/10.1016/j.jclepro.2013.11.044

Liao, L., Luo, L., & Tang, Q. (2015). Gender diversity, board independence, environmental committee and greenhouse gas disclosure. *The British Accounting Review*, *47*(4), 409–425. https://doi.org/10.1016/j.bar.2014.01.002

Liesen, A., Figge, F., Hoepner, A., & Patten, D. M. (2017). Climate change and asset prices: Are corporate carbon disclosure and performance priced appropriately? *Journal of Business Finance and Accounting*, *44*(1–2), 35–62. https://doi.org/10.1111/jbfa.12217

Liesen, A., Hoepner, A. G., Patten, D. M., & Figge, F. (2015). Does stakeholder pressure influence corporate GHG emissions reporting? Empirical evidence from Europe. *Accounting, Auditing & Accountability Journal*, *28*(7), 1047–1074. https://doi.org/10.1108/AAAJ-12-2013-1547

Lipton, M., & Lorsch, J. W. (1992). A modest proposal for improved corporate governance. *The Business Lawyer*, *48*, 59–77.

Long, X., Chen, Y., Du, J., Oh, K., Han, I., & Yan, J. (2017). The effect of environmental innovation behavior on economic and environmental performance of 182 Chinese firms. *Journal of Cleaner Production*, *166*, 1274–1282. https://doi.org/10.1016/j.jclepro.2017.08.070

Lu, J., & Herremans, I. M. (2019). Board gender diversity and environmental performance: An industries perspective. *Business Strategy and the Environment*, *28*(7), 1449–1464. https://doi.org/10.1002/bse.2326

Luo, L., & Tang, Q. (2021). Corporate governance and carbon performance: Role of carbon strategy and awareness of climate risk. *Accounting and Finance*, *61*(2), 2891–2934. https://doi.org/10.1111/acfi.12687

Maso, D. L., Mazzi, F., Soscia, M., & Terzani, S. (2018). The moderating role of stakeholder management and societal characteristics in the relationship between corporate environmental and financial performance. *Journal of Environmental Management*, *218*, 322–332. https://doi.org/10.1016/j.jenvman.2018.04.005

Mason, C., & Simmons, J. (2014). Embedding corporate social responsibility in corporate governance: A stakeholder systems approach. *Journal of Business Ethics*, *119*(1), 77–86. https://doi.org/10.1007/s10551-012-1615-9

Matsumura, E. M., Prakash, R., & Vera-Muñoz, S. C. (2014). Firm-value effects of carbon emissions and carbon disclosures. *The Accounting Review*, *89*(2), 695–724. https://doi.org/10.2308/accr-50629

McKendall, M., Sánchez, C., & Sicilian, P. (1999). Corporate governance and corporate illegality: The effects of board structure on environmental violations. *The International Journal of Organizational Analysis*, *7*(3), 201–223. https://doi.org/10.1108/eb028900

Meng, Y., & Wang, X. (2019). Do institutional investors have homogeneous influence on corporate social responsibility? Evidence from investor investment horizon. *Managerial Finance*, *46*(3), 301–322. https://doi.org/10.1108/MF-03-2019-0121

Moussa, T., Allam, A., Elbanna, S., & Bani-Mustafa, A. (2020). Can board environmental orientation improve US firms' carbon performance? The mediating role of carbon strategy. *Business Strategy and the Environment*, *29*(1), 72–86. https://doi.org/10.1002/bse.2351

Naciti, V. (2019). Corporate governance and board of directors: The effect of a board composition on firm sustainability performance. *Journal of Cleaner Production*, *237*, 117727. https://doi.org/10.1016/j.jclepro.2019.117727

Nguyen, J. H., & Phan, H. V. (2020). Carbon risk and corporate capital structure. *Journal of Corporate Finance*, *64*, 101713. https://doi.org/10.1016/j.jcorpfin.2020.101713

Nielsen, S. (2012). Diversity among senior executives and board directors. *The Sage Handbook of Corporate Governance*, 345–362. https://doi.org/10.4135/9781446200995.n16

Nofsinger, J. R., Sulaeman, J., & Varma, A. (2019). Institutional investors and corporate social responsibility. *Journal of Corporate Finance*, *58*, 700–725. https://doi.org/10.1016/j.jcorpfin.2019.07.012

Nuber, C., & Velte, P. (2021). Board gender diversity and carbon emissions: European evidence on curvilinear relationships and critical mass. *Business Strategy and the Environment*, *30*(4), 1958–1992. https://doi.org/10.1002/bse.2727

Nyombi, C. (2018). The USA as a good comparator for UK in corporate governance. *International Journal of Law and Management*, *60*(1), 135–149. https://doi.org/10.1108/IJLMA-04-2013-0014

Olden, A., & Møen, J. (2022). The triple difference estimator. *The Econometrics Journal*, *25*(3), 531–553. https://doi.org/10.1093/ectj/utac010

O'Neill, H. M., Saunders, C. B., & McCarthy, A. D. (1989). Board members, corporate social responsiveness and profitability: Are tradeoffs necessary? *Journal of Business Ethics*, *8*(5), 353–357. https://doi.org/10.1007/BF00381726

Orazalin, N., & Mahmood, M. (2021). Toward sustainable development: Board characteristics, country governance quality, and environmental performance. *Business Strategy and the Environment*, *30*(8), 3569–3588. https://doi.org/10.1002/bse.2820

Ortiz de Mandojana, N., & Aragon Correa, J. A. (2015). Boards and sustainability: The contingent influence of director interlocks on corporate environmental performance. *Business Strategy and the Environment*, *24*(6), 499–517. https://doi.org/10.1002/bse.1833

Palmer, D. A., Marquis, C., & Kimball, A. (2012). The impact of women top managers and directors on corporate environmental performance. In *Academy of management proceedings* (Vol. 2012, No. 1, p. 10983). : Academy of Management, https://doi.org/10.5465/AMBPP.2012.10983abstract

Peters, G. F., & Romi, A. M. (2014). Does the voluntary adoption of corporate governance mechanisms improve environmental risk disclosures? Evidence from greenhouse gas emission accounting. *Journal of Business Ethics*, *125*(4), 637–666. https://doi.org/10.1007/s10551-013-1886-9

Pfeffer, J., & Salancik, G. R. (1978). *The external control of organizations: A resource dependence perspective*. University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship.

Phung, G., Trinh, H. H., Nguyen, T. H., & Trinh, V. Q. (2023). Top-management compensation and environmental innovation strategy. *Business Strategy and the Environment*, *32*, 1634–1649. https://doi.org/10.1002/bse.3209

Post, C., Rahman, N., & McQuillen, C. (2015). From board composition to corporate environmental performance through sustainability-themed alliances. *Journal of Business Ethics*, *130*(2), 423–435. https://doi.org/10.1007/s10551-014-2231-7

Post, C., Rahman, N., & Rubow, E. (2011). Green governance: Boards of directors' composition and environmental corporate social responsibility. *Business and Society*, *50*(1), 189–223. https://doi.org/10.1177/0007650310394642

Prado-Lorenzo, J. M., & Garcia-Sanchez, I. M. (2010). The role of the board of directors in disseminating relevant information on greenhouse gases. *Journal of Business Ethics*, *97*(3), 391–424. https://doi.org/10.1007/s10551-010-0515-0

Qian, W., & Schaltegger, S. (2017). Revisiting carbon disclosure and performance: Legitimacy and management views. *The British Accounting Review*, *49*(4), 365–379. https://doi.org/10.1016/j.bar.2017.05.005

Rao, K. K., Tilt, C. A., & Lester, L. H. (2012). Corporate governance and environmental reporting: An Australian study. *Corporate Governance: the International Journal of Business in Society*, *12*(2), 143–163. https://doi.org/10.1108/14720701211214052

Rodrigue, M., Magnan, M., & Cho, C. H. (2013). Is environmental governance substantive or symbolic? An empirical investigation. *Journal of Business Ethics*, *114*(1), 107–129. https://doi.org/10.1007/s10551-012-1331-5

Rose, C. (2007). Does female board representation influence firm performance? The Danish evidence. *Corporate Governance: An International Review*, *15*(2), 404–413. https://doi.org/10.1111/j.1467-8683.2007.00570.x

Saka, C., & Oshika, T. (2014). Disclosure effects, carbon emissions and corporate value. *Sustainability Accounting, Management and Policy Journal*, *5*(1), 22–45. https://doi.org/10.1108/SAMPJ-09-2012-0030

Sarkis, J., Gonzalez-Torre, P., & Adenso-Diaz, B. (2010). Stakeholder pressure and the adoption of environmental practices: The mediating effect of training. *Journal of Operations Management*, *28*(2), 163–176. https://doi.org/10.1016/j.jom.2009.10.001

Schnittfeld, N. L., & Busch, T. (2016). Sustainability management within supply chains—A resource dependence view. *Business Strategy and the Environment*, *25*(5), 337–354. https://doi.org/10.1002/bse.1876

Shaukat, A., Qiu, Y., & Trojanowski, G. (2016). Board attributes, corporate social responsibility strategy, and corporate environmental and social performance. *Journal of Business Ethics*, *135*(3), 569–585. https://doi.org/10.1007/s10551-014-2460-9

Singh, V. (2007). Ethnic diversity on top corporate boards: A resource dependency perspective. *The International Journal of Human Resource Management*, *18*(12), 2128–2146. https://doi.org/10.1080/09585190701695275

Stanny, E. (2013). Voluntary disclosures of emissions by US firms. *Business Strategy and the Environment*, *22*(3), 145–158. https://doi.org/10.1002/bse.1732

Sullivan, R. (2009). The management of greenhouse gas emissions in large European companies. *Corporate Social Responsibility and Environmental Management*, *16*(6), 301–309. https://doi.org/10.1002/csr.187

Sullivan, R., & Gouldson, A. (2012). Does voluntary carbon reporting meet investors' needs? *Journal of Cleaner Production*, *36*, 60–67. https://doi.org/10.1016/j.jclepro.2012.02.020

Sundarasen, S. D. D., Je-Yen, T., & Rajangam, N. (2016). Board composition and corporate social responsibility in an emerging market. *Corporate Governance: The International Journal of Business in Society*, *16*(1), 35–53. https://doi.org/10.1108/CG-05-2015-0059

Tang, S., & Demeritt, D. (2018). Climate change and mandatory carbon reporting: Impacts on business process and performance. *Business Strategy and the Environment*, *27*(4), 437–455. https://doi.org/10.1002/bse.1985

Toebelmann, D., & Wendler, T. (2020). The impact of environmental innovation on carbon dioxide emissions. *Journal of Cleaner Production*, *244*, 118787. https://doi.org/10.1016/j.jclepro.2019.118787

Ullah, S., Akhtar, P., & Zaefarian, G. (2018). Dealing with endogeneity bias: The generalized method of moments (GMM) for panel data. *Industrial Marketing Management*, *71*, 69–78. https://doi.org/10.1016/j.indmarman.2017.11.010

Unerman, J., & O'Dwyer, B. (2007). The business case for regulation of corporate social responsibility and accountability. *Accounting Forum*, *31*(4), 332–353. https://doi.org/10.1016/j.accfor.2007.08.002

Uyar, A., Karaman, A. S., & Kilic, M. (2020). Is corporate social responsibility reporting a tool of signaling or greenwashing? Evidence from the worldwide logistics sector. *Journal of Cleaner Production*, *253*, 119997. https://doi.org/10.1016/j.jclepro.2020.119997

Uyar, A., Kuzey, C., Gerged, A. M., & Karaman, A. S. (2023). Research and development intensity, environmental performance, and firm value: Unraveling the nexus in the energy sector worldwide. *Business Strategy and the Environment*, *32*, 1582–1602. https://doi.org/10.1002/bse.3206

Velte, P., Stawinoga, M., & Lueg, R. (2020). Carbon performance and disclosure: A systematic review of governance-related determinants and financial consequences. *Journal of Cleaner Production*, *254*, 120063. https://doi.org/10.1016/j.jclepro.2020.120063

Vilchez, V. F., Darnall, N., & Correa, J. A. A. (2017). Stakeholder influences on the design of firms' environmental practices. *Journal of Cleaner Production*, *142*, 3370–3381. https://doi.org/10.1016/j.jclepro.2016.10.129

Walls, J. L., Berrone, P., & Phan, P. H. (2012). Corporate governance and environmental performance: Is there really a link? *Strategic Management Journal*, *33*(8), 885–913. https://doi.org/10.1002/smj.1952

Weina, D., Gilli, M., Mazzanti, M., & Nicolli, F. (2016). Green inventions and greenhouse gas emission dynamics: A close examination of provincial Italian data. *Environmental Economics and Policy Studies*, *18*(2), 247–263. https://doi.org/10.1007/s10018-015-0126-1

Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal*, *5*(2), 171–180. https://doi.org/10.1002/smj.4250050207

Wintoki, M. B., Linck, J. S., & Netter, J. M. (2012). Endogeneity and the dynamics of internal corporate governance. *Journal of Financial Economics*, *105*(3), 581–606. https://doi.org/10.1016/j.jfineco.2012.03.005

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

Wooldridge, J. M. (2020). *Introductory econometrics: A modern approach* (7th ed.). Cengage.

Yadav, P. L., Han, S. H., & Kim, H. (2017). Sustaining competitive advantage through corporate environmental performance. *Business Strategy and the Environment*, *26*(3), 345–357. https://doi.org/10.1002/bse.1921

Yelowitz, A. S. (1995). The medicaid notch, labor supply, and welfare participation: Evidence from eligibility expansions. *Quarterly Journal of Economics*, *110*(4), 909–939. https://doi.org/10.2307/2946644

Zaman, R., Farooq, M. B., Khalid, F., & Mahmood, Z. (2021). Examining the extent of and determinants for sustainability assurance quality: The role of audit committees. *Business Strategy and the Environment*, *30*(7), 2887–2906. https://doi.org/10.1002/bse.2777

Zhang, L. (2012). Board demographic diversity, independence, and corporate social performance. *Corporate Governance: the International Journal of Business in Society*, *12*(5), 686–700. https://doi.org/10.1108/14720701211275604

Zhang, Y. J., Peng, Y. L., Ma, C. Q., & Shen, B. (2017). Can environmental innovation facilitate carbon emissions reduction? Evidence from China. *Energy Policy*, *100*, 18–28. https://doi.org/10.1016/j.enpol.2016.10.005

Zimmerman, J. L. (1983). Taxes and firm size. *Journal of Accounting and Economics*, *5*, 119–149. https://doi.org/10.1016/0165-4101(83)90008-3

How to cite this article: Muktadir-Al-Mukit, D., & Bhaiyat, F. H. (2023). Impact of corporate governance diversity on carbon emission under environmental policy via the mandatory nonfinancial reporting regulation. *Business Strategy and the Environment*, 1–21. https://doi.org/10.1002/bse.3555