Impact of Green Innovation, Institutional Quality, Natural Resources and GDP on Sustainable Development in Pakistan

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Abstract

This research analyzes how green innovation (GI), institutional governance, natural resource stewardship, and economic growth collectively influence sustainable development (SD) globally. It investigates how governance structures mediate the link between innovation and environmental outcomes in both advanced and emerging economies. The study assesses how variations in resource endowment and growth patterns affect green technology effectiveness. It quantifies GI's direct impact on SD, evaluates institutional capacities for ecological preservation, identifies region-specific technology adoption differences tied to resource reliance, and proposes strategies aligning innovation with governance improvements. Integrating Schumpeterian innovation theory, institutional economics, and resource-based views, the research offers a unified framework, overcoming prior separations between environmental innovation and broader economic/governance contexts. Findings suggest adaptable policies to harmonize growth with ecological resilience, especially in developing economies, advancing global efforts to decouple prosperity from environmental harm. It provides stakeholders evidence-based approaches to balance competitiveness with planetary health, supporting UN goals for equitable, innovation-driven sustainability.

Keywords: Green Innovation, Institutional Quality, GDP Pakistan, Natural Resources, Sustainable Development.

Introduction

The concept of sustainable development refers to the ability to fulfil current needs without compromising the needs of the future generations (Todaro & Smith, 2006). However, such economic development over the long term will require considerable innovation across manufacturing, distribution, and consumption practices. As a result, innovation has become a part of national agendas of every nation and almost all countries have started to implement action plans to support innovation (Arici & Uysal, 2021). Most of the research so far conducted on innovation are rooted in Schumpeter's (1942) *Theory of innovation.* This theory defines innovation as a "process of industrial mutation, that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one" (Śledzik, 2013). This can be described as a mechanism that leads to the introduction of new processes and technologies to mitigate environmental hazards like pollution and the adverse effects on natural resources

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(Castellacci & Lie, 2017). Types of innovations are product, service and process innovations**.** The innovation process enhances cost efficiency and flexibility of organization (Albort-Morant et al., 2016), both of which mitigate environmental risks and augment resource efficiency (Bhutta et al., (2022)., create new opportunities for environmentally friendly practices (Ahmed et al., 2022, reduce pollution rates (Andersen et al.,2018; Dangelico & Pujari, 2010), increase recycling (Fernando, et al., 2019); save energy , achieve competitive advantages (Galindo-Martín, et al., 2020), support strategic goals, enhance organizational performance (Groner, Moradi, 2024)), upgrade service quality (Dangelico, & Pujari, 2010) improve economic performance, design and produce eco-friendly products or services (Ullah et al., 2023), build ecological reputation (Galindo-Martín et al., 2020), and diminish the use of hazardous products and outdated technologies. Hence, green innovation (GI) is an effective pathway for society, organizations, and firms toward environmental sustainability, competitive advantages and sustainable development (Arif et al., 2022).

The transition to sustainable development (SD) is a complex global challenge with political, social and cultural dimensions. This shift has been necessary since the release of the Brundtland Report submitted during the Rio Summit (1992), entitled "Our Common Future" under the auspices of the UNCED. In the 1990s, the integration of environmental considerations into other areas of policy evolved into a recognized institutional challenge. The OECD (2020) observed that, while strong economic growth is essential for achieving sustainable development, it must be ensured that growth should not cause environmental degradation. It calls for promoting economic growth while reducing greenhouse gas emissions — a decoupling that is expected to transform gluttonous old business habits in the developed world (Galindo et al., 2020).

Green technologies are essential not only for maintaining the current standard of living in the advanced countries but also for enabling developing countries to meet basic needs with minimal environmental harm. Although green technologies are not solely designed to promote sustainable development, they can simultaneously mitigate environmental degradation and foster economic growth (Abbas & Sagsan, 2019). These technologies play a pivotal role in enhancing living standards. Developed nations are already benefiting from higher living standards and are striving to extend support to developing countries (Abbas & Sağsan, 2019). Thus, it has been established that green innovation plays a crucial role in fostering sustainable development. This study uses green innovation as a key variable along with institutional quality, natural resources and GDP growth to statistically measure their impact on sustainable development. Therefore, the key research questions of this study are listed below.

Research Questions

1. How does the integration of green innovation (GI) with institutional quality, natural resource management, and GDP growth influence progress toward sustainable development (SD) across diverse economies?
2. What role do institutional frameworks mediate the relationship between green innovation and environmental sustainability in both developed and developing nations?
3. To what extent do variations in natural resource availability and economic growth patterns moderate the effectiveness of green technologies in advancing sustainable development goals?

In order to explore these research questions, this study aims to achieve the following objectives:

Research Objectives

1. To quantitatively assess the direct and indirect impacts of green innovation on sustainable development, accounting for institutional governance, natural resource utilization, and economic growth dynamics.
2. To evaluate the comparative significance of institutional quality in enabling or constraining green innovation's contribution to environmental and economic sustainability.
3. To identify regional disparities in how natural resource dependencies and GDP trajectories shape the adoption and outcomes of green technologies in achieving SDG targets.
4. To propose actionable policy recommendations for harmonizing green innovation strategies with institutional reforms and resource management practices to accelerate global sustainability efforts.

The findings of this study are likely to contribute into existing theoretical and empirical literature on green innovation and sustainable development in several ways. First, this study is likely to expand theoretical framework by integrating Schumpeterian innovation theory with institutional economics and resource-based perspectives, providing a multidimensional framework for analyzing sustainable development. This bridges gaps in prior literature, which often isolates environmental innovation from institutional and macroeconomic factors. Second, this study is expected to create empirical novelty by providing a cross-regional statistical analysis of how green innovation interacts with governance quality, resource endowments, and growth patterns—offering nuanced insights into context-specific pathways for sustainable development. Third,, this study provides practical implication by highlighting synergies between eco-friendly technologies, regulatory frameworks, and economic strategies, the study equips organizations and governments with evidence-based strategies to align competitiveness with ecological resilience.

The rest of paper is organized as follows; Section 2 outlines the theoretical framework, empirical review, hypotheses development, research gap and novelty of study. Section 3 discuss the rigor of research methodology, nature of data, selected variables, econometric model and analytical techniques, Section 4 illustrate empirical results, while section 5 enumerate discussion, policy implication, theoretical contribution, implications for SDGs, limitations and suggestions for further research as well as conclusion.

Literature Review

Theoretical Frameworks

The formal articulation of sustainable development originates with the Brundtland Commission's report Our Common Future (1987), presented to the UN General Assembly. This foundational document defines the concept as "development that meets the needs of the present generation without compromising the ability of future generations," stressing the critical balance between economic advancement and environmental protection. Munasinghe (1992) subsequently emphasized the social dimension, leading to the Comprehensive Sustainable Development (CSD) framework that integrates economic, social, and environmental considerations into decision-making.

This multidisciplinary concept, rooted in "green theory," advocates for environmentally conscious management practices and technologies within organizations. Elkington (2018) formalized this integration through the Triple Bottom Line (TBL) framework, aiming to harmonize environmental, social, and economic responsibilities. Scholars such as Shahzad et al. (2019), Hussain et al. (2018), and Dangelico & Pujari (2010) endorse this framework. Lucas (2019) defines the environmental dimension as supporting ecosystems, clean air and water, conserving finite non-renewable resources, developing eco-friendly products, and minimizing emissions. Guerrero-Villegas et al. (2018) characterize the social dimension by its focus on community relations, human well-being, social justice, equity, and human/labor rights. Concurrently, the business dimension seeks profitability through increased sales and cost minimization (Bhutta et al., 2022).

Green innovation enables firms to reduce their environmental impact via eco-friendly products, processes, technologies, and management systems, minimizing resource use and managing waste (Li et al., 2017; Rossiter & Smith, 2018; Fernando et al., 2019). Green Technological Innovation (GTI), merging environmental science and technology, develops new or improved low-impact processes or products (Bhutta et al., 2022). Green process innovation optimizes production for greater resource efficiency and reduced pollution (Albort-Morant et al., 2016; Rossiter & Smith, 2018). Green product innovation enhances designs using safe materials and improves efficiency to lessen disposal impacts. Green Management Innovation (GMI) implements novel management structures to boost production while decreasing ecological harm (Li et al., 2018; Siva et al., 2016). Effective Environmental Management Systems (EMS) facilitate GMI (Qi et al., 2012), underpinning competitive advantage (Albort-Morant et al., 2016).

Learning from stakeholders (customers, suppliers, etc.) is vital for understanding needs, enhancing satisfaction, and supporting economic sustainability (Porter & Linde, 1995). Financial performance is driven by organizational knowledge capabilities (Shahzad et al., 2019), with well-managed internal knowledge significantly boosting productivity (Sun & Razzaq, 2022). Thus, innovation remains central to sustainable development, though longitudinal and cross-sectoral studies on green innovation's dynamics are notably scarce compared to cross-sectional or sectoral analyses.

Hypotheses Development

Imran et al. (2020) argue that achieving growth necessitates robust environmental and financial governance. Their study across 32 OECD countries reveals that green innovation is most effective in reducing emissions at lower to medium quantiles, whereas fiscal decentralization and sustainable centralization reduce carbon emissions at medium to higher quantiles. Additionally, stronger institutions are crucial for policy effectiveness, particularly where emissions are high. Wan et al. (2021) emphasize that green patenting substantially reduces CO_2 emissions, advocating for regulatory frameworks, eco-taxes, innovation incentives, and public environmental awareness. Similarly, Liao et al. (2022), using data from Chinese firms (2010–2018), find that green innovation—especially invention patents—significantly enhances sustainable development, with pronounced effects in the private sector. Galindo et al. (2020) support this link, identifying positive relationships among innovation, education, and sustainable development across 20 OECD countries. They recommend fostering market access, regulation, and social entrepreneurship. Shahzad et al. (2021) highlight the importance of knowledge management and sustainable development practices (SDP) in shaping corporate green image (CGI), identifying knowledge as a mediating factor. Based on these insights:

H1: Green innovation positively correlates with sustainable development.

Ahmed et al. (2022), through FMOLS and DOLS methods using South Asian data (2000–2018), confirm long-term connections between financial development, institutional quality, and green growth. Khan et al. (2020), employing 2SLS on 15 emerging economies, demonstrate that institutional strength and low ethnic fragmentation support financial development. Zhuang et al. (2010) also identify a bidirectional long-term link between institutional quality and economic outcomes. Dkhili et al. (2018), using GMM estimates for 187 countries, show GDP growth affects both institutional quality and environmental performance—though institutional factors often worsen environmental outcomes, except where government effectiveness prevails. Lyeonov et al. (2019) assert that institutions, technology, and education, especially at secondary and tertiary levels, drive long-term growth. Regional studies (Rossiter & Smith, 2018; Olanipekun, 2023). Also affirm institutions' role in sustainability, and Ahmed et al. (2022) further identify democracy as a positive force. Nonetheless, many studies fail to explain how institutional mechanisms impact sustainability/ weak governance and lack of legal enforcement remain key obstacles to achieving the SDGs (Ahmed et al., 2022). Therefore:

H2: Institutional quality is positively associated with sustainable development.

While SDG coherence is essential, GDP-centric growth (Lyeonov et al., 2019; Mensah, J2019). may undermine sustainability. EU evidence and findings by Safi et al. (2022) and Mensah (2019) caution against relying solely on GDP. Hence:

H3: There is a positive correlation between economic growth and sustainable development.

Natural resources significantly influence sustainable and green economic growth (Ahmad et al., 2020). Thus:

H4: Natural resources positively correlate with sustainable development.

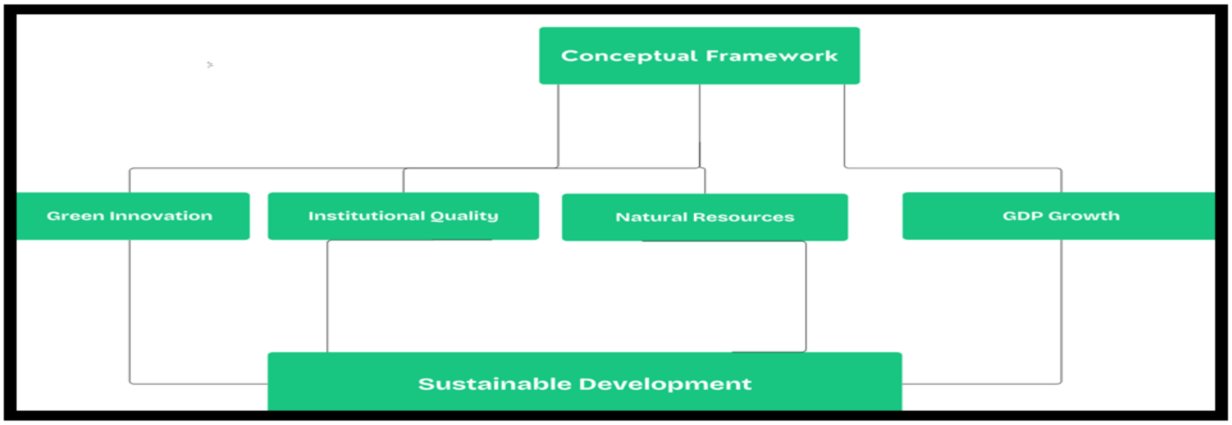
Research Gaps

Existing literature on sustainable development and green innovation exhibits significant gaps. Primarily, studies often isolate individual dimensions (economic, social, environmental) rather than integrating them cohesively, despite. Hanley et al. (1997) Triple Bottom Line framework. Empirical work simultaneously operationalizing all three dimensions within green innovation contexts remains scarce. Second, research heavily relies on evidence from developed economies (OECD), neglecting developing regions like South Asia, particularly Pakistan, where distinct industrial, regulatory, and socio-economic conditions prevail. Third, the combined enabling role of institutional quality and knowledge management processes for driving green innovation towards sustainability is inadequately explored. Fourth, Green Management Innovation (GMI)—involving eco-friendly managerial systems and practices—receives far less attention than product or process innovations, especially critical in developing economies. Fifth, longitudinal and cross-sectoral studies capturing the evolving impact of green innovations are lacking, with research dominated by cross-sectional or sector-specific analyses.

Conceptual Model

This model builds on the bases of hypothetical relationships between green innovation, institutional quality, natural resources, GDP and sustainable development, and is presented in Figure 1.

Figure 1: Research Model



Source: Author owns drawing using Canva software.

Data and Methodology

This study investigates the determinants of sustainable development (SD) in Pakistan using 30 years of secondary data. The analysis incorporates green innovation (GIN), institutional quality (IQ), natural resource rents (NR), and gross domestic product (GDP) as key explanatory variables. Data were obtained from reputable international sources: GIN from the OECD patent database, IQ from the International Country Risk Guide (ICRG), and NR and GDP from the World Development Indicators (WDI). The econometric model was specified to examine the functional relationship:

SD = f (GIN, IQ, NR, GDP),

This mode is operationalized in logarithmic form to address heteroscedasticity:

ln (SD)_t = β_1 + $\beta_2$ln (GIN)_t + $\beta_3$ln (IQ)_t + $\beta_4$ln (NR)_t + $\beta_5$ln (GDP)_t + μ_t.

To assess the stationarity properties of the variables, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests were conducted. The results confirmed that SD, GIN, and IQ are integrated of order one [I(1)], justifying the application of the Autoregressive Distributed Lag (ARDL) bounds testing approach, which accommodates variables integrated at I(0) and I(1) without requiring pre-testing for cointegration. The ARDL framework estimated both the long-run and short-run dynamics. The long-run equation captured elasticities, while the short-run Error Correction Model (ECM) incorporated first-differenced variables and an error correction term (ECM_{t–1}). A significantly negative ECM coefficient confirmed convergence toward long-run equilibrium. This method is appropriate for small sample sizes and has been validated in recent studies (e.g., Chopra et al., 2022; Jiannan & Waseem, 2024; Ahmad et al., 2020). Post-estimation diagnostics, including the Breusch-Godfrey test for serial correlation, the Breusch-Pagan test for heteroscedasticity, and the CUSUM/CUSUMSQ tests for parameter stability, affirmed model robustness.

Results and Analysis

The study's variables—green innovations, institutional quality, natural resources, and GDP—were estimated in order to understand how they affected Pakistan's sustainable development landscape Through the use of both descriptive and dynamic approaches, the study offers a comprehensive understanding of the data.

Descriptive Analysis

Descriptive statistics provide a general overview of the patterns and variabilities, while dynamic analysis investigates the temporal changes and causal relationships. Table.1 provides a complete descriptive study of five variables: sustainable development SD), green innovation (GIN), institutional quality (IQ), natural resources, GDP, and gross domestic product. This analysis describes features of dataset, for example, mean, mode and median value of numerical average measurement, the typical value of each variable, and the maximum and minimum value. The mean values are: LSD averages 4.000232, GIN 1.772429, IQ 0.675429, and NR 0.534073.GIN, which has a median of 1.925723, indicates a somewhat higher concentration around this center value compared to its mean, SD is close to its mean at 3.980706, according to the median values, which represent the midway point of the data. IQ has a median of 0.693147, whereas NR's median of 0.609356 is marginally greater than its mean, suggesting a slight left tilt for NR. When examining the maximum and minimum values, LSD ranges narrowly between 3.959310 and 4.079731, while LGIN shows a wider variation from -0.544727 to 3.526361. IQ and NR have more moderate ranges, with IQ spanning from 0.405465 to 1.098612 and NR from -0.035284 to 1.061660. The standard deviations indicate the spread of the data, with SD being the least dispersed (0.040951), and GIN the most (1.058893), signifying greater variability in GIN. SD and IQ have larger tails to the right in their distributions due to their positive skewness, while GIN and NR have marginally skewed and negatively skewed distributions, respectively.

Table 1: Descriptive analysis: outcomes

	LSD	LGIN	LIQ	LNR
Mean	4.000232	1.772429	0.675429	0.534073
Median	3.980706	1.925723	0.693147	0.609356
Maximum	4.079731	3.526361	1.098612	1.061660
Minimum	3.959310	-0.544727	0.405465	-0.035284
Std. Dev.	0.040951	1.058893	0.168195	0.332501
Skewness	0.814201	-0.524844	0.420949	-0.056780
Kurtosis	2.158151	2.443410	4.143932	1.600265
Jarque-Bera	3.920467	1.646911	2.353603	2.300848
Probability	0.140826	0.438912	0.308263	0.316503
Sum	112.0065	49.62802	18.91200	14.95403
Sum Sq. Dev.	0.045278	30.27385	0.763815	2.985031

Correlation Matrix

Table 2 demonstrates the nature of correlation between sustainable development and explanatory variables. At -0.5600 for covariance, suggest negative correlation between GIN and SD. This suggests that as GIN increase than SD tends to decrease, indicating an inverse relationship between the two variables. This outcome may suggest that a rise in GIN is linked to factors that diminish or inhibit the SD variables. SD and IQ have a positive correlation of 0.0329, which is very near to zero. This slight positive correlation indicates that fluctuations in SD are not significantly associated with fluctuations in IQ, suggesting that these two variables operate largely independently from one another. Alterations to natural resource consumption have close correlation with SD, as seen by the -0.4266-correlation coefficient of these two variables. Lastly, the analysis reveals a positive correlation between GDP and SD, demonstrating that higher GDP is connected with increased SD, with a correlation value of 0.9426. These results are corroborated to economic and environmental theories.

Table 2: Correlation analysis

Variables	Correlation Coefficient	Interpretation
LSD & LGIN	-0.5600	Moderate negative correlation: As LGIN increases, LSD tends to decrease.
LSD & LIQ	0.0329	Very weak positive correlation: Almost no relationship between LSD and LIQ.
LSD & LNR	-0.4266	Moderate negative correlation: Higher LNR is associated with lower LSD.
LSD & LGDP	0.9426	Very strong positive correlation: As LGDP increases, LSD increases significantly.
LGIN & LIQ	-0.3148	Weak to moderate negative correlation.
LGIN & LNR	0.6072	Moderate to strong positive correlation: As LGIN increases, LNR also increases.
LGIN & LGDP	-0.3469	Weak to moderate negative correlation.
LIQ & LNR	-0.5792	Moderate negative correlation.
LIQ & LGDP	-0.0697	Very weak negative correlation: Almost no relationship.
LNR & LGDP	-0.2507	Weak negative correlation.

The correlation analysis reveals that sustainable development is strongly and positively correlated with GDP Green innovation is negatively correlated with sustainable development, but natural resources are positively correlated with it, suggesting possible trade-offs or structural links. The correlation of sustainable development with other variables are weak or moderate, suggesting no major multicollinearity issues but these correlations worth exploring in regression model.

Unit Root Tests

The Augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) tests are used to determine whether a time series is stationary (i.e., its mean, variance, and autocovariance are constant over time) or non-stationary (contains a unit root). A non-stationary series can lead to spurious regression results, where the relationships between variables appear statistically significant but are actually meaningless. The basic difference between two tests is that the ADF test adds lagged difference terms to correct for autocorrelation while PP test adjusts the test statistics to account for serial correlation and heteroskedasticity without adding lagged terms. Table 3 presents the outcomes of both tests.

Table 3: ADF and PP Test Outcomes

Variable	**ADF (Level)**	**ADF (1st Diff.)**	**PP (Level)**	**PP (1st Diff.)**	**Stationarity Conclusion**
LGIN	0.1198	0.0281	0.9992	0.0034	Non-stationary at level, Stationary at first difference (I(1))
LIQ	0.1507	0.0000	0.1507	0.0000	Non-stationary at level, Stationary at first difference (I(1))
LNR	0.2381	0.0040	0.0797	0.0050	Non-stationary at level, Stationary at first difference (I(1))
LGDP	0.4798	0.0025	0.1272	0.0025	Non-stationary at level, Stationary at first difference (I(1))

In Table 3 all variables (LGIN, LIQ, LNR, LGDP) have p-values > 0.05 at level, indicating non-stationarity. Therefore, all variables are integrated of order 1, i.e., I (1), hence, we can use ARDL model because it allows Mixed Integration Order particularly when variables are a mix of I (0) and I(1), but not I(2). Since all variables are I (1), ARDL Model is perfectly suitable. Another characteristic of this model is that it has Cointegration Testing Built-In, which identifies both short-run and long-run relationships through the Bounds Testing Approach. It is more reliable than OLS model, which assumes stationarity of all variables and if we apply this model on non-stationarity data it can lead to spurious results.

ARDL Model

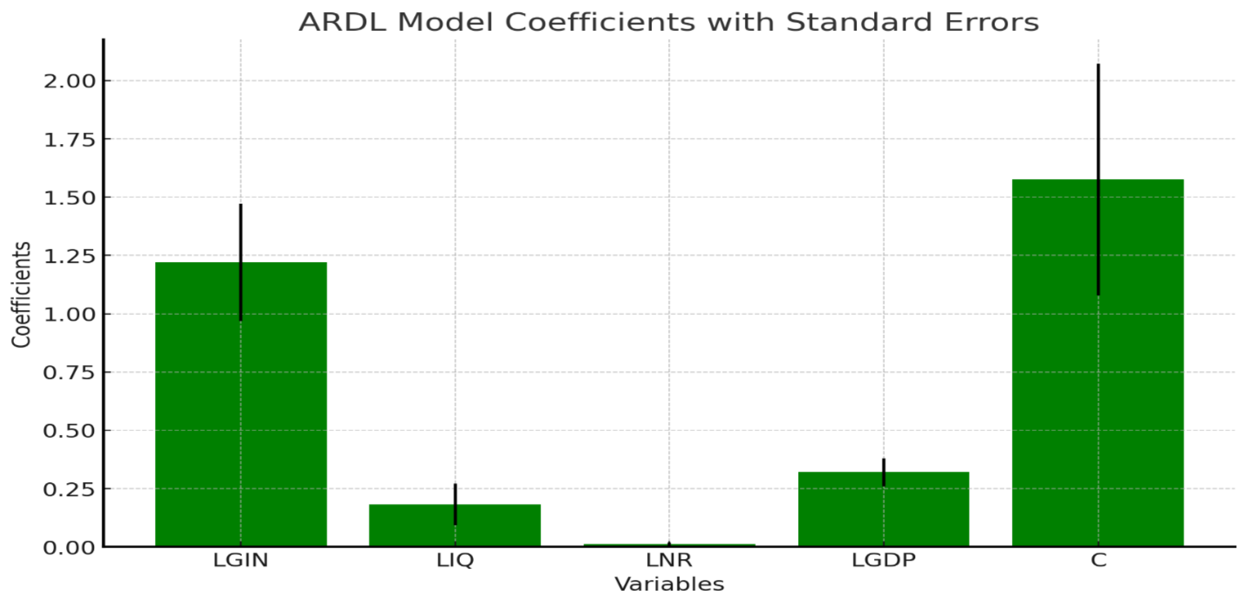
Table 4 summarizes the long-run estimated coefficients from an ARDL model. All independent variables have positive association with dependent variable, sustainable development. The coefficient for green innovation (1.219875, p = 0.0001) indicates that the relationship between green innovation and sustainable development is statistically significant. It implies that a unit increase in LGIN is associated with approximately an increase in sustainable development by 1.22% in the long run, holding all other factors constant. Similarly, Institutional quality (LIQ) has positive coefficient that is marginally significant at 10% level, suggesting that a one unit increase in institutional quality is likely to increase in sustainable development by 18% in the long run. The lower level of significance implies that the link between these two variables is weak or less robust compared to LGIN. The coefficient for LNR (0.011708) is positive, implying positive relationship between natural resources and sustainable development. Its means that a one unit increase in natural resources is associated with an increase in sustainable development by 11.70%. This relationship is also weak or less robust. However, the link between LGDP and sustainable development is highly positive and significant as the coefficient for LGDP is 0.320239. This implies that a one unit increase in GDP is likely to crease in sustainable development by 32%, suggesting a strong positive impact of overall economic output on sustainable development. The overall findings of ARDL model predict green innovation and GDP growth have robust positive long-term impacts on sustainable development. However, institutional quality and natural resources contribute positive but less strong impact on sustainable development compared to green innovation and GDP. Hence, we can conclude that the long-run behavior of the dependent variable (sustainable development) is strongly driven by green innovation and gross domestic product while institutional quality and natural resources play a complimentary role in sustainable development. The increasing GDP definitely causes increase in economic activity, which promotes social sustainability by lowering poverty, creating employment, and raising living standards. Higher GDP growth makes it feasible for the government to invest in infrastructure, which is essential to maintaining a sustainable development. Examples of this infrastructure include clean energy, efficient public transport, and sustainable agriculture. Moreover, economic expansion as measured by the GDP may strengthen public and private sectors' ability to fund R&D, leading to the creation of technology that support sustainable practices as suggested by Muhammad et al. (2024).

Table 4: Long Run outcomes of ARDL model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGIN	1.219875	0.251773	4.845140	0.0001
LIQ	0.182152	0.089824	2.027871	0.0771
LNR	0.011708	0.006666	-1.756317	0.0960
LGDP	0.320239	0.060096	5.328750	0.0007
C	1.575212	0.497135	3.168577	0.0132

The ARDL long-term results are displayed in Figure 2.

Figure 2: Long-term impacts of green innovation, institutional quality, natural resources and GDP on sustainable development



Error Correction Model

The error correction model demonstrates the transition from the prior year to the long-term equilibrium. In Table 5, the coefficient of green innovation (LGIN is +0.015), suggesting the positive and statistically significant relationship between green innovation (GIN) and sustainable development (SD) because (t-Statistic: 2.4072 (significant) and p-value: 0.0427 (significant at 5% level). This means that a one unit increases in green innovation leads to an increase in SD by 0.25%. The coefficient for institutional quality (LIQ 0.036203) is also positive showing positive and statistically significant association between institutional quality and sustainable development because t-Statistic: -2.9039 (significant) and p-value: 0.0198 (significant at 5% level), confirming significant positive link between two variables. Further, the coefficient for natural resources (LNR 0.015556) shows positive link between natural resources and sustainable development. However, this relationship is weak because t-Statistic: 1.9781 (marginally significant) and p-value: 0.0833 (not significant at 5% but significant at 10% level). The coefficient for LGDP (0.267206) depicts strong positive and significant impact of GDP on sustainable development because of t-Statistic: 3.6159 (highly significant) and p-value: 0.0068 (significant at 1% level). Hence, the Error Correction Model confirms short-run effects of all explanatory variables such as LGIN, LIQ, LNR, and LGDP on sustainable development.

The value of the error correction coefficient -0.418900, t-Statistic: -7.4177 (highly significant) and p-value: 0.0001 (significant at 1% level) confirms that 41.89% of the short-run disequilibrium is corrected each period (likely a year or quarter, depending on the data frequency). The adjustment speed suggests that the model returns to equilibrium level quickly following short-run shocks. Thus, the short-term results of Error Correction Model match with the long-term findings of ARDL model, predicting positive impact of short and long-term impact of variables on sustainable development.

Table 5: Error Correction Model outcomes

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGIN	0.006610	0.002746	2.407193	0.0427
LIQ	0.036203	0.012467	-2.903894	0.0198
LNR	0.015556	0.007864	1.978107	0.0833
LGDP	0.267206	0.073898	3.615904	0.0068
Coint Eq (-1)	-0.418900	0.056473	-7.417698	0.0001

Source: Author owns calculation using E-View Software.

Multicollinearity Checks

Table 6 shows that value of VIF of all constructs and it is less than 10 and even VIF value of most of the variables is <5, suggesting that our model is goodness of fit. This also confirm that there are no multi-collinearity issues and all constructs have a unique and distinguished impact on dependent variable.

Table 6: Variance Inflation factor/(VIF)

Indicators	VIF
LGIN	4.88E-06
LIQ	0.000186
LNR	6.53E-05
LGDP	0.000145
C	0.008289

Diagnostic Tests

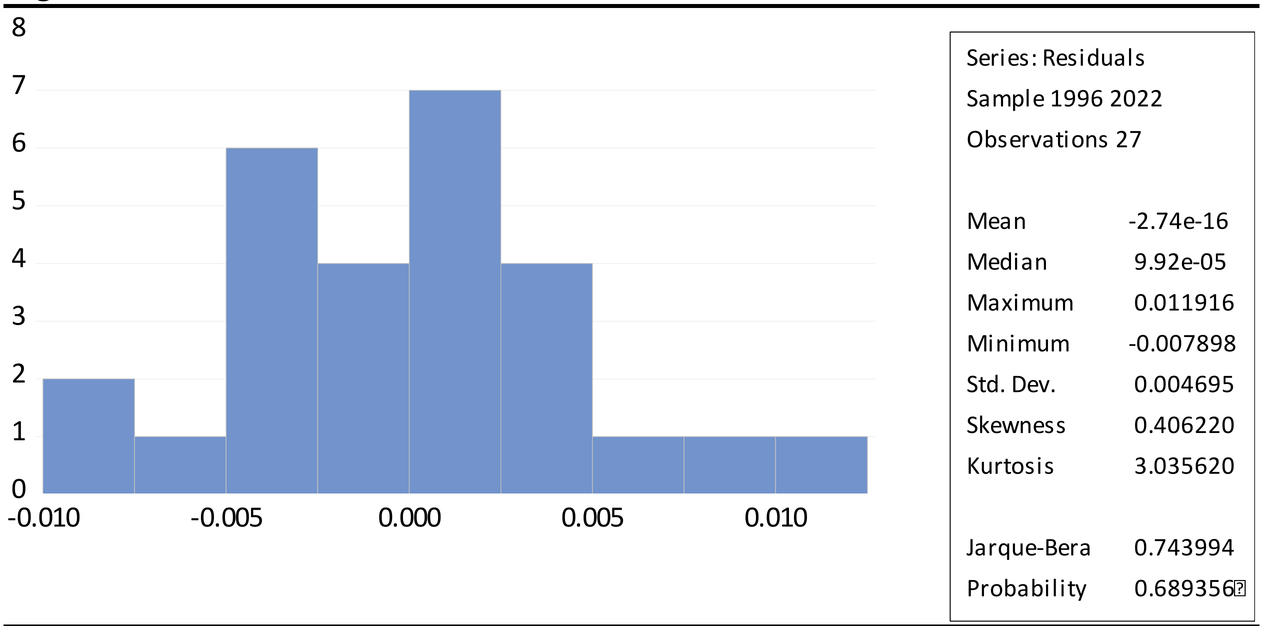
We applied different diagnostic tests to identify heteroscedasticity, Autocorrelation and Normality issues in the model. The results of these tests shown in Table 7 suggest that there is no significant heteroscedasticity and autocorrelation issues in the model, and also the data is normally distributed. Heteroscedasticity Test Statistic is 0.1903 and p-value, which is above common significance levels and it suggest that there are no issues with heteroscedasticity and the variance of the residuals is constant, establishing the reliability of the regression estimates. Similarly, Autocorrelation Test Statistic 0.3904 and p-value: (which is above the significance threshold), indicate that there is no evidence of serial correlation in the residuals and the errors are independent, which is assumed to be important for valid hypothesis testing and reliable coefficient estimates. Moreover, the Normality Test Statistic: 0.68935 and p-value: (appears to be non-significant) reveal that the data is normally distributed and the residuals follow a normal distribution, which is a core assumption of many inferential tests in the regression analysis. All the above diagnostic tests suggest that the model meets the required assumptions. This strengthens the robustness of the model's estimates and the validity of its findings.

Table 7: Diagnostic test results

Diagnostic test statistic	P value	Findings
Heteroscedasticity	0.1903	No problems with heteroscedasticity
Serial+ correlation/ autocorrelation	0.3904	No problems with serial correlation
Normality	0.68935	data is normality distributed

The outcomes of Autocorrelation and normality tests report a negligible p-value, confirming the rejection of null hypothesis that there is no evidence of autocorrelation and the data are normally distributed as depicted in Figure 4.

Figure 3: Normal distribution of residuals



Model Stability Tests

The CUSUM and CUSUM square test is used to identify stability of the model over the period of study. The outcomes of this test are presented in Figure 5 & 6, showing that value is estimated parameter Since neither the deviations nor the squared deviations have crossed the crucial lines, the model is stable. When plotted deviations and squared deviations stay within allowable ranges, it is assumed that the stability is intact.

Figure 4: CUSUM test

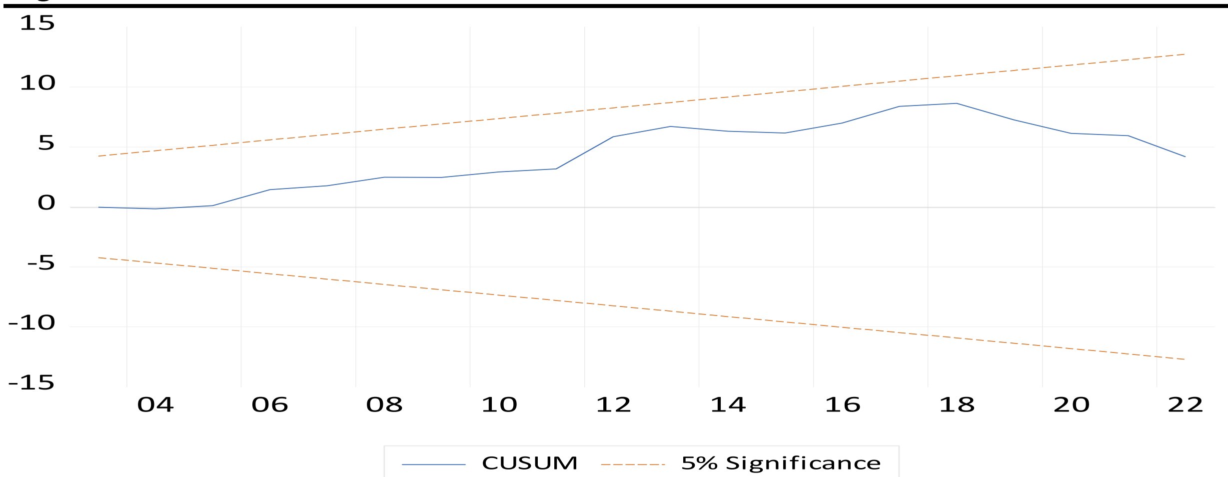
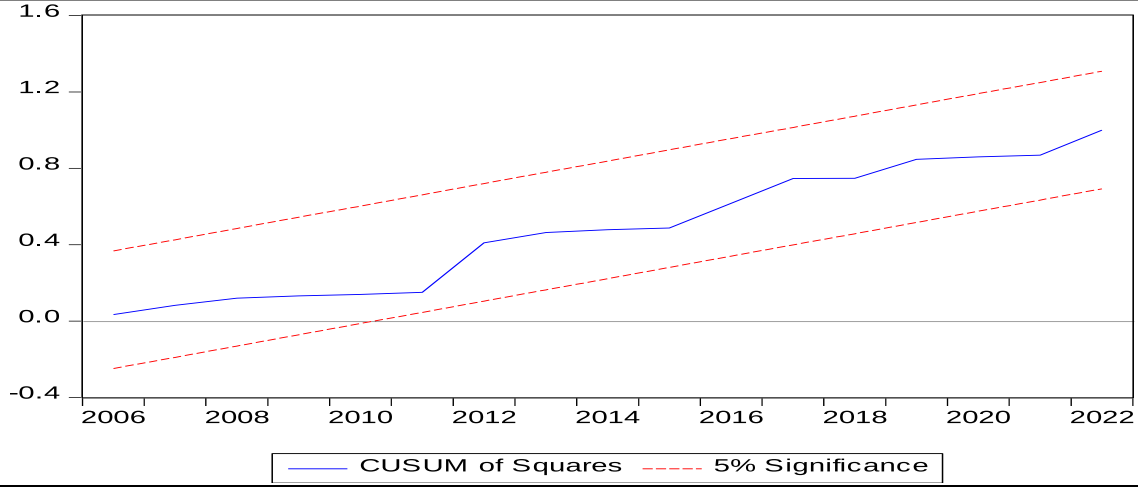


Figure 5: CUSUM of Square



Findings

The empirical results demonstrate that green innovation (GIN), institutional quality (IQ), natural resources (NR), and GDP exert a statistically significant positive impact on sustainable development (SD) in Pakistan in both short- and long-term analyses. These outcomes challenge the "resource curse" narrative, indicating that natural resource endowments can drive SD when managed effectively within strong institutional frameworks. The significant positive effect of green innovation underscores the critical role of environmentally sustainable technologies. These findings align with the study's hypotheses (H1, H2, H3, H4) and corroborate prior empirical work by Shahzad et al. (2019); Safi et al. (2022); Albort-Morant et al. (2016); Galindo-Martín et al. (2020); Sun and Razzaq (2022); Ullah et al. (2023).

Theoretical Contributions

This study substantiates the Theory of Ecological-Economic Integration (Herman & Costanza, 1994) and Elkington's (2018) Triple Bottom Line framework by demonstrating that synergistic integration of ecological, social, and economic responsibilities drives sustainable development. It validates Environmental Economics Theory (Hanley, Shogren, & White, 1997) by showing that effective institutional governance prevents natural resource overexploitation. The positive GDP-SD relationship aligns with the Environmental Kuznets Curve (Kuznets, 1955), supported by empirical evidence from Al-Mulali et al. (2016); Luca Coscieme et al. (2020); Tessa & Moradi (2024). However, the insignificant empirical link between IQ and SD in developing contexts extends critiques by Berg & Desai (2013); Azam et al.; Dubey et al. (2019); Kent (2020, 2021); Foroudi et al. (2022), highlighting theoretical-practical gaps in weak institutional environments.

Practical Implications

To strengthen institutional governance, it is essential to enhance transparency, regulatory frameworks, and accountability mechanisms. This alignment of economic growth with Sustainable Development (SD) goals specifically targets corruption reduction. Investing in green technologies should be prioritized through R&D funding and incentives for context-specific sustainable practices, ensuring natural resource management is integrated into economic planning. Developing integrated policy models that combine Green Innovation (GIN), Institutional Quality (IQ), Natural Resource (NR) management, and GDP growth frameworks is crucial to anticipate trade-offs and design responsive conservation strategies. Furthermore, adopting long-term SD strategies requires balancing economic growth with environmental protection and social inclusion, achieved through institutional capacity building and robust enforcement mechanisms.

Conclusion

This study establishes that Pakistan's sustainable development is positively driven by green innovation, institutional quality, natural resources, and GDP growth, contradicting resource curse assumptions. While affirming core tenets of Ecological-Economic Integration, TBL, and Environmental Economics theories, it reveals critical gaps between theoretical IQ-SD linkages and practical governance constraints. Policymakers must integrate institutional reforms with targeted green investments and resource efficiency models. Future research should prioritize causal analyses, contextual comparisons, and granular data to advance SD frameworks in developing economies.

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