International Journal of Innovative Research and Scientific Studies, 8(6) 2025, pages: 561-572

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Breaking barriers and driving green change: Female board presence, environmental innovation, and the power of effective audit committees

Amani Ebnaoof

Department of Management, University College of Tayma, University of Tabuk, Tabuk, Saudi Arabia.

(*Email: a.ibnauf@ut.edu.sa*)

Abstract

The current study examines the interaction between board-level gender diversity and audit committee effectiveness to determine its effects on environmental innovation among Malaysian publicly traded companies. The study uses regression models based on a five-year panel data set of 198 firms containing 990 annual observations (2020–2024). Environmental innovation is operationalized using the environmental innovation score published in Refinitiv Eikon, and the gender diversity of the board and effectiveness of the audit committee are proxied using published corporate governance measures. The empirical findings reveal a strong, positive association between female representation on the board and the participation of the firm in eco-innovative activities. More critically, it is observed that audit-committee effectiveness increases this influence, with the conclusion that careful audit oversight enhances the impact of women on the environment. A combination of the results supports the conclusion that inclusive leadership and effective governance systems can help foster corporate environmental innovations. The research is relevant to the literature as it establishes a wider geographic and thematic focus of the previous investigation and provides regulators and companies with practical considerations with plans to improve sustainability performance by diversifying the boards and increasing the effectiveness of audit committees.

Keywords: Audit committee effectiveness, Eco-innovation, Environmental innovation, Female board representation, Governance, Green corporate strategy.

DOI: 10.53894/ijirss.v8i6.9644
Funding: This study received no specific financial support.
History: Received: 17 July 2025 / **Revised:** 19 August 2025 / **Accepted:** 21 August 2025 / **Published:** 3 September 2025

Competing Interests: The authors declare that they have no competing interests.
Transparency: The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

The world has turned to environmental innovation, often referred to as green innovation, as the primary tool in global campaigns to slow climate change, reduce resource depletion, and achieve sustainable growth [1]. It refers to the

development and implementation of novel products, processes, or practices that reduce environmental degradation while increasing ecological efficiency [2]. As economies shift toward low-carbon, environmentally accountable operations, environmental innovation becomes both an ethical obligation and a strategic priority for firms that want to remain competitive over the long term, operate in regulatory compliance, and enjoy the confidence of stakeholders [3]. In the case of public institutions, environmental innovation forms the backbone of policy targets linked to environmental protection, sustainable urbanization, and sustainable economic development [2]. In turn, operational efficiencies, improvement of brand reputation, and availability of new market opportunities, especially in industries that are under increased pressure and scrutiny regarding their environmental impacts, are gained by private enterprises. Companies involved in carbon-intensive activities, such as manufacturing, energy generation, and processing of resources, are forced to reduce pollution and waste to maintain their competitive edge and satisfy emerging sustainability requirements [4]. In this regard, the redesign of production processes and the introduction of environmentally friendly technologies allow organizations to reduce emissions and resource use without affecting economic activity [1].

In Malaysia, environmental innovation has major strategic and regulatory importance. National plans and policies explicitly target a low-carbon transition: under the 12th Malaysia Plan and the New Industrial Master Plan 2030, the country has pledged to achieve net-zero greenhouse gas emissions by 2050 and to decarbonize key industries via energy efficiency, renewables, and technology adoption [5]. The government has enacted incentives (e.g., tax allowances and green financing schemes) and stricter environmental standards to encourage corporate adoption of clean technologies. Indeed, programs under the Economic Transformation Program and National Key Economic Areas explicitly promote the use of green technology to conserve the environment and reduce pollution [6]. These policies make environmental innovation a regulatory imperative for Malaysia's polluting sectors, not only to meet climate commitments but also to open new growth and investment opportunities in green industries [7].

In the context of modern research on corporate sustainability, the focus has gradually shifted to gender diversity in corporate boards as a novel factor that determines sustainability performance. Evidence continues to prove that female directors, compared to their male counterparts, add wider stakeholder views and long-term perspectives, thus developing increased sensitivity to social and environmental matters [8]. They have been observed to have a more inclusive decision-making process, increased ethical standards, and a stronger inclination to venture into non-financial risks, which are essential for sustainability issues such as environmental degradation and climate change [9]. Empirical studies have established that female leadership is always correlated with increased environmental performance [10], specifically, the ability to incorporate more effective environmental practices, increased use of green supply chains, and increased sensitivity to regulatory compliance and stakeholder demands [8]. Analysis of related literature in Malaysia indicates that a gender-balanced board refers to a high (fewer) ratio of female representation, indicating quality of governance, strengthened internal control, and reduction of exposure to managerial opportunism [5]. All of these perceptions can be seen as an indication that gender diversity in the corporate board positively affects the credibility of sustainability adherence, which includes environmental innovation. Besides, female directors are much more demonstrative in promoting the concepts of transparency, accountability, and ethics, which are inherently associated with the idea of environmental innovation and long-term care [11].

Although the general trend toward sustainability and green transformation has been pursued in a broader sense [11], research on the impact of female boardroom representation on corporate boards on environmental innovation has been scarce in the context of Malaysia. The majority of existing studies on board diversity in the country have primarily focused on its relationship with overall sustainability initiatives, corporate social responsibility (CSR), and financial results [12, 13]. However, these studies often overlook the more specific mechanisms through which board structure can influence environmental innovation outcomes. According to some reports, gender-inclusiveness in directorship is positively correlated with social performance indicators, indicating that the involvement of female directors leads to greater stakeholder- and community-oriented actions [13]. According to recent literature, female board representation in Malaysia is linked to more favorable environmental outcomes in broad ethical and social domains; yet, the relationship with more technically oriented criteria, including research and development investment in sustainable technology, product redesign, and operational greening, is less clear, with results spanning weak to insignificant correlations [14, 15]. Such remarks identify an empirical gap: although gender-diverse leadership may promote climbing-level ethical and social goals, there is a lack of knowledge of its effects on driving essential technological and strategic innovations in environmental future technology, so this question should be addressed with particular effort [5]. This gap is important to close in order to begin to understand to what extent and in what ways gender-diverse boards indeed propel substantive rather than symbolic gains in environmental improvements.

The scope of audit committees has continued to expand in recent literature. In addition to the historical mandate of overseeing financial reporting and internal controls, audit committees are beginning to actively discuss more governance topics, such as environmental risks, sustainability strategies, and ESG performance [6]. Despite this development, the existing literature is still largely concentrated on the traditional oversight role of the audit committee [16, 17] with little consideration given to how audit-committee effectiveness affects the nonfinancial aspects of corporate performance [18]. Specifically, how audit committees either encourage or discourage environmental innovation has not received much academic attention. Despite the increasing number of studies that have explored the direct effects of audit-committee characteristics on firm outcomes, the possible moderating effect of audit-committee effectiveness, particularly in determining the association between board composition or diversity and environmental innovation, has received little attention. This gap is particularly significant in the modern environmental scene, where strong audit control plays a central role in ensuring credibility, accountability, and overall strategic incorporation of environmental innovation efforts.

This study offers several contributions. First, it contributes to the existing body of literature by addressing a specific empirical gap concerning the role of female board representation in driving environmental innovation, particularly within the context of Malaysia [19]. Second, this study advances the literature by introducing and empirically testing the moderating role of audit committee effectiveness in the relationship between female board representation and environmental innovation. While most prior research has concentrated on the direct impact of audit committees [16], limited attention has been paid to their potential influence as a governance mechanism that strengthens or conditions the effectiveness of board diversity on non-financial outcomes. Finally, the study contributes to the literature by providing empirical evidence from a developing country, Malaysia, where research on the nexus between female board representation and environmental innovation remains limited. Accordingly, by shifting the focus to Malaysian industries, this study addresses an important geographical and contextual gap, offering insights into how gender-diverse boards function under different institutional pressures and governance environments. This enhances the generalizability of previous findings and provides a more inclusive understanding of the role of board diversity in promoting environmental innovation globally.

The remainder of this paper is organized as follows. Section 2 reviews the key literature on environmental innovation and female board representation. Section 3 discusses the theoretical foundation based on the upper echelons and stakeholder theories. Section 4 develops our hypotheses. Section 5 outlines the methodology, including the sample, data, variables, and the model. Section 6 presents the empirical results and analysis. Section 7 concludes the paper with the findings, implications, limitations, and future research directions.

2. Literature Review

2.1. Environmental Innovation

Environmental innovation refers to the development and implementation of products, processes, technologies, or business models that reduce environmental impacts, enhance ecological efficiency, and contribute to sustainable development [5]. It goes beyond conventional innovation by integrating environmental considerations into the core of a firm's operations and strategic directions. Environmental innovation encompasses a wide range of activities, including energy-efficient production, waste reduction, recycling technologies, low-carbon logistics, eco-friendly product design, and cleaner production methods [20]. As environmental concerns become increasingly prominent, environmental innovation has gained traction as a critical pathway for firms seeking to align their economic performance with environmental responsibility [4]. Several factors motivate firms to engage in environmental innovations. Regulatory pressure is one of the most significant drivers, as governments worldwide have introduced stricter environmental standards, emission controls, and sustainability reporting requirements [21]. In jurisdictions such as Malaysia, where country policy guidelines aim to reduce greenhouse gas emissions and promote the use of clean technologies, companies are encouraged by tax incentives, green financing programs, and grants for innovation to adopt eco-efficient behaviors [5]. Dynamic market demand also plays a significant role: increased consumer awareness and an increasing number of customers who prefer sustainable products challenge companies to stand out as green. Simultaneously, the demands of external stakeholders have made environmental responsibility a source of reputation [22]. At the firm level, the desire to pursue environmental innovation is driven by its need to enhance operational efficiency, minimize expenditure on resource use and waste management, as well as gain access to new markets and emerging technologies [5].

2.2. Female Board Representation

The presentation of female board representation refers to females being included in the board of directors, which is responsible for making strategic decisions, overseeing corporate governance, and maintaining organizational values [11]. Scholarship has identified three key drivers that have spurred this process: regulatory reform, investor activism, and the growing awareness of the contribution that diversity leadership makes to corporate performance and sustainability [23]. Research also shows that female directors are ethically sensitive, stakeholder-oriented, and participatory in decision-making [15]. These features are related to more intense supervision, more substantial board discussion, and closer proximity to the development of long-term value through empirical work [11]. There is also extensive literature to support that gender diversity in boardrooms has a positive impact on corporate social responsibility, environmental performance, and risk management [24, 25]. In addition, female directors tend to emphasize ethical, social, and environmental issues, thereby encouraging broader discussions about sustainability and responsible governance [11]. Empirical research indicates that the existence of gender-diverse boards will more effectively enable activity monitoring, control agency costs, and encourage transparency, which will directly influence strategic choices, including those related to green initiatives [26]. Empirical research on sustainability-related topics has attributed a greater percentage of women on corporate boards to increased environmental disclosure levels, increased involvement in climate-related activities, and an increased tendency to adopt socially responsible corporate conduct [27, 28]. Studies in developed countries also indicate that companies with above-average female board representation demonstrate better environmental performance and are more active in their sustainability-related strategies [29]. However, the relationship between gender diversity in boardrooms and environmental performance is not consistent in developing economies because of the heterogeneity of institutional frameworks, cultural practices, and regulatory governance [11].

2.3. Audit Committee Effectiveness

In the existing literature, audit committees are conventionally viewed as the central point for managing fundamental financial duties, such as maintaining the integrity of financial reporting, managing internal control systems, and overseeing the external audit process [7]. Historically, audit committees were formed to serve the interests of shareholders by reducing financial reporting malpractices and improving transparency [7]. Within recent decades, their mandate has been redefined

as there has been a growing global focus on sustainability and social responsibility [18]. Accordingly, recent governance thought affirms a need to broaden the audit committee's duties toward environmental, social, and governance (ESG) risks and sustainability issues [30, 31]. The wider scope indicates that non-financial risks, including climate-related shocks and intensifying social pressures and regulatory environments, can also have material effects on enterprise financial performance and sustainability [7]. In this respect, audit committees currently serve as key governance models in incorporating sustainability and ESG factors into risk management frameworks, as well as disclosure procedures [31]. Empirical studies demonstrate that audit committees increase the accountability of companies, peaking at their environmental performance, ensuring the activities of firms become compliant with the new sustainability rules and ethically consistent with the requirements of their stakeholders [32]. The debates in environmental innovation literature also indicate that enhanced pressure on companies to engage in low-carbon operations and the use of green technologies is causing their boards to increasingly turn to audit committees to analyze the risks and opportunities of such projects [7]. In turn, audit committees contribute to corporate environmental developments by seeking to interrogate sustainability strategies, tracking decisions to become green investors, and also attesting to the authenticity of environmental performance reporting [31].

3. Theoretical Foundation

3.1. Upper Echelons Theory

Upper Echelons Theory (UET) assumes that the values, experiences, and cognitive foundations of top executives are reflected in organizational outcomes [33]. In the case of corporate boards, this theory implies that demographic attributes, including gender, are not only symbolic but also play a role in determining strategic decisions, which also extends to settling environmentally innovative choices [34]. Due to various life experiences and social expectations, female directors are likely to bring different values, including ethical sensitivity, inclusiveness, and a long-term perspective on the well-being of society [18]. These characteristics determine the perception of environmental risks and opportunities, as well as the prioritization of innovation in favor of sustainability by firms. Through concentration at the top of leadership, UET posits that the cognitive diversity that female board members bring can expand the range of discussions on the board, break groupthink, and result in more progressive and socially conscious policies [35]. Such diversity is especially essential when the issues are complicated and uncertain, such as environmental innovation and those with multiple stakeholders [35]. Female board members can promote the commitment of resources to environmentally responsible R&D, approve the incorporation of sustainability objectives into corporate strategies, and push ethical procedures that match the expectations of the public and stakeholders [12]. Another aspect emphasized by UET is that strategic outcomes are not only the product of individual characteristics but also the interplay within the wider leadership environment. In this respect, gender-diverse boards are not only a result of demographic change but also the driver of redefining organizational values and behaviors in response to environmental responsibility [36]. Female directors can create a culture of innovation, transparency, and accountability within the company’s environmental performance through their contribution to the cognitive and value structure of the board [18]. Therefore, UET offers a strong theoretical basis for describing how female representation at the top can stimulate firm-level dedication to environmental innovation.

3.2. Stakeholder Theory

The stakeholder theory is a framework in which the responsibility of an organization is set outside the demands of shareholder capitalism and expands a wide circle of stakeholders, which includes workers, customers, local communities, and the natural environment [37]. The theory focuses on being ethical in terms of governance and transparency in terms of managers, thus promoting the fair incorporation of heterogeneous stakeholders' interests in corporate decision-making. In this paradigm, the inclusion of women on corporate boards will be useful in enhancing the sustainability orientation of the organization [38]. Empirical studies show that women directors have a statistical relationship with social awareness and environmental scrutiny, expanded and inclusive debate, and sensitivity to the issues raised by outside financial parties [18]. The aspects of their representation also relate to the age of orientation at long-term value creation, powerful ethical risk management, and the ability to respond to challenges in the environment, which is widely recognized as a precondition of environmental innovation [18]. In the same way, gender-diverse boards display a heightened focus on environmental innovation, and their female directors favor environmental responsibility, sustainability reporting, and an aggressive approach to fulfilling shareholders' social needs [5]. Thus, the female representation may influence the priorities of the boards such that ecological stewardship is more than mere compliance; it transforms into an essential strategic necessity. Consequently, having women directors acts as a channel through which the concerns of stakeholders, particularly environmentally focused concerns, find their way into the strategic agenda of the firm [25]. Moreover, stakeholder theory further emphasizes the effectiveness of audit committees as a moderating factor. Stakeholder accountability is increased manifold by high-functioning audit committees due to transparency, ethical behavior, and consistency in corporate conduct, along with the expectations of stakeholders [6] The audit committee helps strengthen the governance framework when it is independent, experienced, and active, thereby enabling female members of the board to promote environmental innovation [18]. Through this governance synergy, sustainability initiatives were proposed, evaluated, resourced, and monitored [18]. In short, the stakeholder effect of gender-diverse boards, which are concentrated in audit committees, is multiplied, thereby creating an institutional context that promotes environmental innovation in meeting societal and environmental needs.

4. Hypotheses Development

4.1. Female Board Representation and Environmental Innovation

Recent advances in corporate governance research highlight how the composition of the board of directors has a critical effect on the strategic direction of the organization and, therefore, its process of decision-making in environmental contexts. One such factor is the representation of women on the board, which has become a significant predictor of the firm's sustainability orientation [39]. Based on the upper-echelons perspective, which postulates that the performance of organizations is determined by the attributes and value orientations of their senior executives, it can be concluded that the inclusion of women within the highest managerial ranks can reconstitute how firms conceptualize, and respond to, environmental pressures [35, 36]. Empirical data support the role of female directors in bringing heterogeneous views, increased ethical awareness of societal impact, and an extreme focus on long-term societal implications, thus helping to give rise to and the application of environment-related policies and influencing sustainability innovation [28]. Moreover, stakeholder theory emphasizes the necessity of responding to a wide range of stakeholder interests, including both environmental and social aspects [37].

Although theoretical and empirical evidence that it is linked with female board representation, greater sustainability, and environmental performance has been growing steadily, the literature still documents inconsistent and sometimes contradictory conclusions. While many studies point out the benefits of having female directors, such as the ability to provide ethical leadership, sensitivity to stakeholders, and a long-term perspective [13] other research studies have shown that simply having women on a corporate board is not a sufficient condition to cause significant environmental change. Some researchers assume that structural or cultural barriers can limit the impact of female directors, particularly in spheres where males reign or where a particular organization has established governance traditions [40, 41]. These barriers may be compounded by poor institutional mechanisms for board diversity, lax environmental standards, and organizational culture that fail to recognize the importance of women in strategic leadership in developing countries such as Malaysia [18]. Considering the inconsistent and even conflicting evidence regarding the effects of female board representation on environmental performance and the limited number of studies conducted in developing countries, this paper adopts a more nuanced and less universal perspective. The current analysis hypothesizes that companies with a higher percentage of female representation on the board of directors are more likely to implement environmental innovation programs. Female directors tend to be more ethically conscious, possess a better stakeholder orientation, and have a long-term strategic outlook, which positively influences organizations to be environmentally responsible and to invest in sustainable technologies. Therefore, we propose the following hypothesis.

$H_{1:}$ Female board representation is positively associated with environmental innovation in Malaysian industries.

4.2. The moderating effect of Audit Committee Effectiveness

The growing relevance of sustainability and environmental innovation in corporate strategy has led to an expansion of audit committees' responsibilities beyond traditional financial oversight to include ESG-related risks and opportunities [42] while much of the existing research has focused on the direct role of the audit committee in enhancing reporting quality and internal controls [32] emerging perspectives suggest that audit committee effectiveness may also influence broader governance outcomes, particularly when interacting with other board-level attributes, such as gender diversity [43]. Within the context of stakeholder theory, effective audit committees can be instrumental in ensuring that a firm is able to meet the expectations of a broad variety of stakeholders, including investors, regulators, local communities, and the larger environment [44]. Empirical finance results show that female directors, who are commonly associated with increased responsiveness to stakeholder interests and long-term social performance, express increased support for environmental innovation [12]. However, this effect is significantly augmented when a responsible and effective audit committee integrates ESG factors into its oversight efforts [25]. An effective audit committee may strengthen stakeholder-oriented principles by probing environmental risks and confirming sustainability efforts [18]. The effectiveness of audit committees, therefore, acts as a governance mechanism in which gender-diverse boards gain the ability to initiate and implement environmental innovation strategies [34]. Therefore, audit committee effectiveness is likely to condition the strength of the relationship between female board representation and environmental innovation. Accordingly, we propose the following hypothesis:

$H_{2:}$ Audit committee effectiveness positively moderates the relationship between female board representation and environmental innovation

Accordingly, Figure 1 represents the conceptual framework of the study.

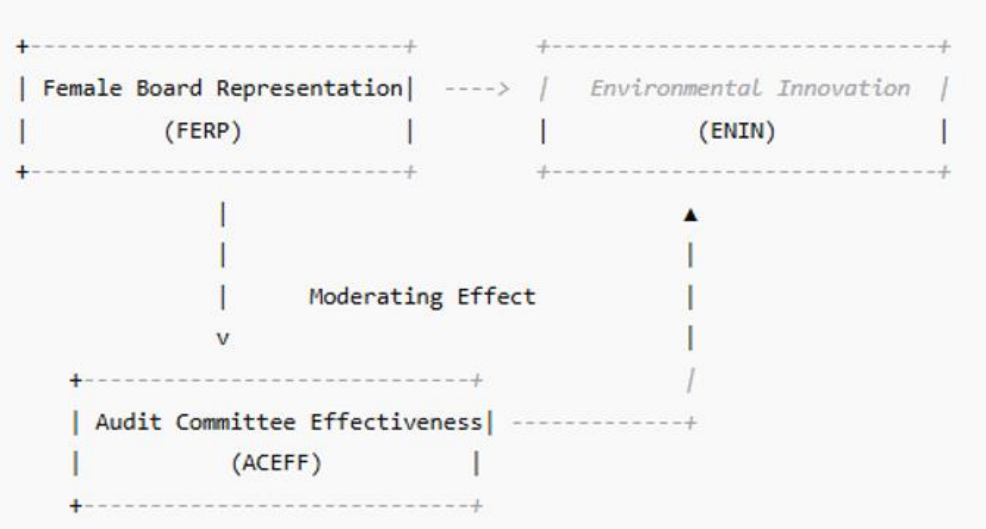

Figure 1.
Conceptual framework.

5. Methodology

5.1. Sample Selection and Data Collection

The sample selection began with all firms listed on Bursa Malaysia between 2020 and 2024, resulting in 4,975 firm-year observations from 995 unique companies. This period was chosen due to the increased availability of environmental-related data and the introduction of regulatory requirements in 2020 mandating greater gender diversity on corporate boards in Malaysia [18]. Further, this study uses the Refinitiv database due to its comprehensive coverage, methodological consistency, and relevance in emerging markets like Malaysia, where publicly available innovation metrics are often limited or inconsistent [5]. Unlike alternative sources, which may rely heavily on firm self-reporting or voluntary disclosures, Refinitiv applies a structured and independent assessment approach, ensuring greater objectivity and comparability [45]. Its robust scoring framework allows for a reliable cross-sectional analysis of environmental innovation, making it especially suitable for examining the relationship between board characteristics and environmental innovation outcomes. Subsequently, we narrowed our sample to include only those observations with available data on environmental innovation from Refinitiv Eikon, resulting in 1,025 firm-year observations for Malaysian companies between 2020 and 2024. Observations lacking information on female board representation, audit committee effectiveness, or any of the control variables were excluded. The final sample used to test our hypotheses comprises 990 firm-year observations from 198 distinct Malaysian firms. Table 1 provides a summary of the sample selection process.

Table 1.
Sample description.

Sample selection	
Number of observations containing environmental innovation data across the duration of the study, 2020-2024	(1025)
Minus observations with missing data for other variables	(35)
Sampled observations	990

5.2. Variables Measurement

Environmental innovation (ENIN) is measured through the environmental innovation score, which is an index extracted using the Refinitiv database. This indicator measures a firm's representation in environmentally focused innovation efforts: the creation of environmentally friendly products, the integration of clean technologies, the increase in energy and resource efficiency, the implementation of systems aimed at reducing emissions and waste, and the overall environmental burden [5] The index provides a standardized, measurable value that is also an indicator of the intensity and efficacy of environmental innovation practices undertaken by a firm over time. The upper quartile scores indicate a strong inclination towards environmental innovation [46]. At the same time, female board representation (FEPR) is quantified in terms of board gender diversity (%) using the data provided by the Refinitiv database, which indicates the percentage of women on the board of directors, calculated as the percentage of total board members who are female [18]. As a continuous variable, the measure permits variation both between firms and across industries: the larger the percentage, the more likely gender diversity is at the board level; thus, a greater presence and potential impact of women in strategic decision-making processes [39]. Meanwhile, a composite index of four indicators of audit committee effectiveness (ACEFF), namely independence, the size of the audit committee, the frequency of meetings, and financial expertise, was calculated, giving a score between zero and four [18]. Additionally, the study incorporates several control variables to account for factors that may influence environmental innovation independent of board gender diversity. Table 2 presents definitions of the study variables.

Table 2.
Variable Definitions.

Variable	Acronym	Measurement
Environmental Innovation	ENIN	The environmental innovation score is a company's capacity to reduce environmental impact through the development and use of innovative technologies, products, services, or processes.
Female board representation	FERP	The number of female board members is divided by the total number of board members and multiplied by 100%.
Audit committee effectiveness	ACEFF	The sum of the 4 indicators (independence, size, meeting, and financial expertise) is within the range of zero and four.
Board effectiveness	BOEFF	Is the sum of the four indicators (independence, size, gender, and meeting). A higher score typically indicates higher board effectiveness.
Institutional Investor	INV	The proportion of the total number of common shares held by all institutional owners of the total common shares outstanding at year-end
ESG Score	ESG Score	ESG scores from Refinitiv which reflect how well a company integrates ESG factors into its operations, strategy, and public disclosures based on publicly reported data.
Firm size	FSIZE	The logarithm of total assets
Return On Assets	ROA	Return On Assets
Return On Equity	ROE	Return On Equity

6. Empirical Findings

6.1. Descriptive Investigation

Table 3 presents descriptive statistics of the variables used in this study. The mean Environmental Innovation (ENIN) score is 21.11, with a wide range from 4.00 to 71.86, indicating substantial variation in Environmental Innovation practices among the sampled firms. Female board representation (FERP) has a mean of 26.04%, suggesting that, on average, over a quarter of board members are female, although some firms report no female representation and others reach up to 62%. The mean Board Effectiveness (BOEFF) score is 3.49 out of a possible 4, while Audit Committee Effectiveness (ACEFF) averages 3.92 out of 4, implying generally strong governance structures across firms. Institutional Investor (INV) ownership has a relatively high mean of 70.14%, reflecting the considerable monitoring influence of institutional shareholders. The ESG Score shows an average of 34.55, with a minimum of 0 and a maximum close to 85, indicating varying levels of ESG engagement and disclosure. Firm Size (FSIZE), measured as the natural logarithm of total assets, averages 11.24, showing a diverse sample of small to large firms. In terms of financial performance, the average Return on Assets (ROA) is 3.42%, while the Return on Equity (ROE) is 3.61%, although both show large standard deviations and minimum values, highlighting performance volatility across the dataset. These statistics collectively illustrate the significant heterogeneity among firms, justifying the inclusion of control variables in the regression analysis to account for firm-specific differences.

Table 3.
Descriptive statistics.

Variables	Mean	Standard Deviation	Minimum	Maximum
ENIN	21.1110	16.4394	4.000	71.8571
FERP	26.0408	13.4456	0.000	62.0000
BOEFF	3.4940	0.9658	1.000	4.0000
ACEFF	3.9230	0.8484	2.000	4.0000
INV	0.7014	0.2004	0.1116	0.9924
ESG Score	34.5540	16.1276	0.000	84.9770
FSIZE	11.2444	1.3331	4.1071	13.5180
ROA	0.03420	0.0886	-0.5311	0.6557
ROE	0.0361	0.5175	-15.5982	0.9353

Note: ENIN = Environmental Innovation; FERP= Female board representation: BOEFF = Board effectiveness: ACEFF = Audit committee effectiveness: INV = Institutional Investor: environmental, social and governance = ESG Score: FSIZE = Firm size: ROA= Return on Assets: ROE = Return on Equity.

6.2. Correlation Matrix

Table 4 displays Pearson's correlation coefficients of the key variables used in this study. The correlation between Environmental Innovation (ENIN) and Female Board Representation (FERP) is positive (r = 0.1292), suggesting a modest association between gender-diverse boards and environmental innovation. Board Effectiveness (BOEFF) and Audit Committee Effectiveness (ACEFF) show stronger positive correlations with ENIN (r = 0.3660 and r = 0.3384, respectively), indicating that firms with more effective governance structures are more likely to engage in environmental innovation. A moderate positive correlation is also observed between ENIN and Institutional Investor Ownership (INV) (r = 0.4435), implying that greater institutional ownership is associated with stronger environmental innovation efforts. By contrast, ENIN exhibits negligible correlations with ESG Score, Firm Size (FSIZE), Return on Assets (ROA), and Return on Equity (ROE), with coefficients close to zero, suggesting that environmental innovation may not be directly tied to a

firm's overall ESG rating or financial performance metrics. Additionally, there was no evidence of multicollinearity among the independent variables, as none of the correlations exceeded 0.70 [18]. This supports the validity of including these variables simultaneously in the regression analysis, without risking distortion from highly interrelated predictors. Overall, the correlation analysis provides initial empirical support for the expected relationships and shows the robustness of the subsequent multivariate regression models.

Table 4.
Correlation Analysis.

Variables	ENIN	FEPA	BOEFF	ACEFF	INVESTOR	ESG	FSIZE	ROA	ROE
ENIN	1.000								
FERP	0.1292	1.000							
BOEFF	0.3660	0.1019	1.000						
ACEFF	0.3384	0.0985	0.3983	1.000					
INV	0.4435	0.0592	0.1291	0.0852	1.000				
ESG Score	0.0556	-0.0287	-0.0160	-0.0292	0.0504	1.000			
FSIZE	-0.1025	-0.0559	0.0443	0.0209	-0.1168	-0.0008	1.000		
ROA	-0.0001	-0.0026	-0.0978	-0.0388	-0.0187	0.1551	-0.0152	1.000	
ROE	0.0164	-0.0251	-0.0419	-0.0480	-0.0102	-0.0097	-0.0270	0.3743	1.000

6.3. Regression Results

Table 5 presents the results of the direct effect regression model examining the relationship between Female Board Representation (FERP) and Environmental Innovation (ENIN), along with several control variables. The coefficient for FERP is 0.1148 and is statistically significant at the 1% level (t = 3.26), indicating a positive and meaningful relationship between the proportion of female directors and environmental innovation among Malaysian firms. This finding suggests that companies with more gender-diverse boards are more likely to engage in environmental innovation practices such as eco-product development, cleaner technologies, and sustainability-oriented R&D. This result aligns with prior studies that highlight the role of female directors in enhancing firms' sustainability orientation. For instance, Bear et al. [47] and Liao et al. [48] found that female directors tend to prioritize long-term stakeholder interests and are more likely to advocate for environmental and social responsibility. In the Malaysian context, where research remains limited, this finding provides valuable empirical evidence that gender-diverse leadership positively contributes to environmental performance. From a theoretical perspective, this result supports the assumptions of both the upper echelons theory and stakeholder theory. According to the upper echelons theory, the demographic and cognitive attributes of top executives, including gender, shape organizational decisions and outcomes [36]. Female board members, often associated with ethical sensitivity, inclusiveness, and long-term thinking, may influence board discussions and strategic directions toward sustainability and innovation [5]. Likewise, stakeholder theory emphasizes the importance of considering diverse stakeholder interests, which female directors are more likely to prioritize [6]. The significant and positive effect of FERP on ENIN reflects the ability of gender-diverse boards to align organizational actions with broader environmental and stakeholder expectations.

Regarding the control variables, board effectiveness (BOEFF) shows a strong and statistically significant positive relationship with environmental innovation ($\beta = 5.6116$, t = 8.94), indicating that high-functioning boards are more likely to support and oversee environmental innovation initiatives. Institutional investor ownership (INV) also exhibits a strong and significant effect ($\beta = 66.292$, t = 9.99), suggesting that firms with higher institutional ownership are under more pressure to adopt sustainable and innovative practices.

Table 5.
Direct Effect Regression Results.

Variables	Coefficients	t-sat
FERP	0.1148	3.26***
BOEFF	5.6116	8.94***
INV	66.292	9.99***
ESG Score	-0.0098	-0.32
FSIZE	-0.3551	-0.29
ROA	-0.5444	-0.1
ROE	0.0222	0.12
R^2	0.28	
Prob > chi2	0	
Obs	990	

Note: ENIN = Environmental Innovation; FERP = Female board representation; BOEFF = Board effectiveness; ACEFF = Audit committee effectiveness; INV = Institutional Investor: environmental, social and governance = ESG Score; FSIZE = Firm size: ROA = Return on Assets: ROE = Return on Equity: *** p<.01, ** p<.05, * p<.1.

Other variables, such as ESG Score, Firm Size (FSIZE), Return on Assets (ROA), and Return on Equity (ROE), do not show statistically significant relationships with environmental innovation in this model. This implies that environmental innovation may be more strongly influenced by governance structures and stakeholder oversight than by firm size or short-term financial performance. However, their inclusion as control variables remains important to ensure that the effects of the

FERP and BOEFF are not confounded by other firm-level characteristics. Overall, these findings underscore the importance of board composition and governance quality in driving environmental innovation and support the view that female leadership on corporate boards plays a strategic role in advancing sustainability goals.

Table 6 presents the results of a hierarchical regression analysis used to test the moderating effect of audit committee effectiveness (ACEFF) on the relationship between female board representation (FERP) and environmental innovation (ENIN). Hierarchical regression is a stepwise modeling approach in which variables are entered into the regression equation in stages to observe changes in the model's explanatory power (R-squared) and assess the incremental effect of added variables or interactions. This method is particularly useful for testing moderation because it allows the researcher to compare the baseline model with the interaction model and determine whether the interaction term contributes significantly to explaining the variance in the dependent variable. In Step 1, the baseline model includes only control variables (e.g., board effectiveness, institutional ownership, ESG Score, firm size, ROA, and ROE), establishing a reference point with an R-squared value of 0.27. In Step 2, FERP is introduced, significantly improving the model fit (R^2 increases to 0.28) and confirming the positive and significant direct effect of female board representation on environmental innovation (β = 0.1148, t = 3.26***). In Step 3, audit committee effectiveness (ACEFF) is added to the model. The coefficient is positive and statistically significant (β = 5.8891, t = 8.13***), suggesting that more effective audit committees are independently associated with greater environmental innovation. The inclusion of ACEFF improved the model's explanatory power (R^2 = 0.32, an increase of 0.04), highlighting its direct contribution. Step 4 introduces the interaction term (FERP × ACEFF, labeled "ACEFF*ACEFF" in the table), which tests the moderating effect. The interaction term is positive and marginally significant (β = 0.0523, t = 1.96), indicating that the effectiveness of the audit committee strengthens the positive relationship between female board representation and environmental innovation. When the audit committee is highly effective, the influence of female directors on environmental innovation is enhanced. The model's R-squared increases to 0.34, with an additional R^2 change of 0.02, indicating that the interaction adds meaningful explanatory power to the model.

Table 6.
The Moderating Effect Regression Results.

Variables		**Step 1**	**Step 2**	**Step 3**	**Step 4**
BOARD	Coef	5.626	5.6116	3.7192	3.572
	t-stat	11.33***	8.94***	5.79***	5.59***
INV	Coef	68.3317	66.2928	54.5387	52.953
	t-stat	18.47***	9.99***	9.38***	9.01***
ESG Score	Coef	-0.0086	-0.0098	-0.0146	-0.01290
	t-stat	-0.35	-0.32	-0.56	-0.50
FSIZE	Coef	-0.7069	-0.3551	-0.7319	-0.5347
	t-stat	-0.76	-0.29	-0.66	-0.47
ROA	Coef	0.0302	-0.5444	-1.5723	-0.9399
	t-stat	0.01	-0.10	-0.34	-0.21
ROE	Coef	-0.0414	0.0222	0.2558	0.3042
	t-stat	-0.06	0.12	1.30	1.56
FERP	Coef		0.1148	0.0806	0.0770
	t-stat		3.26***	2.53**	2.42**
ACEFF	Coef			5.8891	6.6087
	t-stat			8.13***	8.73***
ACEFF* ACEFF	Coef				0.0523
	t-stat				1.96
Number of obs.		990	990	990	990
F-test		56.17	56.17	73.31	67.28
Prob > chi2			0.0000		0.0000
R-squared		0.27	028	0.32	0.34
R2 change			0.01	0.04	0.02

Note: *** p<0.01, ** p<0.05, * p<0.1.

7. Conclusion

This study examines the relationship between female board representation and environmental innovation, with a particular focus on whether audit committee effectiveness moderates this relationship. This research was motivated by the growing global and national emphasis on sustainability, gender diversity, and corporate accountability, particularly within Malaysian industries. Despite increased attention to sustainability-related issues, prior research in the Malaysian context has largely concentrated on board gender diversity's general influence on sustainability or CSR, with a limited empirical focus on its specific effect on environmental innovation. Furthermore, the moderating role of audit committee effectiveness in this relationship has been overlooked. The analysis was based on a sample of 990 firm-year observations from 198 publicly listed Malaysian companies covering the period 2020 to 2024. The study utilized data drawn from Refinitiv's ESG database, incorporating measures for environmental innovation, board gender diversity, audit committee effectiveness, and a set of control variables, including board effectiveness, institutional ownership, ESG score, firm size, and financial

performance indicators (ROA and ROE). Panel data regression and hierarchical modeling techniques were employed to test the direct and moderating effects, respectively.

The findings reveal that female board representation has a statistically significant and positive effect on environmental innovation, affirming that gender-diverse boards are more likely to pursue sustainability-driven strategies. The results also indicate that audit committee effectiveness has a direct positive impact on environmental innovation and moderates the relationship between female board representation and environmental innovation. Specifically, the positive influence of women on boards becomes stronger in firms with highly effective audit committees. These findings are robust across multiple model specifications. Theoretically, this study contributes to both upper echelons theory and stakeholder theory by showing that demographic diversity among top executives, particularly gender diversity, influences firm-level strategic outcomes such as environmental innovation. For policymakers, the findings support gender diversity and board effectiveness regulations as mechanisms for accelerating environmental innovation. For firms, the study highlights that appointing female directors should not be viewed as a symbolic act but as a strategic decision that can be enhanced through strong governance structures such as an active and capable audit committee. Together, gender-diverse leadership and effective governance can serve as powerful levers driving Malaysia's environmental transformation and fulfilling national sustainability commitments. Despite the strengths of these findings, several limitations of this study must be acknowledged. It employs a cross-sectional panel design, which restricts its ability to draw definitive causal inferences. While significant associations are observed, the directionality and long-term evolution of the relationships among female board representation, audit committee effectiveness, and environmental innovation cannot be fully captured. Future research employing longitudinal or experimental designs could offer deeper insights into the causal pathways and the temporal dynamics involved.

References

[1] N. Soewarno, B. Tjahjadi, and F. Fithrianti, "Green innovation strategy and green innovation: The roles of green organizational identity and environmental organizational legitimacy," *Management Decision*, vol. 57, no. 11, pp. 3061-3078, 2019.

[2] B. Bigliardi, M. Yarahmadi, and P. G. Higgins, "Motivations towards environmental innovation: A conceptual framework for multiparty cooperation," *European Journal of Innovation Management*, vol. 15, no. 4, pp. 400-420, 2012. https://doi.org/10.1108/14601061211272358/FULL/XML

[3] C. E. Carrión-Flores and R. Innes, "Environmental innovation and environmental performance," *Journal of Environmental Economics and Management*, vol. 59, no. 1, pp. 27-42, 2010. https://doi.org/10.1016/J.JEEM.2009.05.003

[4] M. Kahia, B. Jarraya, B. Kahouli, and A. Omri, "The role of environmental innovation and green energy deployment in environmental protection: Evidence from Saudi Arabia," *Journal of the Knowledge Economy*, vol. 15, no. 1, pp. 337-363, 2024.

[5] S. R. Baatwah, W. M. Alahdal, A. A. A. Abdalla, and Z. Salleh, "Bridging the cultural gap: The impact of ethnic and gender homophily on environmental innovation," *Journal of Environmental Management*, vol. 391, p. 126363, 2025. https://doi.org/10.1016/J.JENVMAN.2025.126363

[6] A. A. A. Abdalla, A. Y. Alodat, Z. Salleh, and W. M. Al-Ahdal, "The effect of audit committee effectiveness, internal audit size and outsourcing on greenhouse gas emissions disclosure," *International Journal of Disclosure and Governance*, pp. 1-16, 2025. https://doi.org/10.1057/S41310-025-00297-0

[7] A. A. Adam, Z. Salleh, W. M. Alahdal, A. M. Hussien, M. Bajaher, and S. R. Baatwah, "The effect of the board of directors, audit committee, and institutional ownership on carbon disclosure quality: The moderating effect of environmental committee," *Corporate Social Responsibility and Environmental Management*, vol. 32, no. 2, pp. 2254-2270, 2025. https://doi.org/10.1002/CSR.3058

[8] Z. Sanad, R. Shiwakoti, and A. Al-Sartawi, "Gender diversity on corporate boards and earnings management: A review," presented at the The International Conference On Global Economic Revolutions (pp. 340-351). Cham: Springer International Publishing, 2021.

[9] J. Caby, C. Coron, and Y. Ziane, "The effect of top management team gender diversity on climate change management: An international study," *Sustainability*, vol. 14, no. 2, p. 1032, 2022. https://doi.org/10.3390/SU14021032

[10] J. Lu and I. M. Herremans, "Board gender diversity and environmental performance: An industries perspective," *Business Strategy and the Environment*, vol. 28, no. 7, pp. 1449-1464, 2019.

[11] A. A. A. Abdalla, Z. Salleh, H. Hashim, W. Zakaria, and M. A. Rahman, "The effect of corporate governance best practices on the quality of carbon disclosures among Malaysian public listed companies," *Journal of Sustainability Science and Management*, vol. 19, no. 2, pp. 42-71, 2024. https://doi.org/10.46754/jssm.2024.02.003

[12] N. B. J. Ahmad, A. Rashid, and J. Gow, "Corporate board gender diversity and corporate social responsibility reporting in Malaysia," *Gender, Technology and Development*, vol. 22, no. 2, pp. 87-108, 2018. https://doi.org/10.1080/09718524.2018.1496671

[13] S. Wasiuzzaman and W. M. Wan Mohammad, "Board gender diversity and transparency of environmental, social and governance disclosure: Evidence from Malaysia," *Managerial and Decision Economics*, vol. 41, no. 1, pp. 145-156, 2020. https://doi.org/10.1002/MDE.3099

[14] R. Provasi and M. Harasheh, "Gender diversity and corporate performance: Emphasis on sustainability performance," *Corporate Social Responsibility and Environmental Management*, vol. 28, no. 1, pp. 127-137, 2021. https://doi.org/10.1002/CSR.2037

[15] Y. Wang, D. S. Ones, Y. Yazar, and I. Mete, "Board gender diversity and organizational environmental performance: An international perspective," *Current Research in Ecological and Social Psychology*, vol. 5, p. 100164, 2023. https://doi.org/10.1016/J.CRESP.2023.100164

[16] A. Haddad, A. El Ammari, and A. Bouri, "Impact of audit committee quality on the financial performance of conventional and Islamic banks," *Journal of Risk and Financial Management*, vol. 14, no. 4, p. 176, 2021. https://doi.org/10.3390/JRFM14040176

[17] S. Mardessi, "Audit committee and financial reporting quality: The moderating effect of audit quality," *Journal of Financial Crime*, vol. 29, no. 1, pp. 368-388, 2022.
[18] A. Abdelrahman Adam Abdalla, Z. Salleh, H. A. Hashim, W. Z. Wan Zakaria, and W. M. Al-ahdal, "The effect of board of directors attributes, environmental committee and institutional ownership on carbon disclosure quality," *Business Strategy & Development*, vol. 7, no. 4, p. e70023, 2024. https://doi.org/10.1002/BSD2.70023
[19] I. Khatri, "Board gender diversity and sustainability performance: Nordic evidence," *Corporate Social Responsibility and Environmental Management*, vol. 30, no. 3, pp. 1495-1507, 2023.
[20] J.-W. Huang and Y.-H. Li, "How resource alignment moderates the relationship between environmental innovation strategy and green innovation performance," *Journal of Business & Industrial Marketing*, vol. 33, no. 3, pp. 316-324, 2018.
[21] B. Yalabik and R. J. Fairchild, "Customer, regulatory, and competitive pressure as drivers of environmental innovation," *International Journal of Production Economics*, vol. 131, no. 2, pp. 519-527, 2011. https://doi.org/10.1016/J.IJPE.2011.01.020
[22] Z. Liao, "Institutional pressure, knowledge acquisition and a firm's environmental innovation," *Business Strategy and the Environment*, vol. 27, no. 7, pp. 849-857, 2018. https://doi.org/10.1002/BSE.2036
[23] Y. Zhang, J. Sun, Z. Yang, and Y. Wang, "Critical success factors of green innovation: Technology, organization and environment readiness," *Journal of Cleaner Production*, vol. 264, p. 121701, 2020. https://doi.org/10.1016/J.JCLEPRO.2020.121701
[24] X. Cai, B. Zhu, H. Zhang, L. Li, and M. Xie, "Can direct environmental regulation promote green technology innovation in heavily polluting industries? Evidence from Chinese listed companies," *Science of the Total Environment*, vol. 746, p. 140810, 2020. https://doi.org/10.1016/J.SCITOTENV.2020.140810
[25] S. Reddy and A. M. Jadhav, "Gender diversity in boardrooms–A literature review," *Cogent Economics & Finance*, vol. 7, no. 1, p. 1644703, 2019.
[26] Q. Wu, F. Furuoka, and S. C. Lau, "Corporate social responsibility and board gender diversity: A meta-analysis," *Management Research Review*, vol. 45, no. 7, pp. 956-983, 2022.
[27] A. Alazzani, A. Hassanein, and Y. Aljanadi, "Impact of gender diversity on social and environmental performance: Evidence from Malaysia," *Corporate Governance: The International Journal of Business in Society*, vol. 17, no. 2, pp. 266-283, 2017. https://doi.org/10.1108/CG-12-2015-0161/FULL/XML
[28] A. Amin, R. Ur Rehman, R. Ali, and C. G. Ntim, "Does gender diversity on the board reduce agency cost? Evidence from Pakistan," *Gender in Management: An International Journal*, vol. 37, no. 2, pp. 164-181, 2022.
[29] T. T. Lemma, M. Tavakolifar, D. Mihret, and G. Samkin, "Board gender diversity and corporate carbon commitment: Does industry matter?," *Business Strategy and the Environment*, vol. 32, no. 6, pp. 3550-3568, 2023.
[30] A. Buallay and L. Alhalwachi, "Board gender diversity and environmental disclosure: Evidence from the banking sector," *Journal of Chinese Economic and Foreign Trade Studies*, vol. 15, no. 3, pp. 350-371, 2022.
[31] C. J. García Martín and B. Herrero, "Do board characteristics affect environmental performance? A study of EU firms," *Corporate Social Responsibility and Environmental Management*, vol. 27, no. 1, pp. 74-94, 2020.
[32] M. Arif, A. Sajjad, S. Farooq, M. Abrar, and A. S. Joyo, "The impact of audit committee attributes on the quality and quantity of environmental, social and governance (ESG) disclosures," *Corporate Governance: The International Journal of Business in Society*, vol. 21, no. 3, pp. 497-514, 2021.
[33] S. Cadez, A. Czerny, and P. Letmathe, "Stakeholder pressures and corporate climate change mitigation strategies," *Business Strategy and the Environment*, vol. 28, no. 1, pp. 1-14, 2019.
[34] E. Mohamed and M. Hussain, "The role of audit committees in enhancing a transparent corporate reporting," *Humanomics*, vol. 21, no. 1, pp. 30-47, 2005.
[35] D. C. Hambrick, *Upper echelons theory in the palgrave encyclopedia of strategic management*. London: Palgrave Macmillan, 2016.
[36] M. Plöckinger, E. Aschauer, M. R. Hiebl, and R. Rohatschek, "The influence of individual executives on corporate financial reporting: A review and outlook from the perspective of upper echelons theory," *Journal of Accounting Literature*, vol. 37, no. 1, pp. 55-75, 2016.
[37] T. Donaldson and L. E. Preston, "The stakeholder theory of the corporation: Concepts, evidence, and implications," *Academy of Management Review*, vol. 20, no. 1, pp. 65-91, 1995. https://doi.org/10.5465/AMR.1995.9503271992
[38] J. Heath and W. Norman, "Stakeholder theory, corporate governance and public management: What can the history of state-run enterprises teach us in the post-Enron era?," *Journal of Business Ethics*, vol. 53, no. 3, pp. 247-265, 2004.
[39] L. Hu and D. Yang, "Female board directors and corporate environmental investment: A contingent view," *Sustainability*, vol. 13, no. 4, p. 1975, 2021. https://doi.org/10.3390/SU13041975
[40] P. Wasan, S. Luthra, K. Mulchandani, and S. Vishnani, "Interplay between financial markets, environmental stewardship, gender diversity, and firm size in emission-intensive sectors of emerging asian economies: A board-level perspective," *Business Strategy and the Environment*, vol. 34, no. 2, pp. 2139-2166, 2025. https://doi.org/10.1002/BSE.4086
[41] S. De Masi, A. Słomka-Gołębiowska, and A. Paci, "Women on boards and corporate environmental performance in Italian companies: The importance of nomination background," *Business Ethics, the Environment & Responsibility*, vol. 31, no. 4, pp. 981-998, 2022.
[42] L. Ben Mahjoub, "Greenwashing practices and ESG reporting: An international review," *International Journal of Sociology and Social Policy*, vol. 45, no. 1/2, pp. 173-188, 2025.
[43] A. M. Chijoke-Mgbame, A. Boateng, and C. O. Mgbame, "Board gender diversity, audit committee and financial performance: Evidence from Nigeria," *Accounting Forum*, vol. 44, no. 3, pp. 262–286, 2020. https://doi.org/10.1080/01559982.2020.1766280
[44] L. Erasmus and P. Coetzee, "Drivers of stakeholders' view of internal audit effectiveness: Management versus audit committee," *Managerial Auditing Journal*, vol. 33, no. 1, pp. 90-114, 2018.
[45] P. Agnese, F. Battaglia, F. Busato, and S. Taddeo, "ESG controversies and governance: Evidence from the banking industry," *Finance Research Letters*, vol. 53, p. 103397, 2023. https://doi.org/10.1016/J.FRL.2022.103397

[46] M. A. Khalil, R. Khalil, and M. K. Khalil, "Environmental, social and governance (ESG)-augmented investments in innovation and firms' value: A fixed-effects panel regression of Asian economies," *China Finance Review International,* vol. 14, no. 1, pp. 76-102, 2024.

[47] S. Bear, N. Rahman, and C. Post, "The impact of board diversity and gender composition on corporate social responsibility and firm reputation," *Journal of business ethics,* vol. 97, no. 2, pp. 207-221, 2010.

[48] L. Liao, L. Luo, and Q. Tang, "Gender diversity, board independence, environmental committee and greenhouse gas disclosure," *British Accounting Review,* vol. 47, no. 4, pp. 409-424, 2015. https://doi.org/10.1016/J.BAR.2014.01.002