Received: 22 April 2022 | Revised: 4 July 2022 | Accepted: 2 August 2022
DOI: 10.1002/bse.3232

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

Business environmental innovation and CO_2 emissions: The moderating role of environmental governance

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Abstract

This paper examines the effects of environmental innovation on CO_2 emissions as well as the moderating role of environmental governance in this relationship. Based on a sample of companies listed on the London Stock Exchange for the period from 2016 to 2020, the findings show that environmental innovation reduces CO_2 emissions including Scope 1 and Scope 2 CO_2 emissions. Likewise, our findings are associative of a moderating effect of environmental governance on the environmental innovation-CO_2 emissions nexus. We argue that environmental innovation along with better environmental governance leads to a reduction in CO_2 emissions. Our results hold for subsamples of firms with a strong/low environmental governance and ESG performance. Our findings offer important implications for companies and policymakers towards adopting more environmental technologies along with enhancing environmental governance to reduce CO_2 emissions.

KEYWORDS

CO_2 emissions, environmental governance, environmental innovation, sustainable development

1 | INTRODUCTION

Businesses are playing an essential role in meeting crucial environmental performance outcomes through the introduction of new, or revised, manufacturing and operational practices, and through initiatives that result in innovative and sustainable products and practices (Shakeel et al., 2020). This is as a reaction to the manifold impacts of global warming, and the consequences these impacts have on society in general (Zandalinas et al., 2021). Environmental management systems such as preventing pollution, recycling and plastic reuse, energy efficiency, and carbon emissions management are all necessitate innovation (Shi et al., 2021). However, a primary difficulty confronting business leaders is determining how these environmental activities and policies effect CO_2 emissions.

Many scientists, authorities, experts, and academics agree that a green economy is critical and that achieving one without innovation will be impossible (Swainson & Mahanty, 2018). In recent decades, there has tended to be agreement about the value of green technological progress (or eco-innovation) as a tool for achieving sustainability goals, increasing energy efficiency, reducing negative resource use consequences, and lowering pollution and other environmental risks (Asongu & Odhiambo, 2021). Many businesses use environmental innovation as a common environmental strategy to achieve superior environmental and economic outcomes (Khan et al., 2021). This includes developing, implementing, or employing a new product, production process, service, management strategy, or corporate strategy that reduce the environmental risk, environmental damage, and other negative effects of resource use (Iqbal et al., 2021). Recent research

Abbreviations: CO_2, carbon dioxide; ESG, environmental social and governance; GDP, gross domestic product; GHG, greenhouse gas; LSE, London Stock Exchange; OECD, Organization for Economic Co-operation and Development; R&D, research and development; RBV, resources-based view.

has highlighted the importance of technological innovation in accomplishing sustainability goals (Sinha et al., 2020; Song et al., 2019). Technological innovation has a positive impact on the environment since it uses green energy and reduces the usage of fossil fuels (Jordaan et al., 2017). Furthermore, these technologies may be able to help countries improve their manufacturing processes' efficiency. For example, Choudhary et al. (2019) found that the Green Integrated Value Stream Mapping method indicates that combining the lean and green paradigms has a synergistic effect on operational efficiency and environmental performance.

Environmental governance, in specific, aims to regulate collective and individual actions in the pursuit of the common environmental goods and societal outcomes (Newig & Fritsch, 2009). Environmental governance processes and procedures can come together in a number of ways: for example, governance can be driven from the top down by governments, private citizens or actors, or from the bottom up by local communities, or through collective decision and authority via formal co-management agreements or informal networks of actors and organizations (Bennett & Satterfield, 2018). There has been an increase in interest in analyzing the impact of various governance attributes and elements on social and ecological outcomes in order to develop generalizable lessons (Bennett & Satterfield, 2018). More research is needed to better understand the causal relationships between governance and eco-innovation and environmental performance. Therefore, to grasp environmental governance, one must first comprehend how environmental decisions and the policies and processes lead to environmentally and socially sustainable outcomes.

Researchers are increasingly emphasizing the necessity of responsible business and technological innovation within businesses can brought green solutions and can help to reduce the negative impact caused by the industrialization. The reality is that technology is an important part of the global effort to achieve net zero emissions (Dwivedi et al., 2022). Greener production methods, as well as more environmentally friendly and sustainable products and services, are growing more popular (Hole & Hole, 2019). Environmental innovations, on the other hand, are intrinsically linked to business investment in research and development (R&D). Importantly, the results of eco-innovation are not always immediately apparent (Li, Zhang, et al., 2020). Developing environmentally friendly "green" products that are also economically and commercially successful is a major business hurdle (Khan et al., 2021; Yang et al., 2019). More empirical knowledge that is applicable to corporate performance to reduce carbon emissions through innovation is required to address the challenge of developing "win–win" solutions. The debate over the relationship between eco-innovation and commercial success has been inconclusive and underwhelming in general, merely indicating that it will continue. The innovation-driven mode, in theory, might be crucial for transforming new drives and patterns while also boosting economic performance throughout the entire process of a changing economic structure (Jiang et al., 2020). However, in terms of addressing the objective of zero carbon emissions, it still remains a work in progress trying to figure out what opportunities may exist within the numerous innovation revolutions, and in how to use innovation to cut carbon emissions. More study on the influence of eco-innovation on CO_2 emissions is needed to give corporate leaders a solid foundation, and to aid and advise them in achieving superior environmental performance. Given the importance of green innovation in shaping environmental sustainability, the objectives of our paper are two-fold. First, we aim to explore the effect of environmental innovation on CO_2 emissions. In stating our aim, we purport that companies that engage in environmental innovation practices that help in controlling resource can reduce CO_2 emissions. Second, we examine the moderating role of environmental governance in this relationship based on a sample of companies listed on the London Stock Exchange for the period from 2016 to 2020. In doing so, our findings can assist policymakers in assessing the effectiveness of environmental governance in reducing CO_2 emissions. Thus, this study seeks to provide answers to the key questions "what is the relationship between environmental innovation and CO_2 emissions? And what is the role of environmental governance in this relationship?"

This study contributes to the existing literature in several ways. First, unlike prior studies (e.g., Afrifa et al., 2020; Hashmi & Alam, 2019) that relied widely on innovation proxied by the percentage of R&D to GDP or used patent data to proxy environmental innovations (Mongo et al., 2021), this study focuses on environmental innovation technologies that indicates a company's ability to lower environmental costs and responsibilities, while opening up new business potential through new environmental technologies. Second, this study contributes to the debate on factors that drive CO_2 emissions by highlighting the effect of environmental innovation on CO_2 emissions. Third, to the best of our knowledge, our study is the first in the UK context that explore the moderating effect of environmental governance on the environmental innovation-CO_2 emissions nexus. We offer a rich opportunity to investigate the role environmental innovation can play in reducing CO_2 emissions, we also highlight the essential role of environmental governance in this nexus. Fourth, from a methodological perspective, we provide an opportunity to consider variations in specific ESG performance and environmental governance and how they may affect the environmental innovation-CO_2 emissions nexus. We divided the sample into subsamples based on ESG performance and environmental governance. The sub-sampling technique allows for better testing of the correlation between environmental innovation and CO_2 emissions. Therefore, our findings offer important implications for companies and policymakers towards adopting more environmental technologies along with enhancing environmental governance to reduce CO_2 emissions.

The remainder of this paper is organized as follows. Section 2 shows the theory and literature. Section 3 discusses the hypotheses development. Section 4 presents research methodology, followed by section 5 that shows the analysis and discussion. Section 6 concludes the study.

2 | THEORY AND LITERATURE

According to the stakeholder theory, the interests of shareholders should not take priority over the interests of other stakeholders. As a result, rather than focusing on trade-offs, one of the primary objectives for managers in stakeholder theory is to generate mutual benefits for multiple stakeholders (Friedman & Miles, 2002). Innovative thinking may be able to tackle social and environmental problems as well as create mutual benefits and values within the corporation and its stakeholders (Li, Liao, & Albitar, 2020). In contrast, other aspects of stakeholder theory cast doubt on the ability to achieve mutual benefits for all important stakeholders by emphasizing the necessity to choose or even prioritize specific stakeholders (Darnall et al., 2010; Hall et al., 2015). Stakeholders are more inclined to criticize corporations that emit excessive greenhouse gases (Chithambo et al., 2020). Consumers and business partners may, for example, reject carbon-intensive products, consequently reducing sales and profits for the companies that manufacture them. Shareholders of the company may think that organizations that damage the natural environment will be faced by major market ramifications in the longer run (Matsumura et al., 2014). Furthermore, many governments across the world, including the United Kingdom, are now taking active measures to curb the excessive release of carbon emissions and, through the introduction of more restrictive carbon legislation and regulations, to encourage businesses to reduce carbon emissions (Karim et al., 2021; Wagner & Zeckhauser, 2012). This may limit businesses' usual operations. In this backdrop, stakeholder theory has never been more important with company stakeholders playing an even more pivotal role in influencing businesses. A company cannot achieve its strategic goals without satisfying the interests and demands of stakeholders, not just a few key stakeholders, as almost all interested stakeholders will have some connection to the company. These stakeholders will have varying degrees of legitimate influence.

In addition to that, based on the resources-based view (RBV), green products and services need to be as efficient as they can possibly be and core competences will be key to developing innovative, environmentally safe, economic, and widely available products and services (Marín-Vinuesa et al., 2020). The RBV theoretical approach contends that companies that amass scarce, valuable, unique, and non-substitutable resources and capabilities gain an advantage over their competitors (Barney, 2001). Stakeholders will have an increasing part to play in driving businesses towards achieving this. Shareholders and other investors will look to see a fair return for their investment, employees will look for security and equitable pay and rewards, environmental groups will look at the long-term impact of decisions made by businesses on meeting environmental goals (Albitar et al., 2021), customers will look for efficient and affordable alternatives to existing energy products, recovery from environmental damage, reversal of climate change, and so on (de Sousa Jabbour et al., 2020). The process of creating the green economy is one which appears to meet this theory and the stakeholder theory agendas. There has never been a more pressing time to work towards achieving the best aims of these two theoretical concepts.

Due to pressures from environmental deterioration and international climate negotiations, many worldwide organizations such as the United Nations, the European Union, and regulators around the world set climate goals to decrease their overall carbon emissions (van Emous et al., 2021; Zhang et al., 2017). Environmental innovation has been recognized as an efficient way of addressing environmental problems, such as CO_2 emissions (Zhang et al., 2017). At the more micro-level, firms may have several motivations to decrease their overall carbon emissions, which are mainly driven by the different pressures of multiple stakeholders who are aware of the key role of climate protection (van Emous et al., 2021).

Innovations in the environmental area could be those related to renewable energy production such as solar and wind energy and biofuels. These kinds of innovations are an example of environmental innovations that reduce energy consumption related to carbon emissions (Többelmann & Wendler, 2020). Carrión-Flores and Innes (2010) show that environmental innovation has a negative and significant effect on pollution emissions for manufacturing industries in the United States. Based on US data, Konadu et al. (2022) explore whether environmental innovation moderates board diversity-carbon emissions nexus. Most studies that deal with CO_2 emissions and innovation ignore specifically environmental innovation as a potential factor that may contribute to a significant reduction of CO_2 emissions (Ganda, 2019; Mensah et al., 2018; Tnani, 2018) or focus more on the country-level (i.e., macro-level) to compare a group of several jurisdictions (Fethi & Rahuma, 2019; Hashmi & Alam, 2019; Mongo et al., 2021; Többelmann & Wendler, 2020), except Zhang et al. (2017) who estimate the effect of environmental innovation on carbon emissions in China for the period 2000–2013. Their findings show that most environmental innovation measures in China reduce carbon emissions efficiently. More particularly, energy efficiency exerts a significant effect on reducing carbon emissions. Also, they find that resources for innovation and knowledge innovation have an important role in reducing carbon emissions.

3 | HYPOTHESES DEVELOPMENT

3.1 | Environmental innovation and carbon dioxide emissions

The resource-based view provides an adequate theoretical basis to recognize the importance of resources and discuss its valuable contribution to the different aspects of environmental innovation (Lee & Min, 2015). More particularly, it holds that the competitive gain of a firm depends on the resources that are heterogeneous in nature and distinctive in their value, difficulty to imitate, and cannot be substituted (Lee & Min, 2015). Prior studies show that innovation, in general, has a key role in reducing CO_2 emissions across several jurisdictions (Ganda, 2019; Mensah et al., 2018; Tnani, 2018). Ganda (2019) examines whether innovation and technology investment influenced CO_2 emissions in OECD countries. The results show that expenditure on R&D has a negative and significant effect on carbon emissions. Also, the number of patents has a positive and significant effect on carbon emissions. Mensah et al. (2018) show that innovation has a key role in reducing CO_2 emissions in most OECD countries. Further, Tnani (2018) conclude that high-tech exports, R&D

expenditure, and innovation all contribute to a reduction of CO_2 emissions. Some other studies focus more particularly on the effect of technological innovation on CO_2 emissions in different countries (Ali et al., 2016). Investments in advanced and environment-friendly technologies significantly contribute to a reduction of CO_2 emissions and improve environmental quality (Ali et al., 2016). Hashmi and Alam (2019) show that a 1% increase in an environmentally friendly patent contributes to a reduction of carbon emissions by 0.017%. In the same vein, Fethi and Rahuma (2019) investigated the effect of eco-innovation on carbon dioxide emissions for the top twenty refined-oil exporting countries during the 2007–2016 period. They find that eco-innovation negatively affects CO_2 emissions. Mongo et al. (2021) investigate the effect of environmental innovations on CO_2 emissions for 15 European countries over 23 years. Their findings show that, in the long-term, environmental innovations tend to lower CO_2 emissions, whereas in the short-term the observed effect is the opposite, suggesting the existence of a rebound effect. Töbelmann and Wendler (2020) investigate the impacts of environmental innovation on carbon dioxide emissions by using patent counts of environmental patent applications as a proxy of environmental innovation. Their findings show that environmental innovation contributes to carbon dioxide emissions reduction. Zhang et al. (2017) find that most environmental innovation measures in China reduce carbon emissions efficiently. More particularly, energy efficiency exerts a significant effect on reducing carbon emissions. Also, they find that resources for innovation and knowledge innovation have an important role in reducing carbon emissions.

Based on the discussion above, we expect that environmental innovative firms have lower carbon emissions and posit the following hypothesis:

> **Hypothesis 1.** Corporate environmental innovation is negatively associated with CO_2 emissions.

3.2 | The moderating effect of environmental governance

Prior studies that deal with innovation and CO_2 emissions have largely focused on investigating the direct effect of innovation in general on CO_2 emissions (Fethi & Rahuma, 2019; Ganda, 2019; Hashmi & Alam, 2019; Töbelmann & Wendler, 2020). Mongo et al., (2021). All these studies ignore the potential moderating effect of environmental structures on this relationship. Theoretically, stakeholder theory suggests that committing to good governance practices may indicate to the market that firms are concerned about protecting multiple stakeholders' interests (Cormier & Magnan, 2003), and this may influence the link between environmental innovation and carbon emissions. Further, resource-based view suggests that a high commitment level to stakeholders' expectations, in the form of implementing good governance and environmental practices, may help firms get competitive advantages, such as providing better influential environmental innovation, and this may lead to a positive moderating effect on the association between environmental innovation and reduction of carbon emissions.

In fact, due to increasing government and market pressures to protect the environment, companies are facing sustainability challenges in fostering effective environmental innovation capabilities (Cheng et al., 2014; Lee & Min, 2015). Hart (1995) extended the Resource Based View concept to incorporate natural constraints and opportunities and argued that a sustainable competitive advantage can be gained through firm resources that are valuable, costly-to-imitate, rare, and immovable. In other terms, firms should accumulate resources with a longer-term focus rather than focus solely on short term profits that damage the environment. A firm's ability to envision and design sustainable products and technologies can give it an edge in the marketplace. (Lee & Min, 2015). In this regard, Afrifa et al. (2020) examine whether innovation input influences CO_2 emissions and how country-level governance factors may moderate this relationship. They use a sample of 29 emerging countries and 725 country-year observations. Their main findings show that innovation input (proxied by the percentage of R&D to GDP) contributes to a reduction of CO_2 emissions.

At the more micro-level, a firm's commitment to addressing climate change can be gauged from whether it has incorporated climate change issues at the board level. One way to measure this commitment is whether boards control carbon emissions (Prado-Lorenzo & Garcia-Sanchez, 2010), for example, through having a sub-committee responsible for climate change issues or providing incentives to senior executives for carbon mitigation and sustainability targets (Ioannou et al., 2016). To the best of our knowledge, none of the existing studies that deal with environmental innovation and carbon emissions have examined the moderating effect of sustainability governance, and this offers an opportunity to expand the extant literature. Based on the discussion above, we expect that environmental governance moderates the relationship between environmental innovation and CO_2 emissions and posit the following hypothesis:

> **Hypothesis 2.** Environmental governance strengthen the negative relationship between environmental innovation and CO_2 emissions.

4 | RESEARCH METHODOLOGY

4.1 | Data and sample

This paper is based on a sample of companies listed on the London Stock Exchange for the period from 2016 to 2020. The chosen time period allows us to test the impact of corporate environmental innovation on CO_2 emissions and the role of environmental governance on this relationship in recent years. In response to the 2015 Paris Climate Change Agreement, the UK government has also established an explicit aim of achieving net-zero GHG emissions by 2050, for example, balancing CO_2 emissions with CO_2 removal. In June 2019, the UK government updated the 2008 Climate Change Act

(Lorenzoni & Benson, 2014) to incorporate the new goal, making them one of the first European countries to make such a legally binding commitment. Therefore, we focus on the period of 2016–2020. The data are collected from the Eikon database. We winsorize all variables at the 1% and 99% levels to control the effect of outliers.

4.2 | Variables definitions and measurement

4.2.1 | The dependent variable: CO_2 emissions

Following prior research, this study uses the total CO_2 emissions of the company in thousands of metric tons (e.g., Bui et al., 2020; Gerged, Matthews, & Elheddad, 2021). CO_2 emissions are defined as those gases that contribute to the trapping of heat in the Earth's atmosphere, and they include carbon dioxide (CO_2), methane and nitrous oxide (Bui et al., 2020). Total GHG emissions, as defined in this field, equals the total of company Scope 1 and Scope 2 emissions. To make our variables homogeneous, we converted the CO_2 emissions to a natural logarithm (ln CO_2 emissions).

4.2.2 | The independent variable: Environmental innovation

Following previous research (Nadeem et al., 2020; Zaman et al., 2021), this study uses environmental innovation scores received from Eikon database as the independent variable. Environmental innovation score reflects a company's capacity to reduce environmental costs and burdens for its customers, and thereby creating new market opportunities through new improvement in existing environmental technologies and processes or eco-designed products or processes. This environmental innovation score ranges between 0 and 100.

4.2.3 | The moderating variable: Environmental governance

We use the following variables to measure the environmental governance of a company. First, we examine whether the company has a board-level environmental committee (Env_Comm) that discusses and promotes environmental issues. Env_Comm is a binary variable that takes a value of 1 if an environmental committee exists, 0 otherwise. Second, we investigate whether executive's compensation is linked with environmental performance (Exc_Comp). Exc_Comp is an indicator variable that equals 1 if the company provides incentives for individual management of environmental issues, and 0 otherwise. Third, we check whether a company publishes a sustainability report (Sus_Repo) using an indicator variable that equals 1 if a firm publishes sustainability reports, and 0 otherwise. Finally, we consider whether sustainability report is externally assured (Sus_Assur) using an indicator variable that equals 1 if sustainability report is externally assured, and 0 otherwise. Therefore, we measure corporate environmental governance strength by totaling the four components discussed above.

TABLE 1 Definition of variables

CO_2_emissions	The natural logarithm of total CO_2 emissions of the company in thousands of metric tons
L.Env_Innovation	Lagged value of environmental innovation score
Env_Comm	An indicator variable that equals 1 if a board level sustainability committee exists, and 0 otherwise.
Exc_Comp	An indicator variable that equals 1 if executive compensation is linked with environmental performance
Sus_Repo	An indicator variable that equals 1 if a firm publishes sustainability reports, and 0 otherwise.
Sus_Assur	An indicator variable that equals 1 if sustainability report is externally assured, and 0 otherwise.
Env_Governance	Strength of environmental governance of a firm, computed as a composite score by totalling the four environmental governance components (Sus_Assur, Sus_Repo, Exc_Comp, Env_Comm).
Board_Index	The corporate board quality index computed by adding the four dummy variables: Board size: Dummy variable if the number of board members is higher than the industry median, 1; otherwise 0; board independence: Dummy variable if the percentage of independent directors on the board is higher than the industry median, 1; otherwise 0; board meetings: Dummy variable if the number of board meetings is higher than the industry median, 1; otherwise, 0; board diversity: Dummy variable if the percentage of female board members is higher than the industry median, 1, otherwise 0.
ESGScore	Environmental, social and governance (ESG) index
F_Size	Natural log of total assets
Leverage	Debt to total asset ratio
ROA	Return on assets ratio measured by net income to total assets
Liquidity	Current ratio
LOSS	An indicator variable equal to one when the current year's net income is negative, and zero otherwise
Industry	A set of industry indicators based on SIC classification.
Year	2016, 2017, 2018, 2019 and 2020

4.2.4 | Control variables

We included board index, firm-specific related variables and ESG performance as control variables, as prior research mentioned that potential determinants of CO_2 emissions (e.g., Bui et al., 2020; Gerged, Matthews, & Elheddad, 2021). Following Al-Shaer et al. (2022), Board index measured by including four dummy variables, board size, as dummy variable if the number of board members is higher than the industry median, board independence, as dummy variable if the percentage of independent directors on the board is higher than the industry median, board meeting as dummy variable if the number of board meetings is higher than the industry median, board diversity as a dummy variable if the percentage of female board members is higher than the industry median. Further, we control for firm-specific related variables. These are firm size (F_Size) measured by the natural logarithm of total assets; leverage ratio measured by debt to total asset ratio; firm profitability (ROA) measured by net income before extraordinary items to total assets; liquidity ratio measured by current asset over current liabilities, firm loss as a dummy variable equals to one when the current year's net income is negative, and zero otherwise; and industry and year dummies.

4.2.5 | Econometric model

Multivariate regression analysis is used to examine the relationship between environmental innovation and CO_2 emissions. The OLS regression models are stated below. Table 1 provides a definition of the study variables. The regression models include year and industry fixed effects. The dummy variable of industry is derived from the SIC one-digit industry classification.

$$\begin{aligned} CO_2\_emission = {} & \beta_0 + \beta_1 L.Env\_Innovation + \beta_2 Env\_Governance \\ & + \beta_3 Board\_Index + \beta_4 ESGScore + \beta_5 F\_Size \\ & + \beta_6 Leverage + \beta_7 ROA + \beta_8 Liquidity + \beta_9 LOSS \\ & + \beta_{10} Industry\ dummies + \beta_{11} Year\ dummies + \epsilon \end{aligned} \quad (1)$$

An interaction term (L.Env_Innovation*Env_Governance) is used in the regression analysis to examine the moderating effect of environmental governance on the relationship between environmental innovation and CO_2 emissions. Moreover, additional regression models are used to check the robustness of results. Table 1 shows variables definition.

5 | EMPIRICAL RESULTS

5.1 | Descriptive statistics

Table 2 shows the descriptive statistics of the dependent, independent variables and control variables for all companies in the sample. The mean value of the CO_2 emissions is 38.910 and the mean value of environmental innovation score is 27.932 with maximum score equals 99.747. The environmental governance score ranges from 0 to 4, with an average mean value of 1.96. Also, the mean of ESG score 53.175. Regarding board variables, we find that the means of board size of 8.7; independent directors is 31% of board members; and that 26.7% of directors are female. Finally, regarding firm related variables, the mean firm size to be 22.74, measured using the natural log of total assets; the mean ROA is 0.065; the mean leverage 0.182; and that, on average, 15% of the firms sampled have reported losses during the period of the study, and the mean of liquidity ratio is 1.806.

TABLE 2 Descriptive statistics

Variable	Mean	SD	Min	Max
CO_2_emissions	38.910	6.741	2.211	44.246
Scope1	16.629	3.425	0.788	28.106
Scope2	17.584	2.575	0.262	26.683
Env_Innovation	27.932	32.51	0	99.747
Env_Governance	1.96	2.11	0	4
Board_indep	0.310	0.114	0	0.600
Board_size	8.714	2.614	1	17
Board_divers	26.759	11.581	0	66.667
Board_meet	8.972	3.812	0	49
Env_Comm	0.584	0.451	0	1
Exc_Comp	0.216	0.486	0	1
Sus_Repo	0.602	0.41	0	1
Sus_Assur	0.384	0.451	0	1
F_Size	22.74	1.945	9.721	28.81
ESGScore	53.175	20.04	2.107	94.262
Leverage	0.182	0.146	0.021	0.515
LOSS	0.156	0.351	0	1
ROA	0.065	0.153	−1.871	0.93
Liquidity	1.806	1.696	0.368	12.82

Table 3 reports the correlation matrix for variables included the analysis. The correlation matrix shows the correlation between modern environmental innovation and CO_2 emissions. As well as the correlations among the other control variables. This is to make sure that there is no multicollinearity among our model variables. By looking at the correlation matrix (Table 3), we cannot see any evidence that our model has multicollinearity. We also run the VIF (variance inflation factor) and VIF values range from 2.39 to 2.12, with a mean value of 2.11. Overall, the Pearson correlation coefficients and VIF results do not show evidence of significant multicollinearity issues.

5.2 | Multivariate analysis

Table 4 reports the results of the regression model that tests the impact of environmental innovation on CO_2 emissions. The results of estimation model using aggregate CO_2 emissions as a dependent variable (Model 1), Scope 1 emissions (Model 2), and Scope

TABLE 3 Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) CO_2_emissions	1.000									
(2) L.Env_Innovation	−0.044	1.000								
(3) Env_Governance	−0.332[a]	0.181[a]	1.000							
(4) Board_Index	−0.197[a]	0.097[a]	0.099[a]	1.000						
(5) ESGScore	−0.321[a]	−0.255[a]	−0.203[a]	−0.206[a]	1.000					
(6) F_Size	0.079[a]	0.230[a]	0.140[a]	0.205[a]	0.200[a]	1.000				
(7) leverage	−0.299[a]	−0.096[a]	0.081[a]	0.002	0.112[a]	−0.209[a]	1.000			
(8) liquidity	−0.372[a]	−0.100[a]	−0.068[a]	−0.082[a]	−0.156[a]	0.220[a]	−0.247[a]	1.000		
(9) ROA	−0.059[a]	−0.029	−0.095[a]	−0.045	−0.069[a]	−0.147[a]	0.013	0.016	1.000	
(10) LOSS	0.056[a]	0.043	−0.049	−0.012	0.027	0.041	−0.080[a]	0.081[a]	0.621[a]	1.000

[a]Significance at the 5% level or better (two-tailed test).

TABLE 4 The impact of environmental innovation and CO_2 emissions

Variables	(1) CO_2_emissions	(2) Scope 1	(3) Scope 2	(4) CO_2_emissions-FE
L.Env_Innovation	−0.0132*** (0.00281)	−0.0143*** (0.00498)	−0.00811*** (0.00278)	−0.00604** (0.00173)
Env_Governance	−0.298*** (0.0635)	−0.256*** (0.0879)	−0.169*** (0.0626)	−0.149*** (0.0200)
Board_Index	−0.0131*** (0.0010)	−0.0692*** (0.0054)	−0.0746*** (0.0010)	−0.0268*** (0.00294)
ESGScore	−0.0424*** (0.00811)	−0.0344*** (0.0112)	−0.0399*** (0.00799)	−0.0149*** (0.00267)
F_Size	0.569*** (0.0584)	0.437*** (0.0807)	0.542*** (0.0574)	0.1928*** (0.0154)
Leverage	4.606*** (0.672)	6.766*** (0.924)	5.530*** (0.658)	0.0613 (0.0505)
ROA	−0.0228** (0.0160)	−0.0360** (0.0223)	−0.0610** (0.0159)	−0.137* (0.0813)
Liquidity	−0.538*** (0.0500)	−0.0788** (0.0349)	−0.0402 (0.0249)	−0.00945*** (0.00256)
LOSS	0.432** (0.314)	0.264** (0.438)	0.219** (0.312)	0.0396 (0.175)
Industry	Included	Included	Included	Included
Year	Included	Included	Included	Included
Constant	−4.089*** (1.219)	−2.738** (1.702)	−5.050*** (1.211)	−2.452*** (1.175)
Observations	1664	1664	1664	1664
R^2	0.234	0.230	0.238	0.171

Note: Variables are as defined in Table 1.
*$p < .1$.
**$p < .05$.
***$p < .01$.

2 emissions (Model 3). The results show that the coefficient for total CO_2 emissions is negative and significant at the 1% level, suggesting that environmental innovation reduces CO_2 emissions. The results are consistent with some previous studies that highlighted the significant and negative relationship between innovation and CO_2 emissions (Ali et al., 2016; Fethi & Rahuma, 2019; Hashmi & Alam, 2019). Whereas the results are in contrast with the study of Töbelmann and Wendler (2020) that found a non-significant relationship between environmental innovation and carbon emissions. Firms can reduce their environmental impact (reduce CO_2 emissions) by implementing innovative approaches that helps in controlling pollution and resource. The results further explain that the environmental innovation results in reducing Scope 1 and Scope 2 carbon emissions (significance level 1%). The results suggest that firms can decrease emissions of carbon dioxide/greenhouse gases (GHG) through environmental innovations. Further, following Wooldridge (2010), we employ fixed-effects to control for unobservable firm heterogeneities over time that is likely to be constant, yet may affect the predictor-outcome nexus, which is probably not recognized by using OLS estimation method. The appropriateness of using a random-effects rather than a fixed-effects estimation method was decided using the Hausman test, which confirmed that the unobserved firm-specific variables were significantly related to those of the other companies our sample. We found that the fixed-effects model is more appropriate than the random-effects model. Based on the fixed-effects model (Model 4 in Table 4), there is a significant negative relationship between

environmental innovation and CO_2 emissions ($p = -.00604$**). This implies that the findings of running OLS methods, which were presented in Model 1 of Table 4, are not statistically affected by firm-level heterogeneities.

Overall findings indicate that Hypothesis 1 is supported. From a theoretical lens, stakeholder theory emphasizes that there is a need for a fit between the behavior of directors and expectation of stakeholders. The need for approval from stakeholders for survival

TABLE 5 The moderating role of environmental governance on environmental innovation-CO_2 nexus

Variables	(1) CO_2_emissions	(2) Scope 1	(3) Scope 2
L.Env_Innovation	−0.00214*** (0.0014)	−0.00270*** (0.0055)	−0.0092*** (0.0011)
Env_Governance	−0.138** (0.0694)	−0.526*** (0.135)	−0.316*** (0.0960)
L.Env_Inn*Env_G	−0.00231*** (0.00123)	−0.00623*** (0.00251)	−0.0031*** (0.00179)
Board_Index	−0.0225*** (0.00608)	−0.0299*** (0.0113)	−0.0379*** (0.00806)
ESGScore	−0.0253*** (0.00704)	−0.0355*** (0.0127)	−0.0434*** (0.00904)
F_Size	0.839*** (0.0533)	0.485*** (0.0896)	0.592*** (0.0638)
Leverage	1.739*** (0.602)	6.116*** (1.073)	5.185*** (0.764)
ROA	−0.0240* (0.0127)	−0.0477* (0.0253)	−0.0707* (0.0180)
Liquidity	−0.118** (0.0434)	−0.0515* (0.0359)	−0.0186* (0.0255)
LOSS	0.609** (0.241)	0.815** (0.495)	0.770** (0.352)
Industry	Included	Included	Included
Year	Included	Included	Included
Constant	−8.299*** (1.253)	−5.362*** (1.942)	−7.296*** (1.383)
Observations	1664	1664	1664
R^2	0.228	0.225	0.216

Note: Variables are as defined in Table 1.
*$p < .1$.
**$p < .05$.
***$p < .01$.

TABLE 6 Firms with better ESG performance versus firms with low ESG performance

	(1)	(2)	(1)	(2)
	Firms with high ESG vs low ESG		*Firms with strong* environmental governance vs *low* environmental governance	
Variables	Esg > mean	ESG < mean	Env_gov > mean	Env_go < mean
L.Env_Innovation	−0.0146*** (0.00307)	−0.00269* (0.00847)	−0.0138*** (0.00287)	−0.0138* (0.00961)
Env_Governance	−0.200** (0.128)	−0.253* (0.204)	−0.240** (0.211)	−0.273* (0.143)
Board_Index	−0.165** (0.0768)	−0.049* (0.0012)	−0.352** (0.127)	−0.145* (0.041)
ESGScore	−0.0413*** (0.0127)	−0.0386* (0.0212)	−0.0282*** (0.00860)	−0.0759*** (0.0245)
F_Size	0.654*** (0.0655)	0.398*** (0.139)	0.707*** (0.0604)	0.408** (0.178)
Leverage	−4.690*** (0.811)	−5.663*** (1.442)	−4.029*** (0.726)	−5.831*** (1.829)
ROA	−0.0347* (0.0184)	−0.0312 (0.0349)	−0.0337** (0.0161)	−0.0824 (0.0555)
Liquidity	−0.554*** (0.0555)	−0.266* (0.138)	−0.600*** (0.0574)	−0.417*** (0.119)
LOSS	0.467 (0.369)	0.313 (0.618)	0.501 (0.318)	0.105 (1.135)
Constant	−5.484*** (1.395)	−2.601 (3.090)	−5.325*** (1.226)	−4.208 (3.868)
Observations	919	745	934	730
R^2	0.211	0.219	0.178	0.154

Note: Variables are as defined in Table 1.
*$p < .1$.
**$p < .05$.
***$p < .01$.

and to access strategic resources can hint the directors to conform to stakeholders' expectation in terms of the results of environmental innovation. Hence this phenomenon would lead to a reduction of CO_2 emissions. The results also highlight that good environmental governance results in reduction in the aggregate level of carbon dioxide emissions, specifically Scope 1 and Scope 2 emissions. The control variables show that the good quality of board index and ESG scores strongly influence carbon emissions, the direction of the relationship implies that an increase in board index and ESG scores would result in a decrease in carbon emissions. Moreover, as opposed to the liquidity and profit (ROA) levels of businesses; firm size, leverage and loss have a positive influence on the level of CO_2 emissions.

To address the second hypothesis, we used an interaction term of environmental innovation and environmental governance (L.Env_Innovation*Env_Governance). The results in Table 5 show the moderating role of environmental governance in the Env_Innovation-CO_2 emissions nexus. The coefficient of (L.Env_Innovation*Sus_Governance) is significantly negative at 1% level for overall CO_2 emissions (as well as for Scope 1 CO_2 emissions and Scope 2 CO_2 emissions). This suggests that the environmental governance moderates the relationship between environmental innovation and CO_2 emissions. Thus, environmental innovation leads to higher CO_2 emissions reductions in firms with better environmental governance structure. In other words, the level of environmental governance can enhance the ability of environmental innovation to explain the variations in CO_2 emissions as compared to the direct explanatory power of environmental innovation and CO_2 emissions nexus. The findings support the arguments of the RBV suggesting that firms may sustain their competitive advantage when their resources and capabilities (here, eco-innovation) are valuable, not perfectly imitable, rare, and non-substitutable (Hart, 1995; Lee & Min, 2015). The resources a firm acquires to reach sustainable competitive edge will lead to more CO_2 emissions reductions in firms with better environmental governance structure. The results of Afrifa et al. (2020) for the country level governance factors found similar moderating effect. However, to the best of authors' knowledge, there is no analysis on the corporate level that investigated the moderating effect of environmental governance on environmental innovation and CO_2 emissions; thus, the results make an important contribution to the previous CO_2 emissions literature.

A further analysis is performed to ensure that the robustness of our results is consistent and efficient. The firms are divided into subsamples based on ESG performance and environmental governance. The results highlighted that the relationship between environmental innovation and carbon emissions is significant at 1% level for firms with above average environmental governance and ESG scores while it is less significant (10% level) for firms with scores below mean. Hence, it can be concluded that the relationship becomes more pronounced for highly environmentally innovative firms which place more emphasis on ESG activities and have strong environmental governance structures in place. The results are reported in Table 6.

5.3 | Endogeneity test

As environmental innovation could be endogenous and influenced by some omitted variables, a generalized method of moment (GMM) estimator is used to ensure that the results are not severely affected by the issue of endogeneity. Following Gerged, Albitar, and Al-Haddad (2021), a two-step system GMM model is employed as a sensitivity check to address the potential occurrence of endogeneity problems. We use the lagged CO_2 emissions variable as an instrument (Anderson & Hsiao, 1982; Ganda, 2019). Overall, as can be seen from Table 7, our findings hold and show that the relationship between environmental innovation and CO_2 emissions is still significantly negative for aggregate CO_2 emissions scores as well as for Scope 1 and Scope 2.

TABLE 7 Testing for endogeneity: GMM instrumental variable approach

Variables	(1) CO_2_emissions	(2) Scope 1	(3) Scope 2
L.Env_Innovation	−0.0144** (0.00280)	−0.0101** (0.00377)	−0.0289* (0.00308)
Env_Governance	−0.0165** (0.0361)	−0.0148* (0.0664)	−0.0191* (0.0557)
Board_Index	−0.00616* (0.00516)	−0.00318* (0.00901)	−0.00965* (0.00765)
ESGScore	−0.0378** (0.0899)	−0.409** (0.193)	−0.233** (0.134)
F_Size	0.580** (0.351)	0.977** (0.832)	0.579** (0.705)
Leverage	−0.0241 (0.0190)	−0.0308 (0.00903)	−0.000110 (0.00728)
ROA	−0.0339 (0.0346)	−0.00386 (0.0106)	−0.00279 (0.00880)
Liquidity	−0.126 (0.130)	−0.354 (0.157)	−0.0722 (0.129)
LOSS	0.314 (0.110)	0.125 (0.105)	0.142 (0.295)
Constant	−0.182 (1.774)	−6.560 (4.436)	−4.267 (2.740)
Observations	1664	1664	1664

Note: Variables are as defined in Table 1.
*$p < .1$.
**$p < .05$.
***$p < .01$.

6 | CONCLUSION

Given the importance of environmental innovation in shaping environmental sustainability, environmental innovation can play a crucial role in reducing carbon emissions which can also help firms to achieve better environmental performance (Töbelmann & Wendler, 2020). Based on a sample of companies listed on the London Stock Exchange for the period from 2016 to 2020, this study aims to examine the effects of environmental innovation on CO_2 emissions as well as the moderating role of environmental governance in this relationship. The findings show that environmental innovation reduces carbon emissions including Scope 1 and Scope 2 emissions. Likewise, our findings are associated with a moderating effect of environmental governance on the environmental innovation-CO_2 emissions nexus. The results confirm our hypothesis about the impact of environmental innovation on CO_2 emissions. We also argue that environmental innovation leads to lower CO_2 emissions in firms with better environmental governance. Our results suggest that there is a need for integrating environmental issues into governance, along with environmental innovation can lead to lower carbon emissions. We further run additional analyses and divide the sample into subsamples based on environmental innovation score, ESG score, and environmental governance. The findings show that the environmental innovation score is significant and negatively associated with carbon emissions for firms no matter whether they have a high or low ESG score, although it is more significant for firms with a high ESG score. Our findings hold for subsamples of firms with a strong/low environmental governance. We address the endogeneity issue by using GMM techniques, and the results remain consistent.

This study has important implications for companies to improve corporate environmental innovations and reduce carbon emissions. Managers are encouraged to adopt innovative approaches in addressing environmental issues by utilizing existing environmental technologies which leads to a reduction in CO_2 emissions, but also by ensuring that there is a higher level of financial investment in both existing and future technology, encouraging expenditure in research and development. This may be self-directed research or collective expenditure. By this, we mean "pooling of financial resources to invest in high technology developing firms that are at the cutting edge of the 'green' technology movement." Such an approach may result in a more rapid expansion of new technology that can result in an overall improvement in a sector or industry-based approach to energy efficiency and alternative means of energy production. Additionally, policymakers (including national governments collectively, local governments, and industry regulators) need to set out medium- and long-term plans for supporting companies, both practically and financially, in adopting and implementing innovative efficient technologies. This could be through offering grants or subsidies to companies that help to lower their research and development costs. There may currently be a reluctance on the part of policymakers and companies to increase expenditure in the current climate post-COVID, and given the conflict in Europe, but such expenditure will potentially have an important implication, namely, a benefit to the global economy going forward and help to meet some of the COP26 aspirations for a reduction in global warming. In addition, by developing environmental policy tools including pollution abatement subsidies, environmental regulations, green credit, emission levies, and green procurement, the government may encourage green innovation (Li, Liao, & Albitar, 2020).

This paper makes several recommendations and uses appropriate methodologies however, it is important to recognize that the research results should be interpreted with some caution and that important limitations should be considered. Firstly, in terms of limitation, the sampling used concentrates on companies listed on the London Stock Exchange (LSE). It would be of interest to compare the results to those that may arise on other internationally based stock exchanges, for example, Dow Jones, DAX, CAC, Shanghai, Tokyo, so forth, to increase the scope of the study. It is recognized that to do so would take considerable time and effort, and result in additional cost, but this could be undertaken as part of future research using the methodological approach used in this paper. Additionally, access to such data may prove difficult. Secondly, the time constraints restricted the study to not only the LSE but also sampling from a narrow range of years (2016–2020). Expanding future studies to include earlier years would allow for a longitudinal analysis over a more expansive period, and therefore may identify trends in the development of eco-innovation. Equally, including research data from 2021 and 2022 may also show the impact on development of eco-innovation during and post the COVID era, including post-COP26. Thirdly, the sampling is based on a general listing of companies on the LSE. Given that different industries have different characteristics and attitudes towards adopting green innovation and technology, it may have been interesting to have considered the analysis on a sector-by-sector basis but again due to time, effort, and cost constraints, this was not completed. Albitar et al. (2022), conclude that governance mechanisms and ESG drive CSR tones, future research may explore whether business environmental innovation has an impact on the tone of CSR reports. Also, it could also be of interest to future researchers to consider an in-depth qualitative research sampling approach, (considered by some researchers as increasingly relevant (Kumar et al., 2022; Meyer et al., 2018).

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How to cite this article: Albitar, K., Borgi, H., Khan, M., & Zahra, A. (2022). Business environmental innovation and CO_2 emissions: The moderating role of environmental governance. *Business Strategy and the Environment*, 1–12. https://doi.org/10.1002/bse.3232