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Can effective board drive environmental innovation? The moderating power of CSR committee

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Abstract

Purpose – This study aims to investigate the impact of various board characteristics on environmental innovation (EI) among companies listed on the STOXX Europe 600. It also examines the moderating role of CSR committees on the board–EI nexus.

Design/methodology/approach – The sample consists of companies listed on the STOXX Europe 600 index over 12 years (2011–2022). This study uses the Refinitiv Eikon database to evaluate the extent of EI. Panel data regression analysis is used, with two-stage least squares and lagged models used as robustness tests to control for endogeneity.

Findings – The results indicate that board independence and gender diversity significantly increase EI, whereas CEO duality negatively impacts it. Other board attributes, such as board size, show no impact on EI. In addition, the presence of CSR committees moderates these relationships, enhancing the positive effects of gender diversity and board independence and mitigating the negative impact of CEO duality.

Practical implications – This study provides valuable insights for policymakers and corporate strategists aiming to advance environmental responsiveness through strategic board composition and establishing CSR committees. Emphasizing the importance of board independence, gender diversity and CSR committees, the findings suggest practical pathways for enhancing the adoption of EI by creating governance structures that support sustainable practices.

Originality/value – To the best of the authors' knowledge, this is the first study to examine the moderating role of CSR committees on the associations between board characteristics and EI. This research addresses a crucial gap in the current literature, enriching the understanding of corporate governance and sustainability. It provides critical insights for developing policies and strategies that promote EI through effective board composition and the implementation of CSR committees.

Keywords Environmental innovation, Corporate governance, Board characteristics, CSR committees, STOXX Europe 600

Paper type Research paper

1. Introduction

Environmental innovation (EI) is increasingly crucial for sustainable development due to rising environmental degradation and heightened stakeholder awareness of corporate ecological responsibilities (Mohamed Riyath and Inun Jariya, 2024; Ahmed *et al.*, 2024;

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Brunnermeier and Cohen, 2003). As business operations grow and resources become limited, the pressure to balance economic objectives with environmental preservation intensifies, motivating companies to pursue innovations that promote sustainability while meeting stakeholder demands (Estapé-Dubreuil *et al.*, 2016; Hunjra and Hussainey, 2024; Abweny *et al.*, 2024; Alia *et al.*, 2024). These innovations, encompassing advancements in processes, products, corporate practices and marketing, integrate sustainability into business operations, addressing ecological issues while enhancing economic growth, corporate reputation and competitive edge (Nandy *et al.*, 2024). Despite these benefits, EI adoption faces obstacles such as financial risks, lack of data, funding shortages and uncertainty, which often reinforce traditional business models. These challenges emphasize the need for supportive regulations, strategic management and organizational change to enable the shift toward innovative and sustainable business practices (Yin and Wang, 2018; Ruiz-Castillo *et al.*, 2023).

At the microlevel, the success of EI largely centers on how effectively management integrates sustainable practices into business strategies (Farza *et al.*, 2022). Corporate Governance (CG), mainly through the board of directors, is instrumental in guiding organizational behavior toward environmental sustainability (Abdelhaq *et al.*, 2024). The board's strategic influence extends to setting social and environmental goals, enhancing sustainability efforts, promoting innovation and managing EI-related challenges (Nadeem *et al.*, 2020). Research indicates that gender diversity on boards significantly enhances EI (Galia *et al.*, 2015; Nadeem *et al.*, 2020; Farza *et al.*, 2022), and independent directors provide valuable expertise crucial for these initiatives (García-Sánchez *et al.*, 2021). In addition, firms with larger boards are more likely to adopt environmentally sustainable practices (Almaqtari *et al.*, 2023).

CSR committees (CSRCs) have emerged as crucial governance mechanisms that strengthen a firm's environmental performance, demonstrating a commitment to sustainability (Gennari and Salvioni, 2019; Velte and Stawinoga, 2020). These committees assist boards in addressing social and sustainability challenges more effectively, enhancing engagement and accountability in managing CSR strategies (Baraibar-Diez and Odriozola, 2019; Pucheta-Martínez and Gallego-Álvarez, 2019). CSRCs thus play a crucial role in reinforcing and executing the board's environmental strategies, strengthening the firm's overall approach to sustainability.

Research extensively explores environmental governance, particularly examining how corporate board characteristics influence environmental outcomes like environmental disclosure (Khaireddine *et al.*, 2020), performance (García Martín and Herrero, 2020; Khan *et al.*, 2021) and sustainable production practices (Almaqtari *et al.*, 2023). However, there is limited research on the impact of board characteristics, specifically on EI (Farza *et al.*, 2022; Konadu *et al.*, 2022; García-Sánchez *et al.*, 2021; Nadeem *et al.*, 2020; Galia *et al.*, 2015). These studies often focus on specific board attributes within narrow geographical or sectoral contexts. For instance, Farza *et al.* (2022) analyzed board independence and gender among German HDAX firms, whereas Konadu *et al.* (2022) and Nadeem *et al.* (2020) studied gender diversity in US-listed firms. García-Sánchez *et al.* (2021) examined global agri-food firms, and Galia *et al.* (2015) focused on French-listed companies, assessing gender and age diversity.

There are inconsistencies in findings, particularly concerning the influence of female directors on EI. While some studies (Wang *et al.*, 2022; Farza *et al.*, 2022; Nadeem *et al.*, 2020) report a positive effect, others (Agustia, 2023; Traversi *et al.*, 2024) present conflicting results. In addition, a significant gap exists in the literature, as no studies have explored the moderating effects of CSRC on the relationship between board characteristics and EI.

Accordingly, this study aims to bridge this significant gap by evaluating the impact of various board characteristics – including board size, independence, gender diversity and CEO duality (CEOD) – on the EI of firms listed in the STOXX Europe 600 from 2011 to 2022. Moreover, this research examines whether the relationship between board characteristics and EI is influenced by the presence of CSRC.

This study significantly contributes to the literature on the CG–EI nexus, a topic previously explored with mixed results, often focusing on specific attributes within certain national contexts (e.g. Farza *et al.*, 2022; Nadeem *et al.*, 2020; Galia *et al.*, 2015). By analyzing firms listed on the STOXX Europe 600, this research extends its geographic reach and enhances its depth by incorporating the European regulatory context, including frameworks like the NFRD (Velte, 2024). Covering data from 2011 to 2022, the study offers a broader perspective across 17 European countries, contrasting with prior single-country analyses. In addition, it introduces novel insights by examining the moderating role of CSRC in the relationship between board characteristics and EI, highlighting their importance in executing effective environmental strategies. These findings provide practical implications for CSR specialists, corporate policymakers and governance bodies, offering guidance on optimizing board structures and CSRC functionalities to enhance EI and align with current European regulatory standards.

The paper is structured as follows: Section 2 outlines the hypotheses within the context of the theoretical framework and relevant literature. Section 3 details the methodology, including data collection, sample selection, variable measurement and regression models used. Section 4 presents the empirical results, covering descriptive statistics, correlation analysis and regression outcomes. Finally, Section 5 discusses the implications of the findings and offers suggestions for future research.

2. Theoretical framework and hypotheses development

2.1 Theoretical framework

The rising consumer awareness of the environmental impact of corporate activities has compelled businesses to prioritize sustainability initiatives (Abdelhaq and Dwekat, 2024; Alkaraan, 2022; Dwekat *et al.*, 2020b). Companies are now incorporating long-term strategies that integrate innovative processes, products and organizational structures, aligning their operations with stakeholder values (Rahi *et al.*, 2023). These efforts aim not only to minimize environmental damage but also to enhance profitability and competitiveness (Nadeem *et al.*, 2020). Despite these efforts, implementing EI remains complex and costly (Del Río *et al.*, 2016).

EI requires committed leadership and strong organizational structures, with boards playing a critical role in setting strategic objectives and ensuring the implementation of effective environmental management systems (Hussainey *et al.*, 2022; Wagner, 2008). This study uses Agency, Stakeholder, Legitimacy and Resource Dependency Theories to investigate how board characteristics influence EI.

Agency Theory highlights the necessity for governance mechanisms that align managerial decisions with shareholder interests, especially given the risks associated with innovation (Xue *et al.*, 2022; Kayed and Meqbel, 2024; Alta'any *et al.*, 2024). Boards with diverse, skilled members, particularly those with a CSRC, are better positioned to manage these risks and strengthen oversight (García-Sánchez *et al.*, 2019a; Moreno-Ureba *et al.*, 2022). CSRCs are essential in balancing short-term profitability with long-term value creation and guiding environmental policies (Gennari and Salvioni, 2019; Dixon-Fowler *et al.*, 2017).

Stakeholder Theory promotes integrating various stakeholder interests into CG (Voinea *et al.*, 2022). Boards with sufficient expertise can effectively manage sustainability and innovation to meet stakeholder expectations, enhancing corporate reputation (Gennari, 2019; Ginesti *et al.*, 2023). The CSRC's multidisciplinary nature supports these efforts by formulating and evaluating CSR strategies (Velte and Stawinoga, 2020; Orazalin, 2020).

Legitimacy Theory suggests that meeting societal expectations is essential for firms to sustain their operations. As societal values evolve toward environmental consciousness, establishing CSRCs can help firms gain legitimacy and enhance their reputation (Gennari and Salvioni, 2019; Velte and Stawinoga, 2020).

Resource Dependency Theory highlights that board diversity is crucial for accessing resources necessary for strategic development (Uyar *et al.*, 2020). Boards with diverse expertise and networks can secure essential resources, enabling the company to exceed environmental standards and implement effective initiatives (Hillman *et al.*, 2009). CSRCs provide specialized knowledge to support environmental efforts (Dixon-Fowler *et al.*, 2017).

2.2 Hypotheses development

The board of directors oversees management activities, including those related to social responsibility and sustainability (Ramdhony *et al.*, 2023; Alkaraan *et al.*, 2024). The board's composition, structure and activity level indicate a firm's commitment to CSR and its approach to environmental and social concerns (Uyar *et al.*, 2020). High board efficiency and qualifications enhance its capacity to fulfill its responsibilities (García-Sánchez *et al.*, 2020; Rossi *et al.*, 2021; Konadu *et al.*, 2022; Wu *et al.*, 2023). Wang *et al.* (2022) suggested that an efficient board supervises management effectively, curbing opportunistic behavior, improving decision-making and encouraging innovation. Moreover, an efficient board provides essential information and resources, reducing uncertainties associated with innovation (Lu and Wang, 2018).

2.2.1 Board gender diversity. Board diversity, especially the inclusion of female directors, is widely recognized as a critical driver of improved firm performance. Diverse boards reduce agency costs and enhance oversight, contributing positively to firm outcomes (Alqatan, 2024; Konadu *et al.*, 2022). Female directors bring creativity, skills and a solid commitment to legal and ethical standards, strengthening stakeholder relationships and improving a company's reputation and competitive position (Rahman *et al.*, 2024). Their involvement is particularly impactful in environmental performance, as they contribute effectively to decision-making and developing environmental strategies (Elad Fotoh *et al.*, 2018; Nadeem *et al.*, 2020).

Empirical evidence supports that gender-diverse boards are more effective at implementing EI (Alia and Mardawi, 2021). Studies link higher female representation with enhanced EI (Wang *et al.*, 2022; Farza *et al.*, 2022). However, some research (Agustia, 2023; Traversi *et al.*, 2024) indicates that gender diversity may negatively influence EI under certain conditions, highlighting the complexity of managing board dynamics.

According to the Resource Dependency Theory, diverse backgrounds and expertise among board members, especially female directors, reduce a firm's resource dependence and improve performance. Female directors' ethical and cautious nature supports effective board monitoring, aligning decisions with shareholder interests (Issa and Bensalem, 2023). Diversity is crucial for managing complex issues like EI, as it helps boards integrate societal and environmental interests into corporate strategies (Miller and del Carmen Triana, 2009). Female directors' innovative and collaborative problem-solving skills enhance the board's capacity to develop and implement effective EI strategies:

H1. Board Gender Diversity positively affects the environmental innovation of the companies included in the STOXX Europe 600 Index.

2.2.2 Board size. According to Resource Dependency Theory, larger boards offer more resources, expertise and connections that help firms reduce external dependencies and boost their innovative capabilities (Chouaibi and Jarboui, 2012). This diversity is crucial for managing the complexities and risks associated with environmental sustainability initiatives.

Stakeholder Theory aligns with this perspective, suggesting that larger boards are better positioned to accommodate diverse stakeholder interests, which is essential for companies tackling environmental challenges (Freeman *et al.*, 2010; Freeman and Evan, 1990). Members with direct links to key environmental stakeholders – such as regulatory bodies, NGOs and community groups – can help integrate these perspectives into the firm's innovation strategies (Lacetera, 2001; Shapiro *et al.*, 2015). This inclusion ensures that environmental initiatives are comprehensive and aligned with societal goals.

Empirical studies demonstrate the advantages of larger boards due to their diverse expertise, which is critical for decision-making in EI (Cheng, 2008; Fuente *et al.*, 2017). Research shows that larger boards enhance strategic programming and governance effectiveness, leading to improved environmental outcomes (Fuente *et al.*, 2017; Moreno-Gómez *et al.*, 2017). In addition, diverse boards are more likely to develop creative solutions to environmental challenges (Miller and del Carmen Triana, 2009).

However, Agency Theory highlights potential drawbacks, such as increased coordination costs and conflict (Jensen, 1993; Goodstein *et al.*, 1994). These challenges can be mitigated through structured governance practices that enhance coordination, ensuring the benefits of larger boards without inefficiencies. The hypothesis is thus formulated based on these insights:

H2. Board size positively affects the environmental innovation of the companies included in the STOXX Europe 600 Index.

2.2.3 Board independence. Board independence is vital to CG, particularly in the Anglo-American context where ownership is widely dispersed. Agency theory suggests that independent directors play a crucial role in reducing conflicts between shareholders and management by curbing managerial opportunism and ensuring executives prioritize stakeholders' interests (Lu and Wang, 2018; Zhu *et al.*, 2022). Beyond shareholders, Stakeholder theory highlights that independent directors protect a wider group of stakeholders, ensuring adherence to ethical practices and social responsibilities essential for long-term success. Empirical studies, such as those by Ntim and Soobaroyen (2013) and García-Sánchez *et al.* (2020), demonstrate that independent directors enhance management oversight, promoting social responsibility and sustainable development.

Resource Dependency Theory further argues that independent directors provide essential resources, including expertise, information and external networks, vital for innovation and strategic renewal. Studies show that having board members focusing on environmental issues significantly improves a firm's environmental practices (Khaireddine *et al.*, 2020; Osemene *et al.*, 2021). The positive influence of independent directors on EI is supported by research indicating that these directors improve a firm's vision and responsiveness to environmental needs, promoting sustainable innovation (Farza *et al.*, 2022; Lu and Wang, 2018). Based on this evidence, the hypothesis was formulated:

H3. Board independence positively affects the environmental innovation of the companies included in the STOXX Europe 600 Index.

2.2.4 CEO duality. CEOD presents significant governance challenges, particularly regarding EI, as it often results in a concentration of power that weakens board independence and reduces oversight effectiveness in sustainable practices (Krause *et al.*, 2013; Ghardallou, 2022). Agency Theory advocates for separating the roles of CEO and chairman to maintain the necessary independence for effective governance (Korir and Tenai, 2020). This separation ensures that decisions are impartial and align with the long-term interests of shareholders and stakeholders, including environmental priorities (Rossi *et al.*, 2021).

Research suggests that CEOD tends to prioritize financial performance, potentially at the expense of broader social and environmental objectives, which are essential for sustainable corporate strategy (Zhang, 2012). Studies indicate that CEOD can hinder sustainable performance by limiting governance's role in advancing EI (Zhu *et al.*, 2022). It can also stifle contributions from diverse board members, such as female directors, who typically positively influence ESG outcomes (Romano *et al.*, 2020; Ghardallou, 2022). Evidence from Mallin and Michelon (2011) shows that sustainability performance declines under CEOD due to conflicts of interest and a lack of long-term environmental focus.

While CEOD may streamline decision-making, empirical studies highlight that this efficiency often sacrifices the comprehensive and deliberative approach needed for EI (Meckling and Jensen, 1976). The dual leadership structure may lead to a focus on short-term financial gains rather than long-term investments in EI, which are critical for sustainable development (Rossi and Cebula, 2015). Based on these insights, the hypothesis is formulated:

H4. CEO duality negatively affects the environmental innovation of the companies included in the STOXX Europe 600 Index.

2.3 The moderating effect of CSR committee

The formation of a CSRC demonstrates a company's proactive approach to sustainability and CSR, addressing growing stakeholder expectations and the complexities associated with CSR challenges (Spitzeck, 2009; Eberhardt-Toth, 2017). This strategic initiative enhances the firm's legitimacy and effectively shows its commitment to managing social and environmental responsibilities (Godos-Díez *et al.*, 2018; Mallin and Michelon, 2011). CSRCs are vital in advancing environmental and social initiatives, positively influencing eco-innovation and improving governance effectiveness. By overseeing environmental decisions, they manage uncertainties related to strategic actions, ensuring better outcomes (Moreno-Ureba *et al.*, 2022). In addition, CSRCs enhance the management of environmental issues through specialized oversight (Dixon-Fowler *et al.*, 2017; Radu and Smaili, 2021) and guide CSR strategies to create competitive advantages while raising environmental awareness, ultimately reducing negative impacts like emissions (Konadu *et al.*, 2022; Gennari and Salvioni, 2019). This committee supports directors in developing and monitoring CSR strategies, thereby strengthening the board's capacity in these areas (Velte and Stawinoga, 2020; Javeed *et al.*, 2022; Dwekat *et al.*, 2022a).

Empirical studies emphasize the influence of CSRCs on corporate environmental performance. For instance, Pucheta-Martínez and Gallego-Álvarez (2019) found that CSRCs significantly enhance CSR policy transparency and effectiveness, leading to improved stakeholder trust and corporate reputation. Similarly, Endrikat *et al.* (2021) demonstrated that CSRCs align board characteristics with CSR objectives, enhancing overall sustainability practices. Furthermore, CSRCs facilitate decentralized decision-making within the board, enabling targeted management of CSR issues, which improves strategic development, boosts corporate accountability and strengthens the firm's legitimacy and reputation by managing

stakeholder relations and reducing information asymmetries and agency conflicts (García-Sánchez *et al.*, 2019a; Dwekat *et al.*, 2022b).

Qaderi *et al.* (2022) provided evidence that CSRCs amplify the effectiveness of board characteristics on CSR reporting, acting as essential governance mechanisms that increase the demand for CSR assurance. Baraibar-Diez and Odriozola (2019) noted that CSRCs positively influence the link between CSR-related compensation and CSR outcomes, indicating their strategic role in aligning executive compensation with CSR results for improved corporate performance.

Thus, the CSRC is an integral component of modern CG, ensuring that environmental and social policies are effectively implemented, leading to substantial benefits. Based on these arguments regarding the CSRC's impact on board efficiency and CSR performance, the final hypothesis is formulated:

H5. The presence of CSRC moderates the relationships between board characteristics and environmental innovation.

3. Methodology

3.1 Sample selection and data sources

This study draws on a data set comprising firms from the STOXX Europe 600 Index, covering the period 2011–2022, resulting in 6,126 firm-year observations. The STOXX Europe 600 Index includes companies of varying market values (large, medium and small) from 17 European countries, representing approximately 90% of the region's freely traded stock market value. The UK dominates the index, accounting for around 28%, followed by France, Germany and Switzerland, each contributing roughly 15%.

Several factors support the choice of the STOXX Europe 600 Index. European firms are recognized for their commitment to environmental sustainability, influenced by the region's advanced environmental policies and the emphasis on sustainable practices across industries (European Commission, 2021). The European environmental research and innovation policy encourages collaborative efforts across sectors to promote sustainable and economically viable solutions (Mongo *et al.*, 2021). In addition, the increasing demand for eco-friendly products has prompted companies to adopt innovative strategies that enhance product quality while meeting environmental regulations (Song *et al.*, 2020).

The selection of this index is further justified by its broad geographic and industrial representation, encompassing firms from 17 countries with diverse regulatory frameworks, environmental policies and market dynamics. This diversity creates a comprehensive environment to examine the impact of board characteristics on EI. Excluding financial companies due to their unique regulatory conditions (Albitar and Hussainey, 2023; Dwekat *et al.*, 2022a) refines the analysis, allowing for a more focused study of the European corporate sector's board characteristics and EI relationship. Additionally, the robust regulatory landscape shaped by directives such as the NFRD, CSRD, EU Taxonomy Regulation and the proposed CSDD Directive enhances the relevance of this index for this research (Velte, 2024). Previous studies have also used the STOXX Europe 600 Index in CG and CSR research, supporting its appropriateness (Dwekat *et al.*, 2022a; Velte, 2024; Belhouchet and Chouaibi, 2024).

3.2 Variables measurement

3.2.1 Dependent variable. This study measures EI as the dependent variable using the EI Score (EIS) from the Eikon database. The EIS, which ranges from 0 to 100, assesses a

company's ability to develop and improve environmental technologies and processes. A higher score, closer to 100, indicates a greater capacity for EI, demonstrating the firm's effectiveness in minimizing environmental costs and impacts. This metric provides reliable, auditable data, reduces reliance on self-reported information and minimizes replication errors, improving generalizability. In addition, the EIS highlights a firm's ability to gain competitive advantages through the introduction of eco-designed product results or processes, as noted in previous studies (Nadeem *et al.*, 2020; Zaman *et al.*, 2021; Moreno-Ureba *et al.*, 2022). This measurement evaluates how firms manage financial and environmental challenges while enhancing market opportunities.

3.2.2 Independent, moderating and control variables. This study includes key board characteristics such as gender diversity (BOGE), board size (BOSI), board independence (BOIN) and CEOD, which are consistent with previous research. BOGE is measured as the proportion of female directors on the board (Nadeem *et al.*, 2020; Farza *et al.*, 2022). BOSI represents the total number of directors (Godos-Díez *et al.*, 2018; Wang *et al.*, 2019). BOIN is the percentage of independent directors, potentially enhancing EI through stronger oversight (García-Sánchez *et al.*, 2019b; Omran *et al.*, 2021). CEOD is captured as a binary variable where a value of 1 indicates the CEO also serves as chairman, centralizing decision-making (Krause *et al.*, 2013; Nadeem *et al.*, 2020).

Control variables include firm size (SIZE), measured by the natural logarithm of total assets, as larger firms typically have more resources for EI (Nadeem *et al.*, 2019; Farza *et al.*, 2022). Financial leverage (LEV) is the ratio of total debt to total assets, reflecting the firm's financial strategy, which may influence its EI investment capacity (Carmona *et al.*, 2022; Dwekat *et al.*, 2022a). Return on equity (ROE) is also considered, assuming that more profitable firms are better positioned to invest in EI (Nadeem *et al.*, 2019; Kayed *et al.*, 2024).

A CSRC is included as a binary variable, as it indicates a structured approach to CSR, likely promoting EI by prioritizing environmental issues (Albitar *et al.*, 2024; Mardawi *et al.*, 2023). Table 1 summarizes all study variables, providing their definitions and measurement methods.

3.3 Regression model

The following multiple regression model is used to estimate the impact of the characteristics of board of directors on the EI:

$$EIS = \alpha_0 + \beta_{1BOGE} + \beta_{2BOSI} + \beta_{3BOIN} + \beta_{4CEOD} + + \beta_{5SIZE} + \beta_{6ROE} + \beta_{7LEV} + \beta_{8CSRC} + \varepsilon_{it}$$

Table 1 identifies the dependent, independent and control variables; βk are the regression coefficients and $\varepsilon$is the error term or regression residual.

4. Results

4.1 Descriptive and correlation

Table 2 summarizes the descriptive statistics for the study variables. The average EIS is approximately 41%, indicating varying levels of corporate engagement in environmental initiatives. The average board size is 11 members, with 61% being independent directors and 26% women. Around 21% of the firms exhibit CEOD, where the CEO also serves as the board chair.

Regarding control variables, the average firm size, measured as the natural logarithm of total assets, is roughly 15.599. The mean financial leverage is 0.219, reflecting the typical debt-to-asset ratio. A CSRC is present in about 64% of firms, suggesting a widespread

Table 1. Study variables

Variable	Label	Measurement
Dependent variable		
Environmental innovation	EIS	Environmental Innovation Score (EIS), ranges from 0 to 100. The closer the score to 100, the higher the environmental innovation is
Independent variables		
Board gender diversity	BOGE	Female directors' percentage (number of female directors to the total number of the board members)
Board size	BOSI	The number of board members
Board independence	BOIN	The percentage of independent directors on the board
CEO duality	CEOD	A dummy variable (1 if the CEO is also the chairman of the board, 0 otherwise)
Control variables		
Firm size	SIZE	The natural algorithm of the total assets
Return on equity	ROE	Net income to total equity
Financial leverage	LEVE	Total debt to total assets
CSR committee	CSRC	A dummy variable (1 if CSR committee exists, 0 otherwise)

Source: Authors' own work

Table 2. Descriptive statistics

Variable	Mean	Std. dev.	Min	Max
EIS	40.634	31.698	0	99.82
BOGD	26.998	12.78	0	65.64
BOSI	10.965	3.762	4	21
CEOD	0.212	0.494	0	1
BOIN	61.259	22.452	0	100
SIZE	15.599	1.335	12.893	17.818
LEVE	0.215	0.185	0	0.501
ROE	14.195	14.108	−16.05	46.52
CSRC	0.636	0.481	0	1

Source: Authors' own work

emphasis on structured CSR governance. The average ROE stands at 14.195%, indicating overall financial performance among the sampled firms.

Pearson's correlation coefficients, presented in Table 3, evaluate multicollinearity among the study variables. The highest observed correlation is 0.51 between BOSI and SIZE. Correlation coefficients between other variables show low to moderate relationships, all below the critical threshold of 0.70. These results indicate that multicollinearity is not a concern for testing the study's hypotheses.

4.2 Regression analysis

Table 4 presents the regression results from two models: Model 1 (pooled OLS) and Model 2 (Fixed Effects). Continuous independent variables are winsorized at the 1st and 99th

Table 3. Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) EIS	1.000								
(2) BOGD	0.148*	1.000							
(3) BOSI	0.221*	0.120*	1.000						
(4) BOIN	0.081*	0.174*	−0.304*	1.000					
(5) CEOD	−0.072*	−0.074*	−0.213*	0.123*	1.000				
(6) SIZE	0.363*	0.165*	0.512*	0.050*	−0.130*	1.000			
(7) LEV	−0.063*	−0.004	0.017	0.042*	0.037	0.112*	1.000		
(8) ROE	−0.031	0.029	−0.015	0.005	0.020	−0.103*	0.023	1.000	
(9) CSRC	0.2429*	0.1191*	0.2419*	0.1010*	−0.0896*	0.4115*	−0.0302	−0.0303	1

Notes: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$
Source: Authors' own work

Table 4. The impact of board characteristics on firms' environmental innovation

VARIABLES	(1) Innovation	(2) Innovation
BOGD	0.173***(0.0389)	0.166***(0.0414)
BOSI	5.366*(1.776)	6.418(1.695)
BOIN	0.0898***(0.0229)	0.104***(0.0217)
CEOD	−1.879**(1.109)	−3.277***(1.087)
SIZE	7.143***(0.451)	6.616***(0.441)
LEV	−27.69***(3.552)	−40.38***(3.623)
ROE	0.00689**(0.00563)	0.00918*(0.00583)
CSRC	9.686***(1.194)	9.570***(1.161)
Constant	−94.40***(6.094)	−92.67***(6.388)
Year fixed effects	No	Yes
Country fixed effects	No	Yes
Industry fixed effects	No	Yes
Observations	6,126	6,126
Adjusted *R*-squared	0.161	0.229

Notes: The table presents regression model results for European companies listed on the STOXX 600 index from 2011 to 2022. Model 1 uses pooled OLS to analyze the impact of board characteristics on EI, whereas Model 2 incorporates controls for industry, year and country to address time-invariant industry differences and macroeconomic variations. Robust standard errors, adjusted for heteroscedasticity and clustered at the firm and industry levels, are applied to improve accuracy. Variable definitions are provided in Table 1. Statistical significance levels are indicated as follows: *** for 1%, ** for 5% and * for 10%
Source: Authors' own work

percentiles to control for extreme values (Dhaliwal *et al.*, 2011). To address heteroscedasticity, robust standard errors are applied (Hsiao *et al.*, 2022). Model 2 also incorporates year, country and industry-fixed effects to account for time-invariant industry differences and macroeconomic factors.

The analysis shows that female directors, board independence and CEOD significantly impact EI in European companies. Female directors and board independence have positive effects, whereas CEOD negatively influences EI. Board size, however, does not show a significant effect. As a result, hypotheses *H1*, *H3* and *H4* are supported, whereas *H2* is not.

4.3 Results discussion

Gender diversity on boards significantly enhances EI, as shown by a positive coefficient of 0.166 with a 1% *p*-value. This confirms the importance of female directors in promoting corporate strategies that focus on environmental priorities. Boards with higher female representation are more proactive in incorporating environmental issues into their agendas (Moreno-Ureba *et al.*, 2022; Konadu *et al.*, 2022). The European Commission's emphasis on gender equality aligns with these findings, as gender-diverse boards improve decision-making and strengthen stakeholder relations, enhancing a company's environmental and social performance (Farza *et al.*, 2022; Nuber and Velte, 2021). Research suggests that gender diversity contributes unique perspectives that enhance innovation and competitiveness (Mirza *et al.*, 2012). Empirical evidence also highlights that female directors' risk-averse and compliance-focused approaches positively affect employee engagement, creativity and overall firm progress (Nadeem *et al.*, 2019). However, García-Meca *et al.* (2023) emphasized that female directors need sufficient authority on the board to maximize their influence on EI. Other studies indicate that gender-diverse boards are more effective in implementing EI strategies and improving CSR and environmental disclosures (Alia and Mardawi, 2021).

The theoretical foundations support these findings. According to Resource Dependency Theory, board diversity, mainly including female directors, improves firm performance by providing diverse knowledge, expertise and networks that reduce resource dependence (Borgelt and Falk, 2007). These directors' ethical and thoughtful approaches align closely with shareholders' interests, enhancing oversight of EI (Issa and Bensalem, 2023).

The analysis confirms the significance of board independence in improving EI among European companies. Independent boards enhance a company's reputation, ensure compliance with environmental regulations and secure legitimacy, which is essential for CG (Farza *et al.*, 2022). Independent directors mitigate conflicts between shareholders and management, aligning management actions with shareholders' interests and promoting long-term firm sustainability (Lu and Wang, 2018; Zhu *et al.*, 2022). From a stakeholder perspective, these directors maintain ethical standards and social responsibilities, which are vital for the firm's success (García-Sánchez *et al.*, 2020; Ntim and Soobaroyen, 2013). Resource Dependency Theory also highlights the role of independent directors in providing critical resources like expertise and connections, supporting innovation and enhancing environmental practices (Khaireddine *et al.*, 2020; Osemene *et al.*, 2021). Their presence fosters a culture of managerial risk-taking and innovation by enabling access to essential resources and opportunities (Lu and Wang, 2018; García-Sánchez *et al.*, 2020).

In addition, board independence benefits extend beyond shareholder and stakeholder interests. Independent directors protect their professional reputation, preventing misconduct and thus enhancing the firm's reputation (Ruiz-Castillo *et al.*, 2023). Their accountability toward stakeholders and the environment empowers them to positively influence EI (Nadeem *et al.*, 2020).

The regression analysis confirms *H4*, indicating that CEOD negatively impacts EI, as shown by a significant beta coefficient of −3.277 and a 1% *p*-value. This supports Agency Theory's argument that combining CEO and chair roles reduces board independence, impairing the board's capacity to promote environmental strategies (Krause *et al.*, 2013; Ghardallou, 2022). Separating these roles is essential for maintaining independence and unbiased decision-making, ensuring alignment with long-term shareholder and stakeholder interests, including environmental goals (Korir and Tenai, 2020; Rossi *et al.*, 2021). Studies further indicate that CEOD often prioritizes short-term financial performance at the expense

of social and environmental sustainability, hindering effective EI strategies (Zhang, 2012; Mallin and Michelon, 2011).

Research shows CEOD can limit board members' contributions, particularly female directors who positively influence ESG performance (Romano *et al.*, 2020; Ghardallou, 2022). Sustainability performance suffers under CEOD due to conflicts of interest and a lack of strategic focus on long-term environmental objectives (Rossi and Cebula, 2015). This emphasizes the importance of separating the roles to promote sustainable development.

The results indicate no significant impact of board size on EI, consistent with previous studies by Farza *et al.* (2022), Trisnawati *et al.* (2022) and Romano *et al.* (2020). The complexities of decision-making in larger boards may hinder their effectiveness in advancing EI (Cheng, 2008), as reduced motivation among members can dilute the board's effectiveness (Zona *et al.*, 2013).

The regression results show that all control variables significantly impact EI. SIZE and CSRCO positively correlate with EI, as larger firms have more resources to implement sustainable technologies (Zhu *et al.*, 2022; Dwekat *et al.*, 2022a). Larger organizations can manage the substantial investments required for EI, leveraging their capabilities for strategic advantage. The presence of CSR committees further supports sustainability efforts by integrating environmental considerations into business strategies (Dwekat *et al.*, 2022a).

Leverage (LEV), however, negatively affects EI, indicating that high debt levels can constrain a company's ability to fund environmental projects. Firms with high leverage may prioritize financial obligations over long-term sustainability investments, potentially limiting their EI activities (Nadeem *et al.*, 2020). Conversely, firms with high ROE are more likely to support EI initiatives, as they have the financial capacity to invest in sustainable projects, enhancing long-term environmental performance. This relationship between financial health and EI demonstrates that successful firms are better positioned to integrate sustainability into their core operations (Nadeem *et al.*, 2020).

4.4 The moderating impact of CSR committee

The results in Table 5 highlight the moderating role of the CSRC on the relationship between board characteristics (gender diversity, board size, board independence and CEOD) and EI, supporting *H5*. The findings indicate that CSRC significantly enhances these associations, demonstrating its positive influence across various board dimensions. Notably, while the direct impact of CEOD on EI was negative, suggesting that the dual roles could hinder environmental efforts due to conflicts of interest or power concentration (as shown in Table 4), the presence of CSRC effectively mitigates these risks. CSRC provides oversight and strategic alignment with environmental goals, counteracting the governance issues linked to CEOD (Moreno-Ureba *et al.*, 2022).

The CSRC's ability to moderate these effects underscores its crucial role in guiding environmental decisions and strategies, strengthening the board's capacity to address complex environmental and social issues (Moreno-Ureba *et al.*, 2022; Dixon-Fowler *et al.*, 2017). Empirical evidence further supports the impact of CSRCs in aligning board characteristics with CSR outcomes, thereby enhancing sustainability practices (Pucheta-Martínez and Gallego-Álvarez, 2019; Endrikat *et al.*, 2021). These findings highlight the CSRC's essential role in not only supporting but also enhancing the effectiveness of EI efforts led by diverse and structured boards.

4.5 Robustness tests

4.5.1 Generalized estimating equation. In our research, we implemented the Generalized Estimating Equation (GEE) approach, consistent with recent studies (Bolourian *et al.*, 2023).

Table 5. The moderate role of CSR committee

VARIABLES	(1) Innovation
CSRC	30.57***(9.395)
BOGE	0.0481**(0.0749)
CSRC*BOGE	0.170**(0.0829)
BOSI	3.493*(3.122)
CSRC*BOSI	12.03***(3.526)
BOIN	0.0139**(0.0370)
CSRC*BOIN	0.119***(0.0446)
CEOD	−8.650***(2.460)
CSRC*CEOD	6.006**(2.726)
SIZE	6.213***(0.465)
LEC	−35.35***(3.741)
ROE	0.0146**(0.00588)
Constant	−41.52***(11.11)
Year fixed effects	Yes
Country fixed effects	Yes
Industry fixed effects	Yes
Observations	6,126
Adjusted *R*-squared	0.261

Notes: The table examines the moderating effect of the CSRC on the relationship between board characteristics and EI. To ensure analytical precision, robust standard errors, adjusted for heteroscedasticity and clustered at the firm and industry levels, are applied. The regression models incorporate controls for industry, year and country to account for time-invariant industry differences and macroeconomic variations. Detailed variable definitions are available in Table 1. Statistical significance is denoted as follows: *** for 1%, ** for 5% and * for 10%
Source: Authors' own work

This method is ideally suitable for data that may exhibit dependencies, which could lead to autocorrelation issues. It offers a more dependable and robust framework than traditional random and fixed effects models (Liang and Zeger, 1986). The results from Model 2 in Table 6 confirm the robustness of our findings, showing that the impact of board characteristics on EI is consistent with the main model's results in Table 4.

4.5.2 Control for the endogeneity. Endogeneity is a critical concern in governance research, particularly when examining the influence of board characteristics on EI, as director appointments may be biased by a firm's operational and informational context (Nadeem *et al.*, 2020). To address this, the study uses lagged models, positioning independent variables one period ahead of the dependent variables to establish causality. Using this approach, the results from Model 1 in Table 6 are consistent with the main findings, reinforcing the causal relationship.

Furthermore, in line with Nadeem *et al.* (2020), the study applies the two-stage least squares (2SLS) method to control for endogeneity. This technique uses instruments correlated with the endogenous predictors but uncorrelated with the error terms, enabling a clearer interpretation of effects. The results from Model 3 in Table 6, which implements 2SLS, confirm the robustness of the study's findings, demonstrating that the methods effectively manage endogeneity issues.

4.5.3 Control for CSR-sensitive industries. To control for CSR-sensitive industries in examining the impact of board characteristics on EI, the study focuses on sectors such as

Table 6. Different model specifications

VARIABLES	(1) One-year lag Innovation	(2) GEE Innovation	(3) 2SLS Innovation
BOGE	0.160***(0.0460)	0.0783(0.0477)	0.158***(0.0545)
BOSI	6.301*(1.863)	5.024*(1.906)	6.651(2.212)
BOIN	0.106***(0.0241)	0.0668***(0.0224)	0.118***(0.0272)
CEOD	−3.443***(1.170)	−3.713***(1.295)	−1.650**(1.353)
SIZE	6.452***(0.480)	6.529***(0.461)	7.029***(0.492)
LEV	−40.89***(3.991)	−36.04***(3.721)	−23.96***(3.801)
ROE	0.0103*(0.00589)	0.0157*(0.00921)	0.00279(0.00641)
CSRC	8.220***(1.278)	11.10***(1.210)	8.222***(1.318)
Constant	−85.65***(7.014)	−75.63***(7.824)	−96.97***(6.591)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
Observations	5,297	6,126	5,601
Adjusted *R*-squared	0.220		0.151

Notes: The table presents the effects of board characteristics on EI using various regression methods. Model 1 applies a one-year lag for the independent variables, Model 2 uses the GEE model and Model 3 uses the 2SLS method. Robust standard errors, adjusted for heteroscedasticity and clustered at the firm and industry levels, are used to improve accuracy. The models incorporate industry-, year- and country-specific controls to account for time-invariant industry differences and macroeconomic variations. Details on the variables used are available in Table 1. Statistical significance levels are indicated as follows: *** for 1%, ** for 5% and * for 10%
Source: Authors' own work

utilities, mining and production – industries with substantial environmental footprints and a strong incentive to maintain a positive social image (Al-Shaer and Zaman, 2018; Meqbel *et al.*, 2024). These industries comprise around 20% of the firm-year observations in the data set. Consistent with previous research (Dwekat *et al.*, 2022a; Meqbel *et al.*, 2024), the results in Table 7 reveal a significant positive relationship between CSR-sensitive industries and EI, suggesting that firms in these sectors are more inclined to adopt innovative environmental practices. The coefficients and significance levels of the main variables remain consistent with those presented in Table 4, reinforcing the robustness of the findings.

4.5.4 Control for country-level effects. To account for country-level influences on environmental practices, such as legal frameworks, sociocultural factors and cultural dimensions (Meqbel *et al.*, 2024; Dwekat *et al.*, 2022a), this analysis replaces country-specific indicators with broader measures like regulatory quality and cultural dimensions (e.g. power distance, individualism, masculinity and uncertainty avoidance). Regulatory quality, indicating the government's effectiveness in implementing sustainable regulations (Mooneeapen *et al.*, 2022), is associated with improved sustainability performance (Meqbel *et al.*, 2024; Rahi *et al.*, 2023), as companies in such environments are more likely to adopt responsible practices (Uyar *et al.*, 2020). Cultural dimensions also shape CSR practices by influencing stakeholder orientations and social priorities (Orij, 2010). Khlif *et al.* (2015) suggested that leadership styles, resource strategies and ethical decision-making linked to national culture impact sustainability efforts. The empirical results, as shown in Model 1 in Table 7, confirm a significant positive relationship between board characteristics and EI,

Table 7. Control for country-level factors and CSR-sensitive industries

VARIABLES	(1) Innovation	(2) Innovation
BOGE	0.0961**(0.0455)	0.0987**(0.0490)
BOSI	5.725*(1.811)	3.806*(1.964)
BOIN	0.0897***(0.0219)	0.0438*(0.0233)
CEOS	−3.445***(1.196)	−1.135(1.282)
SIZE	6.463***(0.449)	6.822***(0.467)
LEV	−37.49***(3.687)	−25.01***(3.628)
ROE	0.0168***(0.00606)	0.0200***(0.00613)
CSRC	10.83***(1.204)	11.14***(1.218)
Power distance	−0.307***(0.0863)	
Individualism	−0.118(0.0843)	
Masculinity	−0.152***(0.0303)	
Uncertainty avoidance	0.192***(0.0716)	
Rule of law	1.072(1.514)	
CSR_sensitive_industry		6.043***(0.972)
Constant	−72.50***(9.560)	−76.01***(8.350)
Year fixed effects	Yes	Yes
Country fixed effects	No	Yes
Industry fixed effects	Yes	No
Observations	6,109	6,126
Adjusted *R*-squared	0.251	0.204

Notes: The table illustrates the impact of board characteristics on EI while controlling for country-specific factors and CSR-sensitive industries. Model 1 incorporates cultural factors, whereas Model 2 controls for CSR-sensitive industries. To ensure precision, robust standard errors, adjusted for heteroscedasticity and clustered at the firm and industry levels, are used. The models also account for industry-, year- and country-specific controls to address time-invariant industry differences and macroeconomic fluctuations. Detailed variable information is provided in Table 1. Statistical significance is denoted as follows: *** for 1%, ** for 5% and * for 10%

Source: Authors' own work

even after accounting for these country-level factors, supporting the robustness of our findings.

5. Conclusion

This study addresses a significant gap in the literature by analyzing the impact of board characteristics – gender diversity, independence, size and CEOD – on EI among European firms listed on the STOXX Europe index from 2011 to 2022, using a data set of 6,126 firm-year observations. It also investigates the moderating role of CSR committees in these relationships.

The findings emphasize the importance of gender diversity and board independence in promoting EI, supported by legitimacy, agency and stakeholder theories. Female board members and independent directors are linked to stronger environmental commitments. In contrast, CEOD negatively impacts EI, aligning with the notion that concentrated power hinders the board's ability to promote sustainable practices. No significant effect of board size on EI was found. Control variables, such as CSR committees and firm size, positively influence EI, with larger companies and those with CSR committees more committed to sustainability efforts. Financial leverage negatively impacts EI, whereas profitability (ROE) has a positive effect.

The study highlights the significant moderating role of CSR committees, which enhance the relationship between board characteristics and EI. CSR committees effectively mitigate the negative impact of CEOD by promoting oversight and strategic alignment with environmental goals, thereby improving corporate sustainability practices.

These findings have important theoretical and practical implications. The positive impact of gender diversity underscores the need for greater female representation on boards to bring unique perspectives and drive environmental initiatives. In addition, the importance of board independence suggests that companies should prioritize appointing knowledgeable, independent directors to integrate sustainability into corporate strategies. Regulatory support for board independence is essential for effective governance and proactive engagement in EI.

The negative effect of CEOD supports separating the roles of CEO and board chair to avoid power concentration and maintain unbiased, long-term decision-making. Establishing CSR committees further strengthens the effectiveness of board characteristics in promoting EI, ensuring rigorous oversight and strategic alignment with environmental objectives.

Theoretically, this study advances the understanding of CG and EI by demonstrating how specific board characteristics – gender diversity, board independence and CEOD – impact environmental strategies. It supports the application of legitimacy, agency and stakeholder theories, showing that diverse and independent boards enhance a firm's legitimacy, reduce conflicts of interest and address environmental concerns more effectively.

The study provides a foundation for future research to explore the causal mechanisms and other moderating factors affecting these relationships. Further investigation into board member qualifications and experiences could deepen the understanding of their impact on environmental strategies. In addition, future studies could examine board characteristics in developing countries, considering the influence of cultural factors on EI (Ullah *et al.*, 2022).

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