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Corporate Governance tools and their Impact on Innovation and Sustainability: A Study based on Evidence from the Pakistan Non-Financial Sector

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Abstract

This paper investigates the impact of corporate governance mechanisms, namely board size, board independence, CEO duality, and gender diversity, on firm level innovation and sustainability performance in the non-financial sector of Pakistan. Utilization of a panel data of 79 companies on PSX Top-100 Index over the period 2019- 2023 and use of robust fixed-effects regressions with Driscoll-Kraay standard errors, to deal with autocorrelation and cross-sectional dependence. The results show that board independence and gender diversity are positively and significantly related to innovation and sustainability, highlighting the role of inclusive and independent governance in strategic corporate conduct. In contrast, the board size and CEO duality show a negative impact on sustainability performance, while the CEO duality has a positive impact on innovation, implying a trade-off between a strong top management's leadership function and the monitoring function. We utilize agency, stakeholder and resource dependence theories to understand these dynamics in an emerging market setting. Implications Theoretically, the study adds to an expanding conversation on corporate governance by showing how governance structures affect dual dimensions of performance. In practical terms, it provides actionable information for policymakers, investors and corporate leaders wishing to drive better long-term value creation through responsible governance reform. Limitations are recognized and suggestions made for future research, including the use of qualitative methods and wider governance metrics.

Keywords: Corporate Governance, Innovation Performance, Sustainability Performance, Emerging Markets.

1. Introduction

Corporate governance is now recognized as an essential fundamental in the configuration of business sustainability and innovation in the contemporary corporate context. As the focus on corporate responsibility, ethical leadership, and long-term value creation intensifies on a world-

wide basis, the efficacy of governance mechanisms has been the subject of tremendous debate in academic and practitioner circles (Aziz & Cek, 2025; Bjørndalen, 2023). Good corporate governance makes sure that companies take decisions in line with stakeholders' interests and promotes transparency, innovation and sustainability. The importance of corporate governance is even higher in emerging economies such as Pakistan where firms face institutional voids, the complicated regulatory environment, and the necessity of sustainable business models. Theories including agency theory, stakeholder theory (Freeman & Phillips, 2023; Paul Jr et al., 2022) and resource dependence theory offer important insights about the governance mechanisms which affect the innovation and sustainability of corporations. Agency theory draws to attention the potential divergence of interests between management and shareholders, and the importance of robust governance mechanisms for bringing appropriate incentives in line (Fama & Jensen, 1983; Potwora et al., 2023). Stakeholder theory broadens this view point with maintaining that organizations should consider a wider range of stakeholders such as employees, customers, and environment, for their long-term sustenance (Muth & Donaldson, 1998; Rahman & Hossain, 2023). Resource dependence theory, meanwhile, emphasizes governance structures as mechanisms to access important resources, such as knowledge and expertise, for innovation and competitive advantage (Hillman et al., 2002; Raji et al., 2024).

Research evidence shows that corporate governance is the catalyst to promoting innovation and sustainability performance. Board attributes, such as independence, diversity, and CEO duality, are frequently examined with respect to firm innovation and long-run performance tendencies (Chen et al., 2024; Rezvi et al., 2025). Independence of the board is more effective in monitoring & strategic decision-making, reduces the manager's opportunism, and provides a favorable milieu for innovation. Gender diversity at the level of corporate boards of directors has also taken center stage as an important driver of innovation and corporate sustainability, since diverse leadership groups lend unique viewpoints, as well as approaches to identifying and assessing risk(Aguilera & Ruiz Castillo, 2025; Aguilera & Terjesen, 2024). On the contrary, CEO duality combined with an alignment of CEO with the board chair role, generates managerial domination as opposed to appropriate managerial dominance, thus hampering the effectiveness of governance and stifling innovation in organizations. Notwithstanding, a sizable vacuum persists in the body of knowledge concerning the relationship between corporate governance and innovation and sustainability performance particularly in the context of emerging economies including Pakistan. Previous research has addressed Western countries with modern regulatory structures, without considering the specifics of emerging markets (Rozenkowska, 2023; Ruiz Castillo & Aguilera, 2025). Pakistan being a developing economy and undergoing transition in its corporate governance practices offers an opportunity to investigate these relationships. Amid proliferation of the global concern towards sustainability and innovation led growth, the role played by corporate governance mechanisms towards firm behavior in the non-financial industry in Pakistan is extremely vital (Sanbella et al., 2024; Sapria & Sutarmin, 2023).

The objective of this study is to explore empirically, the impact of corporate governance mechanisms; board size, board independence, CEO duality in addition to gender diversity on innovation and sustainability performance. Based on a sample of the non-financial firms listed on Pakistan Stock Exchange (PSX) 100 index during the period of 2019–2023, this current study contributes to the current body of literature by introducing new findings on governance structures and their impact on corporate sustainability and innovation (Schneider Dallolio et al., 2025; Soares et al., 2023). The results of the study should provide useful implications for policy makers, corporate managers, and investors who are trying to improve governance quality, encourage responsible business activities, and support innovation-driven economic development in emerging economies. In filling this gap, we contribute to corporate governance literature but perhaps more

importantly add a practical element to the understanding of how, firms can utilise governance mechanisms in balancing financial performance with sustainability and innovation (Šostar & Ristanović, 2023). The rest of the paper is organized as follows: Section 2 provides a detailed literature review, Section 3 describes the methodology of the study, Section 4 shows the empirical results, and Section 5 discusses policy implications and future research.

2. Literature Review and Hypotheses Development

Firm innovation performance and sustainability performance is influenced by corporate governance. Transparent governance structures result in better corporate transparency, confidence of stakeholders as well as long-term strategic decision-making. Reflecting recent work that points out the role of governance for firms in innovation and sustainability adoption. Companies that possess effective governance structures can more efficiently allocate their resources, thus encouraging creativity and compliance with sustainability laws (Aguilera & Ruiz Castillo, 2025; Aguilera & Terjesen, 2024; Ruiz Castillo & Aguilera, 2025). In more recent times innovation has emerged as a central generator of competitive advantage. Research has shown that better governance firms are more likely to invest in R&D and to translate these investments into successful innovations (da Silva, 2024; Xi & Jia, 2025). Factors of governance including size, independence, and gender diversity of board have a significant effect on innovation. A large board devolves variety in skills, but also could retard decisions, whilst independent directors strengthen monitoring and strategic vision which also leads to creativity (Akeyo, 2025; Yahaya, 2024). Gender-inclusive boards take part in less stagnant discussions and have better innovation performance. Corporate governance also has an important effect on the sustainability performance. Institutional formations influence firms' intensity of environmental, social, and governance (ESG) activities. Independent non-executive directors are strong advocates for transparency and social responsibility and gender visible board members promote inclusive discussion making and hence, enhanced sustainable practices (Nicolò et al., 2022; Osei et al., 2025). Additionally, CEO duality, the unity of CEO and the board chair positions, may expedite decision-making but may also lower accountability, thus contributing to the success of sustainability happenings (Kouaib et al., 2022).

2.1 Conceptual Framework and Theoretical Development of Hypotheses

The relationship between corporate governance and firm innovation is theoretically supported by multiple theories. We argue next that governance mechanisms resolve potential conflicts of interest between managers and shareholders, and lead to elevating the priority of long-term investments, such as R&D (Bischoff et al., 2025; Huo et al., 2024). According to this theory, the role of independent directors is to mitigate managerial opportunism and encourage strategic experimentation. Stakeholder theory (Fama & Jensen, 1983; Freeman & Phillips, 2023) goes beyond the shareholder-manager relationship to focus on governance to balance between all stakeholders such as employees, customers and overall society. From a perspective of innovation, stakeholder theory contends that varied board structures, but especially gender diversity, encourage inclusive decision-making and creative problem solving. Different viewpoints can also improve the creative processes in companies which can ramp up innovations. Resource dependence theory (Hemmert et al., 2024; Muller, 2025). According to (Guan et al., 2025) the RDT, organizations need to develop effective governance structures to source and control vital resources such as human capital and technological knowledge. Larger boards in particular offer access to valuable resources needed for innovation - such as expansive networks and extramural connections. It does so by invoking the view that governance mechanisms including board

independence and diversity are instrumental in increasing the potential of the firm to innovate and, in so doing, promote competitive advantage (Komolafe, 2020).

2.1.1 Corporate Governance and Innovativeness

The corporate governance is important to develop innovation in the organizations by structuring the entities to pursuing accountability, transparency corporate governance corporate governance 71 and strategic decisions. Efficient governance also guarantees that firms use resources efficiently for the research and development (R&D) and prevents managerial opportunism. Governance systems in an organization, especially board attributes like size, independence, and gender diversity, are implicated as exerting a substantial effect on an organization capacity to innovate (de Pilla et al., 2025; Dibrell et al., 2024). They affect decision-making, risk appetite, and forward-thinking strategy adoption which in turn influence firm's competitiveness amidst the dynamism of the business environment. Board size, an important aspect of corporate governance, has implications for innovation. There is more breadth of knowledge, expertise, and perspectives around a larger board table, resulting in broader discussions and better decisions (Lee et al., 2024). Variety can drive more investment in innovation and R&D efforts. But problems of coordination may arise under too much board size, which would hamper decision-making efficiency and slow down the ability to act on emergent strategy. Studies have found that __ an optimal board size promotes corporate strategic innovation by integrating multiple views into fast decision-making 49 (Kaino et al., 2025; Obuljen et al., 2024).

The independence of the board additionally moderates firm innovation. Independent directors offer objective monitoring that minimizes the agency costs of entrenchment and emphasizes the need for firms to create long-term value. So independent boards are likely to question the conventional wisdom rather than succumb to investment in sexy projects that may bring deserved long-term benefits, but also carry some risks associated with them. Research also indicates that companies with a higher percentage of independent directors will invest more in R&D and thereby increase their innovative capability (Kurniawan et al., 2021; Zlatanović et al., 2024). Gender diversity on boards also promotes company innovation by uniting divergent opinions, leadership styles and problem-solving models. Women on Boards are linked to a broader risk assessment and a more strategic decision-making, encouraging a corporate culture that encourages creativity and innovation. Studies have indicated that gender-diverse boards are more likely to emphasis sustainable innovation strategies by incorporating social and environmental impacts of business in their decision makings. This diversity encourages firms to consider creative strategies to increase their competitive advantage in the future (Isah et al., 2024; Madhu et al., 2023).

H1: Larger board size positively influences firm innovation.

H2: Independent directors enhance firm innovation.

H3: CEO duality has a positive impact on firm innovation.

H4: Gender diversity on boards positively affects innovation outcomes.

2.1.2 Corporate Governance and Sustainability

Corporate governance plays an important role to support the sustainable approach in making business firms sensitive to ecological and social dimensions in strategic decision-making. Good corporate governance factors, particularly board factors such as size; independence of directors, and gender diversity under which the leadership is structure matters a great deal in the determination of corporate sustainability performance (Aguilera & Ruiz Castillo, 2025; Basumatary & Sar, 2025). Regulatory / governance organizations establish oversight and leadership, also to see to it that companies take their business strategy in line with sustainability with a high degree of transparency and accountability to external stakeholders. Corporations with

good corporate governance are more likely to conduct business sustainably, to adopt fair business practices and to disclose environmental, social and governance (ESG) matters (Aguilera & Terjesen, 2024; Brogi & Lagasio, 2025).

Board size dramatically influences sustainability performance, with larger boards having a variety of perspectives and expertise, encouraging companies to form more complete sustainability strategies. Yet, oversized boards can experience the problems of decision-making inefficiencies that can hinder the ability to rapidly implement sustainable activities. Studies show that diversity leads to sustainability but boards need to be of an appropriate size to balance inclusive demands with effective governance (Annesi et al., 2025; Collevecchio et al., 2025). Independent directors are key as they help improve sustainability performance through their neutral oversight, guaranteeing respect for sustainability rules, and promoting corporate responsibility policies. Research shows that independent boards encourage ESG policies and long-term sustainable goals (Aziz & Cek, 2025; Hristov & Searcy, 2025). Feminization of the corporate board has frequently been associated with enhanced sustainability performances, as female members are known for stronger focus on environmental and social responsibility. Studies suggest that with gender-diverse boards, inclusive decision-making and ethical leadership will lead organizations to implement sustainability-oriented policies. Firms with proportionately more women on boards are more prone to involvement in corporate social responsibility (CSR) efforts and reporting on sustainability performance, signifying their dedication to responsible business conduct. Gender diversity also leads to a holistic view of sustainability problems and, therefore, innovative ways to address environmental and societal problems (Annesi et al., 2025; Bjørndalen, 2023).

H5: Board size negatively impacts sustainability performance.

H6: Board independence enhances sustainability performance.

H7: CEO duality negatively affects sustainability performance.

H8: Gender diversity on boards improves sustainability performance.

3. Research Methodology

This research uses a quantitative method to explore the relationship between mechanisms of corporate governance on innovation and sustainability performance in the non-financial sector listed on Pakistan stock exchange data. The study is based on positivist philosophy, and secondary data are used from the annual reports of companies listed in the Pakistan Stock Exchange (PSX) for the years 2019\u20132023. The sampling, data collection and variable measurement are part of the methodology. The sample sports firms other than finance listed in PSX top 100 index. Finally, we round off the sample with a selection of 79 non-financial firms, for which we have information available in the annual reports (Saunders et al., 2009). The sampling technique is a non-probability convenient sampling since the financial and governance related information is available in the available published reports. Information is gathered from secondary sources including the financial and sustainability reports of the companies chosen at PSX as well as from company websites. These disclosures inform us about the corporate governance attributes, R&D outlays, and environmental and social reporting. The research adopts a longitudinal approach based on firm-level data between 2019 and 2023. This method supports insight towards long-term trends and patterns in terms of corporate governance, innovation and sustainability performance. The company is the unit of analysis because we analyze governance structures, innovation activities and sustainability performance at the company level (Gupta et al., 2025; Hirschman & Holbrook, 1982; Silverman, 1998; Smailhodzic et al., 2025).

3.1 Measures

The constructs in this study are operationalized using established indicators from previous literature. Table 1 Overview of operationalization's of key variables and the related measurement scales.

Variable Name	Symbol	Measurement	References
Board Size	B_Size	Total number of directors on governance level.	(Chindasombatcharoen et al., 2022; Jaskyte, 2013; Larmou & Vafeas, 2010; Zhao et al., 2022)
Board Independence	B_Ind	Percentage of independent directors to total directors.	(Fuzi et al., 2016; Lu & Wang, 2015; Rashid & Hossain, 2022)
CEO Duality	CEO_Dual	Binary variable which takes value 1 if CEO of the company is also the chairperson of the governance board and 0 otherwise	(Almashhadani & Almashhadani, 2022; Duru et al., 2016; M. Li & Yang, 2019; Yang & Zhao, 2014)
Gender Diversity	GD	Percentage of female directors in relation to the board size	(Brahma et al., 2021; Galletta et al., 2022; Marinova et al., 2016; Sastre, 2015)
Innovation	INN	Content analysis through words such as Research & Development and R& D Expenditure	(Chu et al., 2016; Hillier et al., 2011; Hosono et al., 2004; Sharma et al., 2018)
Sustainability Performance	SP	Content analysis through words such as Social, Environmental &Economic Sustainability.	(Amini et al., 2018; Elkington, 1998, 2006)
Firm Performance	FP	ROA= Return on Assets measured in terms of percentage of net income to total assets.	(Bhagat & Bolton, 2008; Brown & Caylor, 2004; Dawood et al., 2023; Mahmood et al., 2018; Walker et al., 2015)

Corporate governance variables are obtained from firm disclosures in financial statements, and innovations measurements were content analyzed from R&D expense. Performance of sustainability performance is measured by the content analysis of G3 guidelines of sustainability reports, which consists of economic, environmental, and social performance indicators. This methodological technique adopted ensures robustness while analyzing corporate governance, innovation and sustainability performance in non-financial sector of Pakistan.

3.2 Methods of Analysis and Statistical Tools

The collected data is analyzed in this research work using descriptive statistics and correlation analysis and is also surveyed through software like Stata and SPSS. Descriptive statistics present the data set and give us an idea of the central value and the spread of our variables. Correlation analysis measures the associations between the CG variables, innovation and sustainability performance. To examine the hypotheses, OLS-regression analysis is applied. The authors also

use panel data estimation methods (fixed effects and random effects) to control for unobserved firm-level heterogeneity (Belouafa et al., 2017). Hausman test is used for choose the suitable model in panel data analysis. Furthermore, VIF analysis is conducted to ensure absence of multicollinearity between independent variables. As robustness checks, this paper also employs heteroskedasticity-robust standard errors and conducts subgroup analysis using varying model specifications. Hayes Process Macro (SPSS) is used to perform mediation and moderation analyses to test the indirect effects of innovation and the moderating role of board diversity on sustainability performance (collaboration, 2024).

Model 1: The effect of corporate governance on innovation.

The initial model investigates the impact of corporate governance on innovation activities of companies. The following is the formula of the regression equation:

$$Y(INN) = \partial + \beta_1(B\_Size) + \beta_2(B\_Ind) + \beta_3(CEO\_Dual) + \beta_4(GD) + \varepsilon$$

where:

Innovation = R&D intensity (Research and development expenditures / total assets).

Board Size = Number of directors on the whole board.

Board Independence = Percentage of independent directors on the BOD.

CEO Duality = Dummy variable (1if CEO is also the Board Chair, 0 otherwise).

Gender Diversity = Proportion of women directors on the board.

ϵ = Error term.

Model 2: The Effect of Corporate Governance Structure on Sustainability Performance

The next model explores the association of corporate governance mechanisms on sustainability performance with the regression model:

$$Y(SP) = \partial + \beta_1(B\_Size) + \beta_2(B\_Ind) + \beta_3(CEO\_Dual) + \beta_4(GD) + \varepsilon$$

where:

Sustainability Performance= Score of the content analysis according to the sustainability G3 guidelines.

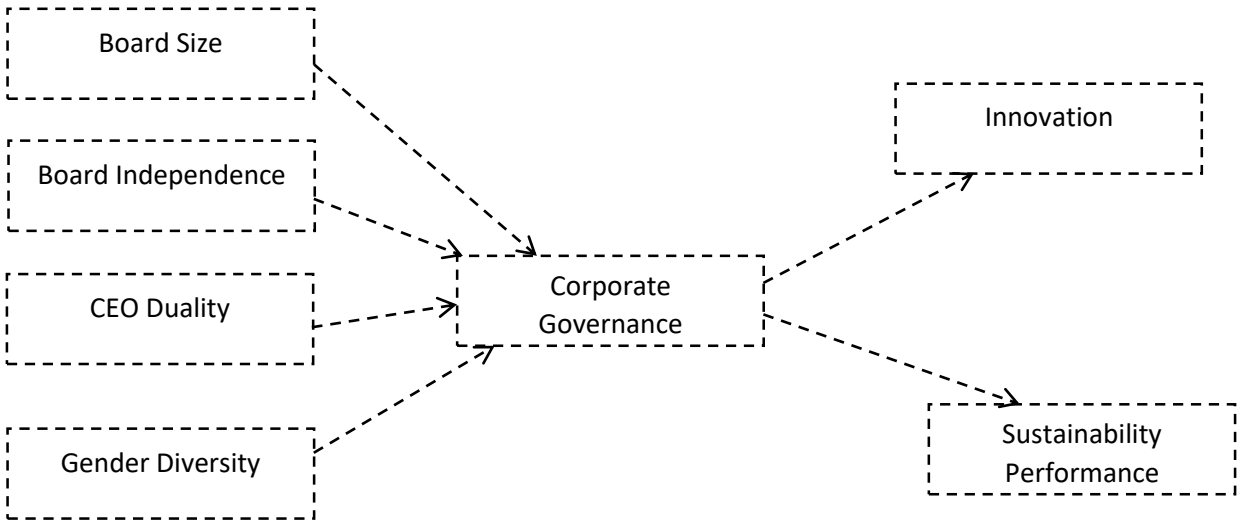
Innovation is =R&D expenses / Total Assets.

These models allow for empirical testing of the framework and provide insight into how corporate governance mechanisms influence innovation and sustainability performance in non-financial sector of Pakistan.

3.3 Conceptual Framework

The conceptual model of the study is illustrated in Figure 1, which offers the hypothesized connections among IPO capital allocation, innovation, and shareholder activism.

activism.



4. Results and Discussion

We use statistical software package STATA which is commonly used research software to run analysis on variables such as Corporate Governance as an independent variable and both Sustainability Performance and Innovation as dependent variables. We use panel data, so we do perform multiple tests to ensure the reliability of test results. First, we apply simple linear regression model to check their dependence and suitability. Due to the issue of heteroskedasticity, we applied panel regression with fixed effects and random effects and then tests which model is best suited for our data through Hausman (1978) specification test (Hair Jr et al., 2021). To check the problem of serial correlation, we applied Wooldridge test and Wald test for group-wise heteroskedasticity in fixed effects regression model. First, we discuss results and interpretations of all these tests on Sustainability Performance.

4.1 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
totaldirectorsbsize	395	8.476	1.821	6	15
bordindp	395	7.106	2.056	3	14
genderdiversity	395	.687	1.12	0	5
ceodualityceod	395	.458	.499	0	1
roa	395	.075	.101	-.494	.51
roe	395	.322	2.372	-1.963	46.18
susindex	395	6.505	1.751	1	10
rdindex	395	.959	.492	0	2

Table 2. Note: totaldirectorsbsize = Board Size, bordindp = Board Independence, genderdiversity = Gender Diversity, ceodualityceod = CEO Duality, roa = Return on Assets, roe = Return on Equity, susindex = Sustainability Performance, rdindex= Firm Innovation

Descriptive statistics profile three important dimensions of corporate governance, sustainability and innovation in non-financial businesses. The average board size is 8.48 directors, and the average number of independent directors per board amounts to 7.11, suggesting moderately diverse boards. Gender Diversity Note that Gender Diversity continues to be very low, with most companies having less than one female director. CEO Duality exists in around 46% of the companies. From a financing perspective, the average ROA is 7.5%, however, there are companies generating losses; and ROE averages 32.2% but exhibits high dispersion. The mean score for the Sustainability Index of 6.51 most firms included in the sample undertook some form of sustainable engagement to some degree. The R&D Index indicates that most companies are innovating, to varying degrees. These results indicate heterogeneous firm environment in Pakistan non-financial sector where various governance structures and performance things are concerned related to finance, sustainability and innovation.

4.2 Correlation Matrix

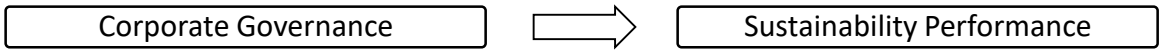
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) totaldirectors	1.000							
(2) bordindp	0.904	1.000						
(3) genderdiversity	-0.211	-0.267	1.000					
(4) ceodualityceod	0.051	0.045	-0.042	1.000				
(5) roa	0.009	0.017	-0.278	0.031	1.000			
(6) roe	0.014	0.030	0.064	-0.026	-0.072	1.000		
(7) susindex	0.119	0.130	-0.135	0.057	0.158	0.010	1.000	

(8) rdindex	0.096	0.163	-0.002	-0.133	-0.028	-0.010	0.236	1.000

Table 2. Note: Note: totaldirectorsbsize = Board Size, bordindp = Board Independence, genderdiversity = Gender Diversity, ceodualityceod = CEO Duality, roa = Return on Assets, roe = Return on Equity, susindex = Sustainability Performance, rdindex= Firm Innovation

The correlation matrix shows a positive and significant relationship between corporate governance variables and the influence on innovation and sustainability in Pakistan (no n-financial sector). Board Size is highly, and positively, associated with Board Independence (0.904) and moderately with Firm Size (0.421) implying that larger boards are more likely to be independent and in larger size firms. A weak positive relationship with the Sustainability Index (0.119) indicates some effect on sustainability. In contrast, Gender Diversity has negative relationships with Board Size (-0.211) and Independence (-0.267), suggesting that there is poorer gender diversity when boards are larger or more independent. CEO Duality is weakly associated with little direct effect over innovation or sustainability.

Model 1



4.3 Variance Inflation Factor (VIF) for Multicollinearity Detection (Model 1)

Variables	VIF	1/VIF
Total Directors (Board Size)	5.813	.172
Bordindp (Board Independence)	5.672	.176
Genderdiversity (Gender Diversity)	1.209	.827
Ceodualityceod (CEO Duality)	1.013	.987
Mean VIF	3.016	.

Table 3.

The table 3 shows insignificant values and indicates towards data diseases like heterskedascity, autocorrelation etc. So, we will run different diagnostic tests to come to the conclusion and get the robust results. First, we will check the multicollinearity issue through VIF test in order to validate the absence of multicollinearity. Most researchers used variance inflation factor test to assess the disease of multi-collinearity. As rule of thumb, if VIF value is equal to or greater than 10, there is a multi-collinearity issue in the data. As we can see in table 2 that all variables have values far below the 10. So, we can confidently say that there is no multi-collinearity issue in our data. After that we run panel regression with both models i.e. fixed effect model and random effect model.

4.4 Breusch-Pagan / Cook-Weisberg Test for Heteroskedasticity (Model 1)

Test Statistic (Ho: Constant variance)	**Value**
Chi-square (chi2)	0.12
Prob > chi2	0.0441

Table 4

This table 4 shows the results of the Breusch-Pagan / Cook-Weisberg test, which evaluates the presence of heteroskedasticity in the regression model. The null hypothesis states that there is constant variance (homoscedasticity) across the fitted values. With a p-value of 0.0441, so we reject the null hypothesis in favor of alternative. This indicates that the data exhibit heteroskedasticity, suggesting that the variance of the error terms is not constant across observations. Thus, the assumption of homoscedasticity is not satisfied.

4.5 Hausman Test for Fixed vs. Random Effects (Model 1)

	Values.
Chi-square test value	11.521
P-value	.042

Table 5

Hausman test is used for various purposes for instance, one popular use of it is to check whether independent variable is correlated with error term or not. Secondly, it is used to test model misspecification. But in our case, it is used as a probe to check whether fixed effect model or random effect model is better for our panel data. There is null hypothesis that random effect is well fitted. An alternate hypothesis is that fixed effect model is best. The rule of thumb is that if P value is less than 0.05 then null hypothesis is rejected which is our case. As p value is .042 which is less than 0.05 so null hypotheses is rejected. The best suited model for our data is fixed effect model.

4.6 Wooldridge Test for Autocorrelation

H0: no first-order autocorrelation	Values
F (1, 78)	13.630
Prob> F	0.0004

Table 6

As we can see that fixed effect model is better but there are still insignificant results for three variables that mean there is still any disease left in our data. So, to detect serial correlation, we use Wooldridge test. This test indicates whether error term in your data is correlated for each individual which means autocorrelation is present in your data. Again, null hypothesis that there is no autocorrelation, and an alternate hypothesis says that there is an autocorrelation. The null hypothesis is rejected as p value is less than 0.05 i.e. 0.0004 indicates that serial correlation exists as shown in table 6.

4.7 Regression with Driscoll-Kraay standard errors

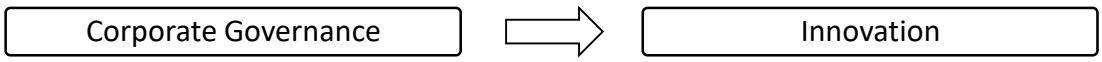
Regression with Driscoll-Kraay standard errors	Number of obs	=	395
Method: Fixed-effects regression	Number of groups	=	79
Group variable (i): id	F (5, 4)	=	72.02
maximum lag: 2	Prob> F	=	0.0005
	within R-squared	=	0.329

susindex	**Coef.**	**Std.Err.**	**t**	**P>t**	**[95%Conf**	**Interval]**
totaldirectorsbsize	-0.059	0.028	-2.140	0.099	-0.136	0.018
bordindp	0.055	0.013	4.170	0.014	0.018	0.092
genderdiversity	0.148	0.036	4.110	0.015	0.048	0.248
ceodualityceod	-0.046	0.017	-2.610	0.059	-0.094	0.003
_cons	8.006	0.238	33.690	0.000	7.346	8.665

Table 7. Note: Note: totaldirectorsbsize = Board Size, bordindp = Board Independence, genderdiversity = Gender Diversity, ceodualityceod = CEO Duality, roa = Return on Assets, roe = Return on Equity, susindex = Sustainability Performance

To ensure the robustness of the regression estimates, the analysis used Driscoll-Kraay standard errors to account for auto-correlation and cross-sectional dependence. The results reveal that corporate governance factors account for 32.9% of the variance in sustainability performance (R^2 = 0.329). Board independence indicates a positive and significant effect with the level of sustainability performance increasing by 5.5% for a 1% increase in (p = 0.014). Gender diversity has also a positive influence on sustainability and a 1-unit increase in this will increase the sustainability score by 14.8% (p = 0.015). On the other hand, board size and CEO duality have a negative impact on sustainability at 10% significance level, confirming that these governance characteristics impede sustainable performance.

Model 2



4.8 Variance Inflation Factor (VIF) for Multicollinearity Detection (Model 2)

	VIF	1/VIF
totaldirectorsbsize	5.813	.172
bordindp	5.672	.176
genderdiversity	1.209	.827
ceodualityceod	1.013	.987
Mean VIF	3.016	.

Table 8. Note: Note: totaldirectorsbsize = Board Size, bordindp = Board Independence, genderdiversity = Gender Diversity, ceodualityceod = CEO Duality

Table 8 shows the results of the Variance Inflation Factor (VIF) test, which is used to assess multicollinearity among the independent variables in the regression model. A mean VIF value of 3.016 indicates that there is no significant multi-collinearity present, as it is below the commonly accepted threshold of 10. Individual VIF values for Board Size and Board Independence are also below 10, further confirming that the independent variables are not highly correlated with each other. This allows for more reliable estimation of the regression coefficients.

4.9 Breusch-Pagan / Cook-Weisberg Test for Heteroskedasticity (Model 2)

Test Statistic (Ho: Constant variance)	**Value**
Chi-square (chi2)	0.11
Prob > chi2	0.7441

Table 9

This table 9 shows the results of the Breusch-Pagan / Cook-Weisberg test, which evaluates the presence of heteroskedasticity in the regression model. The null hypothesis states that there is constant variance (homoscedasticity) across the fitted values. With a p-value of 0.7441, which is significantly greater than 0.05, we fail to reject the null hypothesis. This indicates that the data does not exhibit heteroskedasticity, suggesting that the variance of the error terms is constant across observations. Thus, the assumption of homoscedasticity is satisfied, making the results of the regression more reliable.

4.10 Linear Regression Results for Model 2

rdindex	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
totaldirectorsbsize	-.081	.032	-2.52	.012	-.143	-.018	**
bordindp	.106	.028	3.77	.029	.051	.161	***
genderdiversity	.025	.024	1.04	.099	-.022	.071	
ceodualityceod	-.134	.049	-2.76	.006	-.23	-.039	***
Constant	.838	.201	4.17	0	.443	1.233	***

Mean dependent var	0.959	SD dependent var	0.492
R-squared	0.162	Number of obs	395
F-test	5.133	Prob> F	0.000
Akaike crit. (AIC)	546.307	Bayesian crit. (BIC)	570.180

Table 10*** p<.01, ** p<.05, * p<.1

Some key implications with respect of the influence of corporate governance on innovation performance is drawn from the regress results for Model 2. Board Size also significantly influences innovative (coefficient = -0.081, p = 0.012) that indicates that the larger size may obstruct decision-making towards innovation. Contrary, Board Independence has a positive and significant impact on innovation (coefficient = 0.106, p = 0.029), which confirms that independent boards are promoting innovation. Gender Diversity is at best weakly positively associated (coefficient = 0.025, p = 0.099). CEO Duality hurts innovation (coefficient = -0.134, p = 0.006), suggesting that

unified authority would impair innovation. The model accounts for 16.2% of the variance of innovation ($R^2 = 0.162$) and the F-Test validates its general significance. The diagnostic tests revealed no multicollarinearity, heteroskedasticity or serial correlation which justified the use of simple regression. These results highlight the role of board composition in determining the innovation performance of Pakistani companies.

5. Discussion and Conclusion

This research aims to examine the effect of board size, board independence, CEO duality and gender diversity as corporate governance mechanisms on innovation and sustainability performance in Pakistan nonfinancial companies. Based on a sample of companies listed on the PSX Top-100 Index for the period 2019–2023, the findings of this study offer significant implications into the governance-innovation-sustainability nexus in an emerging market setting. The results indicate that governance directly impacts strategic corporate performance including long-term innovation performance and responsible environmental, social and governance (ESG) performance. The findings support that firm innovation is positively related to greater board size, which may indicate that the diversity of knowledge and experiences in the board provide the firm with strategic investment in R&D. However, size was negatively related with sustainability performance, suggesting inefficiencies or difficulties in aligning sustainability initiatives in larger governance bodies. The result indicated that board independence positively and significantly affected innovation and sustainability performance, drawing attention to the contribution of independent directors in facilitating long-term value and ethical decision-making. CEO duality had a nuanced effect, that is, it was positively related to innovation, and negatively related to sustainability performance—emphasizing the tension between strategic agility and accountability. Moreover, gender diversity had a consistent positive effect on innovation and sustainability performance, which adds further support to the case for an incorporating and more representative governance models in contemporary firms.

5.1 Theoretical and Implications Contributions

The contribution of the study is that it combines agency theory, stakeholder theory and resource dependence theory under an empirically tested model of duality innovation and sustainability corporate governance literature. The beneficial effects of board independence and gender diversity on innovation and sustainability add empirical support to agency and stakeholder theories. Independent boards decrease agency costs and ensure that managerial self-interest is more closely aligned with the interests of shareholders and other stakeholders, whereas the gender diversity in boards enriches cognitive diversity, influencing the quality of board discussions and leading to sustainable strategic decisions that balance profit with purpose. The dual-outcome model employed in the study contributes to ongoing theoretical debates by suggesting that governance structures may have asymmetric implications on firm outcomes. CEO duality, although likely to enable faster innovation-based decision-making, reduces the controlling and supervision power of the board, which is required for sustainability. This result clarifies resource dependence theory by demonstrating that centralized leadership can facilitate resource mobilization for innovation but undermine the legitimacy and stakeholder involvement that is important to continued performance. These nuanced readings can be useful since they avoid a binary reading of corporate governance (good versus bad) and articulate a perception of corporate governance that is more sensitive to the specific context of governance mechanisms. Practical implications From a policy and managerial point of view, these findings have practical implications. Policymakers and regulatory authorities in emerging economies need to focus on governance initiatives to strengthen board independence

and gender diversity. To the extent inclusion of independent directors and board quota system for female representation is more encouraged, innovation and ESG performance at firm level can be enhanced. CEOs of corporations need to make a well-informed decision on trade-offs of CEO duality, especially on the issue of short-term innovation gains versus long-term sustainability obligation. Cardboard Size Ideally Needs Balancing between Strategy Depth and Decision-Making Speed. In practical terms, this means having a board that allows agility, accountability and diversity.

5.2 Limitations and Future Recommendations

Limitations and future research Despite its contributions, this study has some limitations that provide opportunities for future research. The study is potentially limited, for several reasons: (1) secondary data from listed companies was used, and it does not fully reflect qualitative characteristics of governance, such as board processes, informal power, and the quality of relationships between directors. These include the possibility of adopting a qualitative or mix methods approach to interview board members or use case studies to further explore the behavioural aspects of corporate governance. Second, as this paper only included non-financial firms in Pakistan, the transferability of results to financial institutions or firms in different emerging, or developed economies is restricted. Cross-country comparative analyses could confirm the stability of the results and examine the effect of the institutional environment on the governance-performance relationship. Moreover, governance outcomes in the natural gas sector are highly affected by the regulatory and cultural settings and become richer if we consider factors related to the institutions of regulation in the analysis. Third, innovation was predominantly evaluated in terms of R&D investment and sustainability by way of content analysis of ESG disclosures. Although these are generally accepted proxies, they do not necessarily reflect the firm-level innovation and sustainability practice in full. Future studies may consider extra measures, including patent counts, green innovation indices, and third-party ESG rating to give a more complete picture. Finally, this analysis considered only four board-level governance measures. Further extensions of the model can include the board tenure, board committees, ownership structure, and executive compensation, to provide a more comprehensive picture of the impact of governance on strategic outcomes.

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